

MINISTRY OF EDUCATION AND TRAINING
UNIVERSITY OF TRANSPORT AND COMMUNICATIONS

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**RESEARCH ON STATE MANAGEMENT OF
URBAN PASSENGER TRANSPORT IN
HANOI IN THE CONTEXT OF THE
FOURTH INDUSTRIAL REVOLUTION**

Major: Transportation Organization and Management

Code No: 9.84.01.03

SUMMARY OF THE DOCTORAL THESIS

HA NOI - 2026

The dissertation has been completed at:

University of Transport and Communications

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The dissertation was defended at the University-level Doctoral dissertation committee at the University of Transport and Communications At ... hours, on ... day ... month ... year 2026

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INTRODUCTION

1. Rationale for the Study

Rapid urbanization and motorization in Hanoi have substantially increased travel demand and the number of vehicles, while transport infrastructure development has failed to keep pace with vehicle growth. In 2025, Hanoi had approximately 8.8 million residents and more than 8.4 million vehicles, of which motorcycles accounted for about 86%. The number of vehicles increased by approximately 5% annually, far exceeding the transport infrastructure development rate of about 0.35% per year. Private vehicles continued to account for a large share of traffic, while public passenger transport met only approximately 18–20% of residents' travel demand. This situation places considerable pressure on infrastructure, traffic congestion, the environment, and the state management of urban passenger transport.

One important cause of this situation is that state management of urban passenger transport has not kept pace with socioeconomic and technological development. Transport planning remains insufficiently coordinated; coordination mechanisms among management agencies are limited; and integration among transport modes remains weak. The rapid emergence of digital platform-based transport services also presents new challenges for the institutional framework and management approaches.

In this context, the Fourth Industrial Revolution (Industry 4.0), characterized by artificial intelligence (AI), Big Data, the Internet of Things (IoT), cloud computing, the Global Positioning System (GPS), intelligent transport systems (ITS), AI-enabled cameras, electronic payments, and real-time data analytics, is directly transforming the management, operation, and organization of urban passenger transport. However, transport data in Vietnam have not yet been integrated consistently; technological infrastructure remains inadequate; data sharing among agencies faces difficulties; and many new solutions have been implemented in isolation.

Against this theoretical and practical background, the research topic entitled “Research on State Management of Urban Passenger Transport in Hanoi in the Context of the Fourth Industrial Revolution” is both theoretically and practically significant and timely. The dissertation contributes to supplementing and improving the theoretical foundations of state management of urban passenger transport in the context of digital transformation. It also offers practical value by proposing solutions to enhance the

effectiveness of state management and develop a modern, smart, and sustainable urban passenger transport system in Hanoi in particular and Vietnam in general.

2. Research Objectives

- General objective: To systematize, clarify, and deepen the theoretical foundations of state management of the urban passenger transport system and propose solutions to strengthen state management capacity for urban passenger transport in the context of the Fourth Industrial Revolution.

- Specific objectives:

- (1) To systematize and clarify the theoretical foundations of state management of urban passenger transport and the requirements for management reform in the context of Industry 4.0.

- (2) To analyze and assess the current state of state management of urban passenger transport in Hanoi in the context of Industry 4.0.

- (3) To develop a research model for assessing factors affecting the effectiveness of urban passenger transport development; and, based on the model testing results and the findings concerning the application of technology in state management, to propose solutions to strengthen state management capacity for urban passenger transport in Hanoi in the context of Industry 4.0.

3. Research Object

The research object: the state management of urban passenger transport in Hanoi.

4. Scope of the Study

The scope of the dissertation is defined as follows:

- Spatial scope: Hanoi.

- Temporal scope: The dissertation uses empirical data from 2010 to 2025 to conduct its analysis and assessment. It also considers the targets and orientations of state management agencies up to 2030, with a vision toward 2050.

5. Research Methodology

The doctoral candidate adopts an approach combining qualitative and quantitative research to comprehensively analyze state management of urban passenger transport in the context of Industry 4.0. In the initial stage, qualitative methods are employed to systematize the theoretical foundations, develop the research framework,

and identify groups of factors influencing state management of urban passenger transport in the context of Industry 4.0.

The doctoral candidate develops a research model and research hypotheses as the basis for the subsequent quantitative stage. Following the development of the research model, the dissertation uses a structured questionnaire survey to measure the influence of various factors on the effectiveness of urban passenger transport development under the application of Industry 4.0 technologies. Based on the survey findings, together with the analysis, comparison, and assessment of the current application of technological advances in Hanoi, the doctoral candidate develops solutions to improve the effectiveness of state management of urban passenger transport in Hanoi in the context of Industry 4.0.

6. Structure of the Dissertation

In addition to the Introduction, Conclusions and Recommendations, and Appendices, the dissertation comprises four chapters:

Chapter 1. Literature Review of Studies Related to the Dissertation Topic

Chapter 2. Theoretical and Practical Foundations of State Management of Urban Passenger Transport

Chapter 3. Analysis and Assessment of the Current State of State Management of Urban Passenger Transport in the Context of the Fourth Industrial Revolution

Chapter 4. Proposed Solutions to Strengthen State Management of Urban Passenger Transport in the Context of the Fourth Industrial Revolution

CHAPTER 1.

