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A THREE-STAGE FRAMEWORK FOR EFFICIENT DEPLOYMENT OF INTELLIGENT TRANSPORTATION SYSTEMS IN URBAN AREAS

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Abstract

Rapid urbanization in big cities worldwide leads to severe traffic congestion and damages the urban living environment. Intelligent Transportation Systems (ITS) play a crucial role in addressing the growing challenges of urban transportation, such as congestion, pollution, and safety concerns. However, there is a lack of studies to present an overall framework to deploy ITS efficiently in urban areas considering each city's unique conditions. Therefore, this paper develops a three-stage framework to simplify the process of efficient deployment of ITS application services in a specific city. Three stages include identifying potential ITS services, evaluating and ranking the priority of ITS application services, and analyzing legal requirements as well identifying any gaps or areas where the current legal framework may fall short in accommodating ITS technologies. The three-stage framework considers the specific transportation challenges and requirements of each urban area/city, taking into account factors such as traffic patterns, infrastructure limitations, environmental considerations, and future development plans. A case study of Hai Phong city was presented where expert surveys were conducted to assess the current transport situation, evaluate satisfaction and expectation regarding applying ITS services. By providing a comprehensive framework for the efficient deployment of ITS in urban areas, this paper offers valuable insights and guidance to policymakers, transportation planners, and researchers. The framework can be as reference for other similar cities grappling with transportation challenges, facilitating the implementation of effective ITS solutions to transform advanced and sustainable urban transportation systems.

Keywords: urban transport; intelligent transport systems; smart transport; deployment framework; Vietnam.

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1. Introduction

Urbanization across the world is experiencing a constant increase. Approximately 53% of the world's population resides in urban areas, and it is projected to reach 67% by 2050. Urban travel already accounts for more than half (64%) of all travel conducted, and this percentage is anticipated to double by 2050 [1]. The rapid population growth and escalating travel demands present significant mobility obstacles, including shifts in travel patterns and a greater desire for speed, convenience, and reliable services [2].

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In developing countries worldwide, transportation issues related to capacity, safety, environmental compatibility, and economic efficiency are prevalent. These challenges affect both passenger and freight transportation. In particular, Vietnam grapples with problems such as traffic congestion, accidents, and environmental pollution obstructing the sustainable development. Notably, major cities like Ho Chi Minh and Hanoi cities predominantly rely on motorcycles as the primary mode of transport [3, 4]. Over the past two decades, motorcycle ownership in Vietnam has been growing at a rate exceeding 10% per year, resulting in a current ownership rate of 460 motorcycles per 1,000 individuals and as a globally second position [4]. As of 2022 recorded by General Statistics Office of Vietnam, cities such as Hanoi, Ho Chi Minh, and Hai Phong cities had approximately 4.35 million, 5.5 million, and 1.5 million personal vehicles, respectively. Currently, the area allocated for transport in these cities only accounts for about 8% of the total urban land area, whereas the prescribed standards and legal requirements call for a range of 24% to 26% and 16% to 26%, respectively. These factors have given rise to negative effects such as traffic congestion, environmental pollution, traffic security and safety, and a decline in the quality of urban life. Consequently, there is a pressing necessity to establish a more advanced transportation system [1, 5].

To effectively address the transport issues in major cities, a comprehensive solution is required, as depicted in Fig. 1 [6]. This solution encompasses several key components, including urban planning and developing a well-connected urban transport network; upgrading and expanding urban infrastructure; developing public transportation along with transport demand management policies, and especially integrating intelligent transportation systems (ITS). The term ITS is commonly used to refer to the integrated implementation of information and communication technologies (ICT) in transportation [7]. Specifically, ITS is considered as a transport management solution based on modern information technology, combining traffic engineering, communication technology, hardware and software technologies to improve safety and efficiency of the transportation system. The application of ITS can be employed across various aspects of the transport system, such as vehicles, infrastructure, and the drivers or users, all interacting dynamically [8]. ITS provides solutions for traffic management, information dissemination, interaction between vehicles and road infrastructure, emergency response, and, most importantly, safety [9]. The primary purpose of ITS is to assist transportation network controllers and other stakeholders (such as citizens, operators, and management agencies) in their decision-making process, utilizing precise real-time data about traffic and vehicle conditions [10].