LITERATURE REVIEW OF STUDIES RELATED TO THE DISSERTATION TOPIC

1.1. Studies on the Fourth Industrial Revolution

International studies on the Fourth Industrial Revolution (Industry 4.0) primarily clarify its nature, characteristics, and transformations arising from the development and convergence of digital, physical, and biological technologies. Klaus Schwab argues that technologies such as artificial intelligence (AI), the Internet of Things (IoT), Big Data, cloud computing, and robotics are transforming the operations of both the private and public sectors, requiring governments to strengthen institutional adaptability and innovate governance approaches [82], [83]. Studies on e-government and smart government indicate that effective technology adoption in the public sector depends not only on technical solutions but also on strategy, organizational arrangements, data quality, legal frameworks, and coordination mechanisms [47]; In particular, Smart government emphasizes data integration, information sharing, and enhanced decision-making capacity [30]. Other studies address AI applications in traffic management, transport scheduling, and autonomous vehicles [56], [71], [85], as well as the development of Mobility as a Service (MaaS) and integrated mobility platforms [53], [54], [58].

1.2. Studies on State Management

International studies on state management of urban passenger transport focus on three main areas: management models, policy mechanisms, and changes in state management driven by technological development. Finn (2011) demonstrates that public passenger transport management can be organized in different ways depending on institutional conditions, the capacity of regulatory authorities, and private-sector participation [42]; Żukiewicz (2020) further indicates that management models are influenced by government organizational structures and the decentralization of management responsibilities [97]. Numerous studies emphasize clearly delineating responsibilities and strengthening coordination among administrative levels and agencies [69], [70], [98]. Regarding policy, Dalkmann and Sakamoto (2012) proposed an integrated policy approach for urban transport, combining regulation, infrastructure investment configuration, traffic demand management, and sustainable operational development [34]. Padam stresses the need for a coherent policy framework linked to

integrated planning, technology selection, and clear allocation of functions across management levels [70].

1.3. Studies on Urban Passenger Transport

International studies on urban passenger transport mainly address planning, network organization, public passenger transport performance, and travel mode choice. Verma (2014) systematizes fundamental issues relating to travel demand, mode choice, network organization, infrastructure, and public passenger transport management in developing countries [91], de Oña (2023) identifies relationships among service quality, satisfaction, and intentions to use public passenger transport among current users of private vehicles [67]. These studies suggest that the effectiveness of urban passenger transport development depends jointly on network organization, service characteristics, and the ability to encourage residents to shift travel modes.

In Vietnam, Nguyen Thanh Chuong (2007) developed a set of indicators and methods for assessing the performance of bus-based public passenger transport, with an application to Hanoi [4]. Vu Thi Huong, Nguyen Thanh Chuong, and Vu Trong Tich (2020) examined bus choice behavior in Hanoi and identified the effects of demographic characteristics, trip characteristics, vehicle characteristics, environmental awareness, subjective norms, and the attractiveness of private vehicles [9].

1.4. Identification of Research Gaps and Research Directions

- Existing studies primarily focus on technological applications in transport operations, such as ITS, AI, IoT, Big Data, and MaaS, without fully examining changes in state management models, instruments, and approaches when digital data become the foundation of management.

- Nhiều nghiên cứu xem xét riêng xe buýt, taxi hoặc đường sắt đô thị, chưa tiếp cận toàn bộ hệ thống VTHK đô thị gồm vận tải cá nhân, vận tải công cộng và vận tải bán công cộng dưới góc độ QLNN.

- Many studies consider buses, taxis, or urban rail separately rather than examining the entire urban passenger transport system, including private, public, and semi - public transport from a state management perspective.

- Most studies focus on high-income countries; state management models suited to the conditions of Vietnam and Hanoi in the context of Industry 4.0 remain insufficiently developed.

In response to these gaps, the dissertation focuses on the following questions: which technologies can be applied to management activities and how they can enhance management capacity; how organizational structures should change; and how integrated mechanisms encompassing planning, policy design, and implementation should be developed.

- Research Framework

Based on the identified research gaps and the findings of relevant scientific studies, the dissertation develops the research framework shown in Figure 1.1 to identify appropriate solutions for improving the effectiveness of state management of urban passenger transport in Hanoi in the context of Industry 4.0.

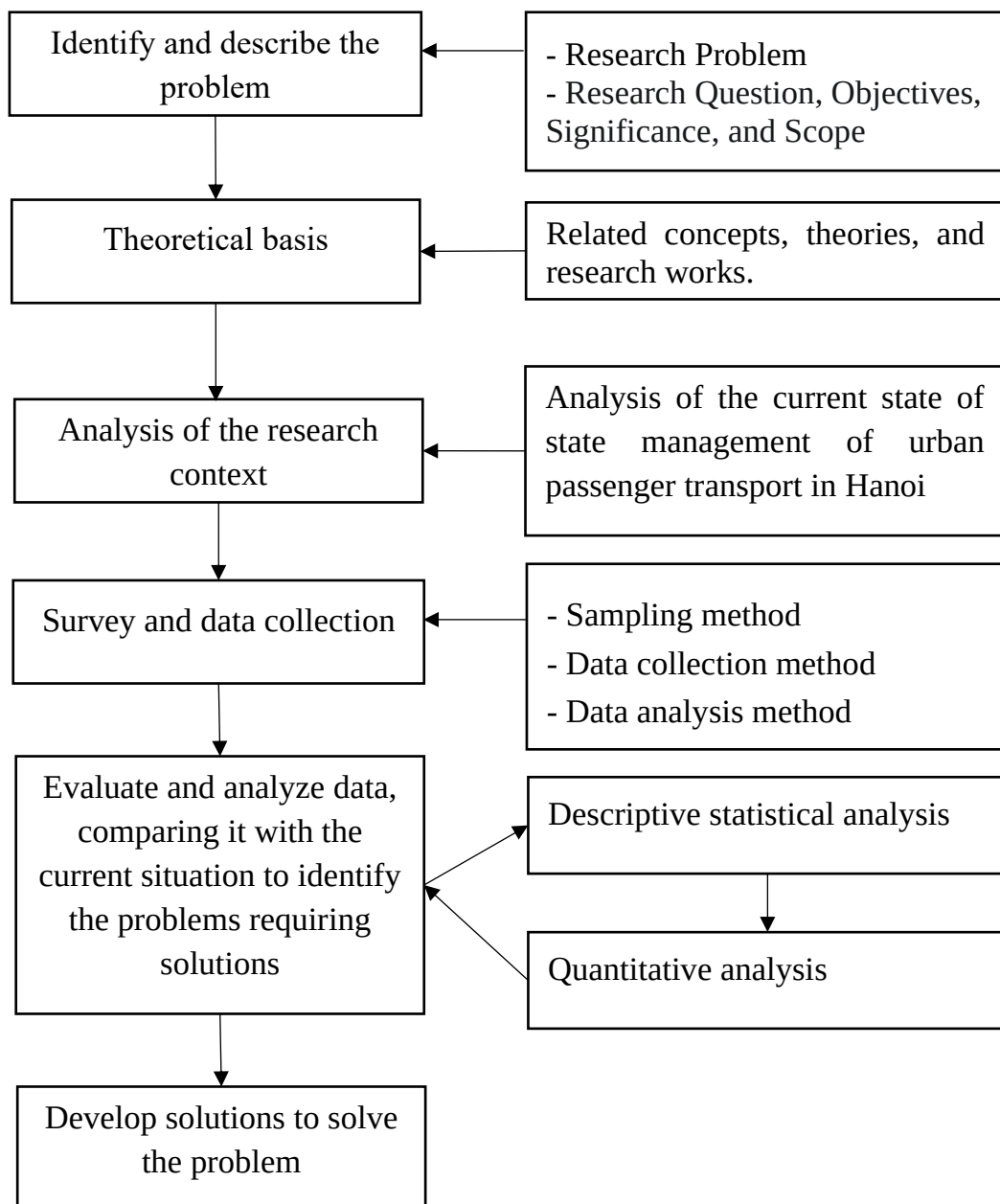


Diagram 1.1: Research Framework of the Thesis

CHAPTER 2.

THEORETICAL AND PRACTICAL FOUNDATIONS OF STATE MANAGEMENT OF URBAN PASSENGER TRANSPORT

2.1. The Fourth Industrial Revolution

The Fourth Industrial Revolution emerged around the turn of the twenty-first century, building upon the digital revolution. Industry 4.0 is based on digital technologies and the integration and interconnection of physical, digital, and biological technologies, bringing profound changes to production, management, and social life. Its most significant distinction from previous industrial revolutions lies in the ability to connect and process large volumes of data in real time. Machinery, equipment, people, and databases can be interconnected through the Internet, enabling intelligent governance and production models with high levels of automation and reducing dependence on traditional manual labor [82].

Through advanced technologies such as artificial intelligence (AI), Big Data, the Internet of Things (IoT), cloud computing, blockchain, automated robotics, virtual reality, and smart sensor systems, Industry 4.0 affects urban passenger transport in the following ways:

- Transforming transport system organization and operations from conventional arrangements to technology-enabled management, data processing, and computer- and AI-assisted traffic organization.
- Introducing new transport services, such as app-based ride-hailing, ride-sharing, on-demand transport, and autonomous vehicles, thereby increasing competition and restructuring the urban passenger transport market.
- Increasing users' expectations regarding the convenience of transport infrastructure, service quality, and environmental protection.
- Improving the capacity of public authorities for data-driven management and forecasting.
- Requiring institutional reform and stronger management capacity to respond to development, leverage advanced technologies, and ensure information security and effective supervision in the digital environment.

2.2. State Management of Urban Passenger Transport

Urban passenger transport encompasses the organization, management, and operation of transport vehicles to carry passengers within urban areas safely, conveniently, promptly, and efficiently, meeting residents' daily travel needs and contributing to urban socioeconomic development. Based on transport characteristics and user groups, urban passenger transport is divided into three main categories [18]:

- Private transport (private cars, motorcycles, and bicycles);
- Public passenger transport (buses, urban railways, metro systems, taxis, app-based motorcycle taxis, etc.);
- Semi-public passenger transport (official vehicles and non-commercial vehicles transporting officials and employees).

State management of urban passenger transport refers to the organized exercise of state authority by competent public agencies to guide, regulate, organize, and control urban passenger transport activities, ensuring that travel needs are met safely, efficiently, and equitably, in line with urban development objectives. The dissertation examines state management through management models, functions, contents, methods, and instruments.

The principal areas of state management include developing and implementing legal normative documents; infrastructure planning and development strategies; organization, operations, and supervision; inspection and examination; human resource development; and the application of technology in management. Under Industry 4.0, these activities are gradually shifting from manual and fragmented processes toward data-driven management, connectivity, and real-time analysis.