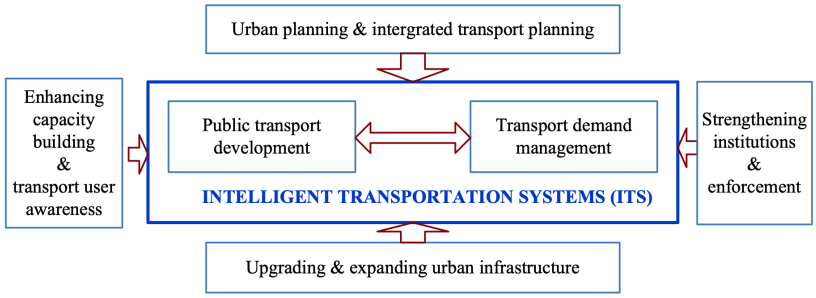

Figure 1. A comprehensive approach for enhancing urban transport systems [6]

The statistical report of the US Government Audit Office [11] shows that for every 1 USD invested in applying ITS for traffic operation and management, the benefit achieved is 25 USD from ensuring traffic safety, smoothly movement and environmental protection. The U.S. Federal Highway Administration [12] conducted a survey for several cities in the United States and found that the use of ITS has reduced accidents by 40% to 50%. Similarly, according to a report by the Korea Expressway

Corporation [13], the application of ITS since 2009 in Korea has reduced the number of accidents by 67% and the number of deaths by 50% in this country. For urban transport, if 1 USD was invested in a smart traffic light system, the benefit would be 40 USD from saving time and saving fuel consumption, namely 25% reduction in waiting time and 22% reduction in emissions [11]. The improvement of traffic flow and reduction of traffic congestion also have a positive impact on emissions and fuel consumption [12]. The data reported by the cities of Los Angeles and California showed a 13% decrease in fuel consumption and a 14% decrease in emissions. For the city of Abilene, the application results have shown an overall impact in terms of emissions reduction of 6%, fuel consumption reduction of 10% in HC, 13% in CO and 4% in nitrous oxide. For the city of Toronto, fuel consumption fell by 6%, carbon monoxide emissions by 5% and hydrocarbon emissions by 4%. However, a key question remains: how can we apply ITS effectively in urban transport operation and management, considering each city's unique conditions?

To overcome the above discussed issues, there are several measures that have been recently addressed. Hiep et al. [14] presented park and ride (P&R) solution in order to encourage transport users switching to use public transport systems and reduce private vehicles entering the Hanoi city center, especially for motorcycles. Hiep et al. [15, 16] carried out a analysis in order to identify congestion causes and provide remedy schemes of traffic organization and management for reducing congestion during rush hour surrounding the entrance gate of schools in Hanoi urban areas, especially for examining the effects of picking up primary school students by motorcycles on surrounding street's traffic. Hiep [17] evaluated the application of Parking Demand Management solutions for Central Business Districts in Vietnam. These studies have introduced some specific ITS's application services such as smart ticketing, real-time information, mobile application for after school pickup. Furthermore, Hai and Hiep [18] presented main applications of ITS on expressways and urban transportation, including traffic management system (TMS), electronic toll collection (ETC), monitoring and surveillance of overloaded vehicles. Hiep [6] has analyzed and identified benefits, potential services and requirements of applying ITS in operation and management for urban transport in Vietnam. Then, this study presented high-potential solutions for applying ITS services and its priority application levels corresponding to classified types of cities in Vietnam.

However, there is a lack of studies to present an overall framework to deploy ITS efficiently in urban areas considering each city's unique conditions. Therefore, this study utilizes Hai Phong city as a case study in order to illustrate a framework for efficient deployment of ITS in urban areas. Hai Phong is one of the five cities directly under the central government and it has rapid urbanization, population growth, ongoing transportation infrastructure development, diverse transportation modes, government support, and collaboration opportunities. Recently, Hai Phong city has initially established a Public Transport Authority (PTA) which was supported by the World Bank's initiative, as an efficient solution for sustainable urban transport development [19]. The ITS application has been discussed in the PTA's organization and operation. By selecting Hai Phong city, a case study can present valuable insights into the challenges and opportunities associated with deploying ITS in an urban environment, thereby contributing to the development of effective strategies and frameworks to smart city initiatives that can be replicated or adapted in other major cities in Vietnam and other regions facing similar transportation issues.

This paper is organized as follows. Section 2 provides fundamental requirements of ITS deployment in management and operation of urban transportation. Section 3 develops a methodology for efficient deployment of ITS application services in urban areas. A case study of Hai Phong city is shown in Section 4, where an expert survey was conducted to assess the current transport situation,

evaluate satisfaction and expectation regarding applying ITS services. Finally, Section 5 concludes the principal results. This research endeavor is to contribute to a better understanding of ITS deployment fundamentals and provide valuable insights for efficient deployment of ITS services for management and operation of urban transport, especially for similar cities in Vietnam as well other regions.

2. Fundamental requirements of ITS deployment

An assessment by the World Bank [20] has shown the potential of ITS deployment in developing countries to shorten the time considerably if appropriate opportunities are utilized (Fig. 2). Developed countries have gone through a period of testing and evaluating the effectiveness of ITS. Thus, the experience of developed countries will help developing countries learn and deploy ITS more effectively.