2.5.2. New Requirements for State Management in the Context of Industry 4.0

Rapid scientific and technological advances have accelerated the pace of social activities and transactions, which can now take place within seconds. Technology also supports faster individual decisions - for example, ride-hailing applications suggest travel modes based on travel time and fares. Urban passenger transport is likewise profoundly affected by Industry 4.0 and must adapt to residents' mobility needs, transport market developments, and competition among operators. Although the fundamental objective of state management remains the stable and efficient development of urban passenger transport, management approaches must adapt to

changes in the regulated sector: (1) shifting from stringent ex ante controls toward an enabling approach that facilitates transport development; (2) adopting a coordinated state management model that utilizes shared data, interoperable data exchange, and cross-sectoral collaboration; (3) conducting management activities through digital data analysis, dynamic planning, and real-time monitoring, while diversifying investment capital to attract investment in advanced technologies; (4) integrating digital data into traditional management instruments and adopting new instruments such as intelligent transport systems (ITS) and AI-based automated decision-making; and (5) extending the scope of management to digital platforms, transport data, intermediary service providers such as Mobility as a Service (MaaS), and emerging modes such as autonomous vehicles and flying taxis.

2.6. International Experience in State Management of Urban Passenger Transport

2.6.1. Experience of Japan

Japan is among the world's pioneers in developing intelligent transport systems (ITS). It established a comprehensive plan comprising nine programs, with specific research and development roadmaps, timelines, and quantified targets for evaluating outcomes. In addition, the Japanese Government has promoted Mobility as a Service (MaaS) platforms to address pressing challenges, including population ageing, population decline, and inadequate transport services in rural and mountainous areas.

2.6.2. Experience of China

Although China began implementing ITS later than Japan, its government and researchers developed a shared view that ITS development need not wait until transport infrastructure is fully completed. Integrating ITS technologies during infrastructure design and construction is more cost-effective than installing them after construction [95]. China uses smart-card ticketing systems in urban public passenger transport as a means of collecting foundational data for analyzing travel demand and optimizing public transport networks [87].

2.6.3. Experience of Malaysia

Malaysia has prioritized the development of a National ITS Architecture. This architecture serves as an overall blueprint for the ITS ecosystem, ensuring that future vehicles and equipment can connect, share data, and operate compatibly and interoperably. This approach helps prevent duplicated investments and improves the nationwide efficiency of ITS operations. Notably, Malaysia's SMART Tunnel is a dual-

purpose infrastructure project that provides floodwater drainage and traffic management, while offering an additional access route to southern Kuala Lumpur.

2.6.4. Lessons for Hanoi

The following lessons are particularly relevant to applying technology in the state management of urban passenger transport in Hanoi:

- The State should play a leading role in developing smart transport strategies, ensuring consistency among transport planning, digital infrastructure, databases, and management structures.

- Hanoi should establish a phased roadmap for technology adoption.

- Data should serve as the central foundation of modern urban passenger transport management.

- Public passenger transport should be developed toward multimodal integration and a people-centered approach.

- Institutions, technical standards, and mechanisms for mobilizing private-sector participation in smart transport development should be improved.

CHAPTER 3.

ANALYSIS AND ASSESSMENT OF THE CURRENT STATE OF STATE MANAGEMENT OF URBAN PASSENGER TRANSPORT IN THE CONTEXT OF THE FOURTH INDUSTRIAL REVOLUTION

3.1. Current State of Urban Passenger Transport

Hanoi's urban passenger transport system is developing amid rapid population and vehicle growth, while land allocated to transport and transport infrastructure expand more slowly. Private transport continues to account for a large share; public passenger transport has expanded through buses, BRT and urban rail, but its modal share remains below the required level. Semi-public transport is a distinctive mode that accounts for a relatively small share of the transport network and still faces limitations in the digitization of management data.

Table 3.1: Growth Rates of Population, Transport Vehicles and Land Allocated to Transport

No.	Indicator	2010	2025	Growth	Average Annual Growth Rate
1	Population	6.6 million people	8.8 million people	33%	2.02%/year
2	Number of private vehicles	3.8 million	8.4 million	121.05%	5.09%/year
2.1	Cars	0.3 million	1.2 million	300%	9.05%/year
2.2	Motorcycles	3.5 million	7.2 million	105.71%	4.63%/year
3	Share of Land Allocated to Transport	8%	12.13%	4.13 percentage points	0.35%/year

- Private transport: The figures in Table 3.1 show that private vehicles remain residents' preferred choice. Hanoi has adopted several technologies for managing private vehicles, including license plate identification, digitized population and vehicle databases, and electronic toll collection (ETC) tags.

- Public passenger transport: Hanoi has the widest variety of public transport modes in Vietnam, including lower-capacity services such as motorcycle taxis, taxis and

public bicycles, and higher-capacity services such as buses, BRT and urban rail. Buses contribute the largest passenger volume, carrying 410 million passenger trips in 2025. Modern technologies are being gradually introduced into bus management and operations, including onboard GPS, bus information applications, electronic tickets and surveillance cameras. Urban rail has employed advanced technologies since its introduction in Vietnam, including operation control centers (OCC), automatic fare collection (AFC), electronic payments and biometric identification. However, Hanoi has put only slightly more than 20 km of urban railway into operation, and its passenger volume remains low.

3.2. Current State of State Management and Technology Application

State management of urban passenger transport involves both central and municipal authorities, with the Hanoi administration directly implementing local management responsibilities. State management has gradually improved, but several limitations remain:

- Coordination and data-sharing mechanisms among agencies remain limited.
- Hanoi has introduced various technologies, including vehicle tracking devices, traffic cameras, intelligent road signs and control centers. However, integration remains uneven; data are stored in separate systems, and a comprehensive shared database supporting state management has not yet been established.
- Policies have gradually established a framework for digital transformation, e-government, clean vehicles and smart transport. Nevertheless, sector-specific regulations on standardization, connectivity, sharing and use of transport data have not kept pace with technological advances and new business models.
- Planning needs to move beyond a relatively static approach toward greater use of population, travel demand and traffic-flow data for forecasting, updating and evaluating alternatives.
- Limited interoperability among monitoring devices prevents management authorities from obtaining a comprehensive view of the network. The dissertation therefore emphasizes the need for an integrated platform in which data are standardized at source and shared for operations, monitoring, inspection and policy evaluation.
- Inspection and examination are gradually shifting from ex ante controls and on-site inspections toward data-based ex post supervision.

- The competencies required of management personnel are shifting from primarily regulatory and professional knowledge toward a combination of transport expertise and digital skills.

To date, the application of science and technology in the state management of urban passenger transport in Hanoi has produced the following achievements:

(1) Installation of intelligent traffic equipment, including AI cameras, intelligent traffic signals and electronic information boards; some equipment has already delivered tangible benefits.

(2) Deployment of electronic payment systems: cars have been fitted with chips enabling electronic payments, and Hanoi has introduced cashless parking payment services on several streets.

(3) Establishment of control centers to monitor timetable compliance, assess traffic congestion and support flexible vehicle dispatch during incidents.

(4) Initial development of electronic payment systems.

(5) Establishment and development of intelligent traffic control centers.

(6) Broader mobilization of private and social resources for transport infrastructure and smart urban development.

3.3. Survey-Based Assessment of the Application of Fourth Industrial Revolution Technologies in Urban Passenger Transport

3.3.1. Development of the Research Model

The doctoral candidate considers bus transport the most suitable subject for assessing the application of Fourth Industrial Revolution technologies in urban passenger transport because buses account for the largest passenger volume in the urban transport network and have experienced both the pre-digital period and the subsequent rapid development of digital technologies.

The survey examines bus-based public passenger transport as a representative empirical case to quantify the effects of selected Industry 4.0-related factors on the development effectiveness of this mode. Its findings are not directly generalized to all urban passenger transport modes; rather, they provide supplementary empirical evidence for analyzing and proposing state management solutions. The survey aims to quantify the effects of selected Industry 4.0-related factors on the effectiveness of bus-based

public passenger transport development in Hanoi. The quantitative model does not directly measure the effectiveness of state management of urban passenger transport. That effectiveness is primarily assessed through analyses of institutions, organizational structures, management activities and instruments, and actual outcomes, as presented in the preceding sections. The model findings provide supplementary empirical evidence on relevant factors and, together with the assessment of current conditions, inform the state management solutions proposed in Chapter 4.

On this basis, the doctoral candidate develops the following multiple regression model:

$$HQ = \beta_0 + \beta_1CN + \beta_2HT + \beta_3NL + \beta_4DV + \beta_5NT + \varepsilon_{HQ}$$

Where:

Dependent variable (Y):

- Y - Effectiveness of bus-based urban passenger transport development (HQ);

Independent variables (X):

- X1 - Application of digital technologies in management and operations (CN);

- X2 - Intelligent transport infrastructure (HT);

- X3 - Adoption of green vehicles and clean energy (NL);

- X4 - Quality of bus services following digital transformation (DV);

- X5 - Public awareness of and access to technology (NT).

The survey questionnaire was developed based on previous studies. Part 2 focuses on assessing the effects of five selected factors on bus-based public passenger transport and residents' bus-use behavior in Hanoi. The study employs a five-point Likert scale: 1 - Strongly disagree; 2 - Disagree; 3 - Neutral; 4 - Agree; 5 - Strongly agree. Of 450 questionnaires distributed, 430 valid responses were obtained, as follows:

Table 3.2. Composition of the Survey Sample by Respondent Group

Respondent Group	Number	Share (%)
Bus users	130	30.200
State management officials	110	25.600
Enterprise managers	100	23.300
Transport experts	90	20.900

Source: Calculations by the doctoral candidate

The sample includes management officials, enterprises, experts and service users. This composition provides perspectives on state management, service provision and bus service use.

3.3.2. Model Estimation Results

The doctoral candidate estimated the model using the survey dataset. The measurement scales were tested using Cronbach's Alpha, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) before estimating the multiple regression model. The regression results are as follows:

Table 3.3: Regression Model Results

Variable	B	Std.Error	Beta	t	Sig.	VIF
	Unstandardized B	Standard Error	Standardized Beta	t	Sig.	
(Constant)	-1.176	0.207		-5.684	0.000	
CN	0.344	0.028	0.382	12.239	0.000	1.020
HT	0.281	0.027	0.327	10.368	0.000	1.040
NL	0.186	0.028	0.210	6.745	0.000	1.017
DV	0.291	0.026	0.347	11.023	0.000	1.033
NT	0.211	0.027	0.240	7.749	0.000	1.006

Source: Calculations by the doctoral candidate

The regression equation using unstandardized coefficients is:

$$HQ = -1.176 + 0.344CN + 0.281HT + 0.186NL + 0.291DV + 0.211NT$$

All five independent variables (CN, HT, NL, DV and NT) are positively associated with the dependent variable HQ. Based on standardized Beta coefficients, CN (0.382), DV (0.347) and HT (0.327) have the strongest effects.

3.3.3. Results of Model Fit Assessment

Model Summary Test Results

Table 3.4: Model Summary Test Results

Statistic	Value
R	0.771
R Square	0.594
Adjusted R Square	0.589

Statistic	Value
Std. Error of the Estimate	0.299
Durbin-Watson	2.093

Source: Calculations by the doctoral candidate

The results indicate $R^2 = 0.594$ and adjusted $R^2 = 0.589$. Thus, the five independent variables explain approximately 59.4% of the variation in the dependent variable HQ. This represents a relatively good explanatory power for a study in public management. The Durbin - Watson statistic is 2.093, close to 2, suggesting no serious residual autocorrelation was detected. This further supports the reliability of the regression results.

The doctoral candidate also conducted ANOVA, multicollinearity and residual diagnostics, and tests of differences among respondent groups using one-way ANOVA and Welch's test. Overall, the tests indicate that the research model has a high level of fit in terms of statistical significance and practical explanatory power. The findings demonstrate that the application of Industry 4.0 technologies has a significant effect on the effectiveness of bus-based public passenger transport development in Hanoi.

3.3.4. Implications of the Survey Findings

The survey and model testing results identify differences in the effects of the factors on the effectiveness of bus-based public passenger transport development. They provide empirical evidence for identifying priority areas in improving state management of urban passenger transport. Accordingly, for factors found to have statistically significant effects, particularly DV, CN and HT, state management authorities should consider their relative importance when designing policies, allocating resources and selecting appropriate management instruments.

3.4. Overall Assessment of State Management of Urban Passenger Transport in Hanoi in the Context of Industry 4.0

3.4.1. Private Passenger Transport

The management of vehicles and drivers has gradually incorporated databases, registration, technical inspection and technology-enabled supervision. Nevertheless, the large number of private vehicles, their rapid growth and frequent use place enormous pressure on infrastructure. Policies to restrict private vehicles have not brought about

commensurate changes because public passenger transport has not yet become a sufficiently attractive substitute.

3.4.2. Public Passenger Transport

Hanoi has expanded its bus network, developed BRT and urban rail, and gradually introduced clean vehicles, electronic tickets, cashless payments, vehicle tracking and passenger information services. These developments provide an important foundation for an integrated public passenger transport system. Nevertheless, connections among modes remain inconvenient; transfer infrastructure, stops, parking facilities and accessibility are limited; and data and ticketing systems have not been fully integrated.

3.4.3. Semi-Public Passenger Transport

Semi-public passenger transport accounts for a relatively small share of traffic in Hanoi. Policies directly governing this category mainly focus on strict supervision of standards, quotas and the efficiency of vehicle use by the organizations responsible for those vehicles, so that procurement, use and maintenance are as effective as possible and public resources are not wasted.

3.4.4. State Management in Response to Industry 4.0 Trends

A notable achievement is the increasingly comprehensive policy framework for e-government, digital transformation, and science and technology. Hanoi has begun to establish control centers, camera systems, management software and digital platforms. Technology has strengthened monitoring, information provision and data-processing capacity. The main limitations include fragmented digital infrastructure and data; insufficient unified standards, technical regulations and data-sharing mechanisms; limited use of AI, Big Data and predictive analytics in state management; inadequate digital workforce capacity; and coordination mechanisms that have not yet been designed for data-driven governance.

3.4.5. Causes of Existing Limitations

These limitations arise from both objective and subjective factors. Urbanization and vehicle growth have proceeded rapidly while infrastructure investment resources remain limited, and technology changes faster than institutional reform cycles. Subjectively, organizational models and coordination mechanisms have not kept pace with integrated management requirements; data remain fragmented; personnel

specializing in data and technology are insufficient; technology investment in some areas is piecemeal; and the legal framework for transport-sector digital transformation remains incomplete.

CHAPTER 4.

PROPOSED SOLUTIONS TO STRENGTHEN STATE MANAGEMENT OF URBAN PASSENGER TRANSPORT IN THE CONTEXT OF THE FOURTH INDUSTRIAL REVOLUTION

4.1. Orientations, Requirements, and Objectives

The development orientation for urban passenger transport in Hanoi is linked to smart urban development, green transport, and high-capacity public passenger transport systems. State management needs to shift from fragmented management to integrated, data-driven management, ensuring connectivity and consistency among planning, infrastructure, vehicles, enterprises, and residents.

The objective of strengthening state management capacity is to achieve modern, intelligent, transparent, and people-centered governance. For management activities, the focus is on digitalization and data-driven governance; for society, improving service quality and accessibility; for the economy, reducing management and travel costs; for urban development, establishing an integrated public transport system; and for technology, leveraging AI, data, and digital platforms to support decision-making.

Based on the identified limitations in state management of urban passenger transport, the orientations, requirements, and objectives of state management, and the survey results concerning factors affecting the effectiveness of public passenger transport, the dissertation proposes the following solutions in order of implementation priority: (1) Reforming the state management organizational structure and establishing a shared-data-based management apparatus; (2) Institutionalizing coordination principles and clearly defining the lead and coordinating responsibilities of each agency and unit; (3) Prioritizing the application of Industry 4.0 technologies; (4) Investing in transport infrastructure in coordination with digital infrastructure; (5) Strengthening staff capacity and developing human resources; (6) Improving the legal and regulatory framework for digital transformation in state management; and (7) Developing a system for evaluating state management effectiveness.

4.2. Solutions to Strengthen State Management Capacity for Urban Passenger Transport in Hanoi in the Context of Industry 4.0

4.2.1. Reforming the Organizational Structure for State Management of Urban Passenger Transport

The dissertation proposes a data-driven state management model in which data

constitute the foundation linking management functions. The model aims to establish a management focal point capable of aggregating, sharing, and analyzing data from buses, metro systems, taxis, cameras, journey-monitoring devices, electronic payment systems, and other sources. Organizational reform entails not only changes in organizational structure but also changes in decision-making processes, shifting from incident-based responses toward proactive, predictive management.

Given the conditions analyzed above, the dissertation proposes the following intelligent and data-driven model for urban transport management, including the urban passenger transport system:

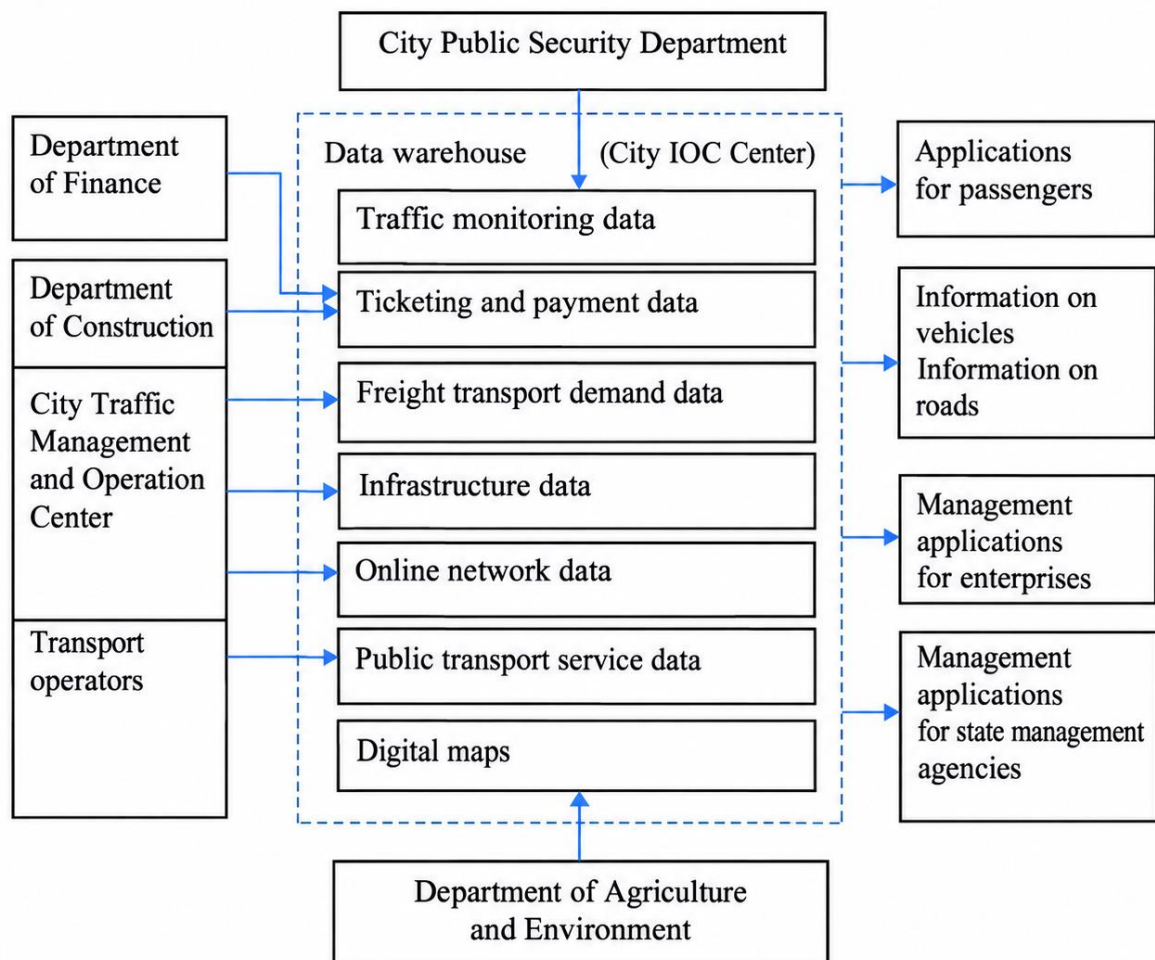


Figure 4.1. Data-Driven State Management Model for Urban Passenger Transport

In the immediate term, priority should be given to establishing a focal point for data management, clearly defining responsibilities among agencies, standardizing

information-exchange procedures, and gradually developing a shared database for urban passenger transport.

4.2.2. Reforming Coordination Mechanisms in State Management of Urban Passenger Transport

Whereas coordination among agencies and units previously relied mainly on traditional administrative procedures, paper-based information exchange, and separate sector-specific processing, it should now shift toward an interconnected model featuring digital data sharing and real-time management. Hanoi should develop an inter-agency coordination mechanism on a unified digital platform and formalize it through legal normative documents or coordination regulations, specifying the following:

- (1) Clearly identifying the lead agency and the responsibilities of each agency and unit within the coordination mechanism.
- (2) Shifting from a mechanism of 'providing data upon request' to one of 'continuous data connectivity and sharing'.
- (3) Developing detailed procedures and coordination mechanisms for handling emerging situations in real time.
- (4) Specifying responsibilities for updating, checking, and providing feedback on data quality.
- (5) Establishing mechanisms for inspecting and evaluating coordination effectiveness.
- (6) Strengthening the participation of transport enterprises and technology-platform providers in coordination mechanisms.

4.2.3. Applying the Achievements of the Fourth Industrial Revolution to Urban Passenger Transport Management

This solution focuses on establishing a unified transport database; applying AI and Big Data to analysis, forecasting, and operations; expanding ITS, AI-enabled cameras, and monitoring systems; developing electronic ticketing, digital payments, and integrated journey information; and establishing mechanisms for connecting data from transport enterprises and platforms with state management agencies.

4.2.4. Coordinated Investment in Transport and Digital Infrastructure

Transport infrastructure should be designed alongside digital infrastructure from the planning and investment stages. Existing systems may be utilized in the short term, but common standards for digital technology infrastructure in transport management should be introduced promptly as a basis for design, investment, and upgrading. Given the substantial capital requirements, a phased implementation roadmap and stronger mobilization of private and other non-state resources are necessary.

4.2.5. Strengthening Staff Capacity and Human Resource Development

Officials should receive training to collect, use, and analyze transport data; employ ITS, Big Data, and AI to support forecasting, monitoring, and decision-making; and acquire knowledge of data governance, information security, green transport, and multimodal transport management. In addition to training, professional development, and technology transfer, mechanisms should be established to attract specialists in data, digital technology, and intelligent transport.

4.2.6. Improving the Legal and Regulatory Framework for Digital Transformation in State Management

Specific regulations should be developed or proposed on transport data digitalization, data standards and technical regulations, system interoperability, and information sharing. The dissertation proposes that Hanoi aim to complete common standards and technical regulations for digital transformation in urban passenger transport by 2027 and, by 2030, finalize the legal framework and operational procedures for the shared database.

4.2.7. Developing a System for Evaluating the Effectiveness of State Management of Urban Passenger Transport

In addition to the above solutions, to ensure that the application of Industry 4.0 technologies to state management of urban passenger transport is effective, the dissertation proposes developing a set of criteria for evaluating state management effectiveness. This set of criteria may be applied after the Industry 4.0 technology solutions have been implemented to identify bottlenecks and make timely policy adjustments.

CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The Fourth Industrial Revolution (Industry 4.0) is bringing about profound changes in transport and urban management. Advances in artificial intelligence (AI), Big Data, the Internet of Things (IoT), cloud computing, and intelligent transport systems (ITS) are transforming the organization, management, and operation of urban passenger transport.

The dissertation has systematized the theoretical foundations of state management of urban passenger transport and clarified its roles, contents, and emerging requirements in the context of digital transformation and smart cities. Based on an examination of the current situation in Hanoi, the dissertation identifies positive developments in institutions, infrastructure, technology adoption, and digital management platforms, while also highlighting limitations relating to technological infrastructure, databases, human resources, coordination mechanisms, and the capacity to apply Industry 4.0 technologies.

The quantitative survey of bus-based public passenger transport shows that all five groups of factors- CN, HT, NL, DV, and NT - are positively associated with the dependent variable HQ. The model explains 59.4% of the variation in HQ ($R^2 = 0.594$; adjusted $R^2 = 0.589$). These findings provide supplementary empirical evidence and should not be directly generalized as a measure of the effectiveness of state management across the entire urban passenger transport system.

On this basis, the dissertation proposes seven groups of solutions that are modern, coordinated, and data-driven. Priority should be given to reforming the management apparatus, establishing a shared database, and institutionalizing coordination mechanisms among agencies and organizations. Solutions concerning technology adoption, digital infrastructure, human resources, the legal framework, and performance evaluation should be implemented in a coordinated manner according to a phased roadmap.

B. Recommendations

- For the Government and central ministries and agencies:
- + Improve the legal framework for digital transformation, digital data, and intelligent transport in the transport sector.

- + Establish an integrated national transport database that enables interoperability among ministries, agencies, and local authorities.

- + Introduce mechanisms and policies to support the development of intelligent transport systems and public passenger transport.

- + Increase investment in digital infrastructure, intelligent traffic management centers, and smart urban governance platforms.

- + Develop unified technical regulations for ITS, transport data, and digital platforms used in transport management.

- For Hanoi:

- + Reform the smart urban transport management model through the application of digital technologies and Big Data.

- + Develop and promulgate regulations on inter-agency coordination through digital platforms.

- + Establish an integrated transport data system to support real-time management and operations.

- + Expand the use of AI, Big Data, and intelligent cameras for traffic monitoring, regulation, and forecasting.

- + Accelerate the development and integrated connectivity of high-capacity public transport systems, including urban rail and bus rapid transit (BRT).

- + Research, develop, and promulgate a system for evaluating state management performance to monitor and assess the fulfillment of duties by agencies and organizations.

- + Strengthen public communication to encourage changes in private vehicle use and promote public transport.

LIST OF THE DOCTORAL CANDIDATE'S SCIENTIFIC PUBLICATIONS

1. Hai Binh Nguyen (2026), Evaluating the Cost-Benefit of Safety Risk Management Measures in Urban Public Transport Systems.
2. Hai Binh Nguyen (2026), Assessing the Institutional, Technological, and Financial Conditions for Deploying an Intelligent Transportation System (ITS) for Urban Traffic Management in Vietnam.
3. Trung Anh Nguyen, Hung Trong Dinh, Hai Binh Nguyen (2025), Building a Model to Evaluate Factors Affecting the Development of Logistics Services on the Lao Cai–Hanoi–Hai Phong–Quang Ninh Economic Corridor, Proceedings of the International Conference on Sustainability in Civil Engineering (ICSCE 2024).
4. Prof. Dr. Tu Sy Sua, Nguyen Hai Binh, Pham Ngoc Bao, Nguyen Quang Tai Anh (2024), “Green Development in Road Freight Transport in Vietnam,” Proceedings of the Scientific Conference “Green Development in Transport.”
5. Prof. Dr. Tu Sy Sua, Nguyen Hai Binh, Nguyen Quang Tai Anh, Nguyen Huu Que (2025), “A Study of International Experience in Sustainable Urban Transport Development: Lessons for Vietnam,” Proceedings of the Scientific Conference “Sustainable Transport Development in the Context of Digital Transformation.”