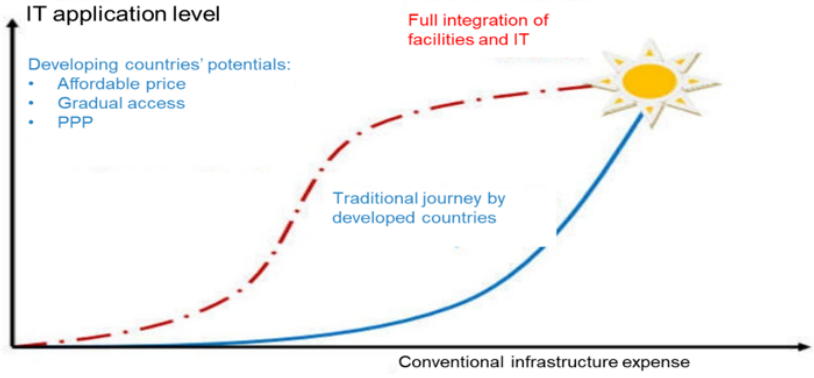

Figure 2. ITS deployment in developing countries

Besides, the ITS system is deployed based on information and communication technologies (ICT), so the technology used in the ITS is frequently changed and developed rapidly. Devices are always improved with better features to meet the convenience of the application. Therefore, the ITS system consists of a number of independent systems that need to ensure the functionality of working together and being ready for a new replacement. In order to effectively deploy the ITS system in countries with developing economies like Vietnam, Fig. 3 describes the fundamental criteria for deploying ITS that needs to be guaranteed in terms of compatibility, expandability/scalability, interoperability, and integration [21]. Compatibility ensures that when the software or hardware in a system needs to be upgraded by the original manufacturer or replaced with a new solution from another manufacturer, the system will still work properly. Expandability/scalability shows the ability to upgrade to ensure that the system being deployed can be upgraded to improve the functions of internal devices and software or that existing external devices and software are integrated into the system to enhance the system perfectly. Interactive ability ensures that two systems deployed and operated separately can be linked together to function as a single system. Interoperability should be ensured in the case of multiple systems being operated by a single operator. Integration capabilities to connect and harmonize many applications into one system. Additionally, standardization is the driving force behind implementing a ITS architecture systematically and supporting interoperability and interchangeability. Therefore, the issue of

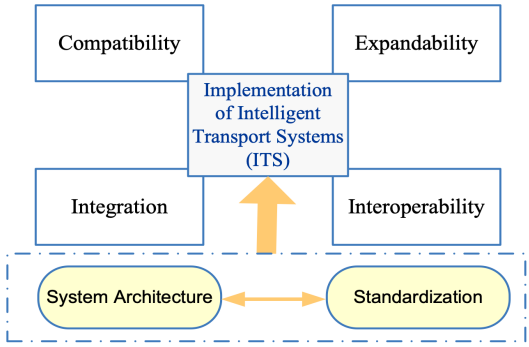

Figure 3. Fundamental requirements for ITS deployment [21]

building system architecture and standardizing ITS systems is very crucial before planning to deploy practical applications on a large scale of each country.

One of the significant challenges associated with ITS is the rapid evolution of the technology that underpins their functionalities. The need for thorough evaluation becomes paramount with each new technology lifecycle and the introduction of potential innovations. ITS assessment offers numerous benefits, including preventing and mitigating risks that could lead to project failure if the objectives are not met. Evaluation plays a crucial role throughout the development and deployment process of any ITS. Three key types of assessment are vital: feasibility assessment for project selection, implementation monitoring, and impact assessment. Feasibility assessment is conducted during the planning stage to prioritize implementation projects based on available funding. Therefore, before implementing the application of an ITS, it is essential to identify smart traffic services that are suitable, feasible, and effective. By conducting comprehensive assessments, we can ensure the successful deployment and utilization of ITS, thereby maximizing their potential benefits in urban areas.

3. Framework for efficient deployment of ITS in urban areas

Selecting suitable ITS for each urban area/city is imperative due to the wide array of available ITS services. Every city has unique transportation needs, infrastructure, and characteristics that require tailored solutions. The necessity of carefully choosing suitable ITS lies in the fact that not all services are equally applicable or effective in every urban setting. Different cities face distinct challenges such as traffic congestion, road safety issues, public transport inefficiencies, or specific environmental concerns. By selecting the most appropriate ITS services for a particular urban area/city, local authorities can address these specific challenges effectively and efficiently. A thoughtful selection process takes into account factors such as the urban area/city's size, population density, existing transportation infrastructure, urban layout, and future growth projections. It ensures that the chosen ITS services align with the urban area/city's goals, promote sustainable transportation practices, optimize traffic flow, enhance safety, and improve overall mobility. The suitability of ITS services varies from city to city, making it essential to carefully assess and select the most suitable solutions to maximize their potential benefits and address the unique transportation needs of each urban area.

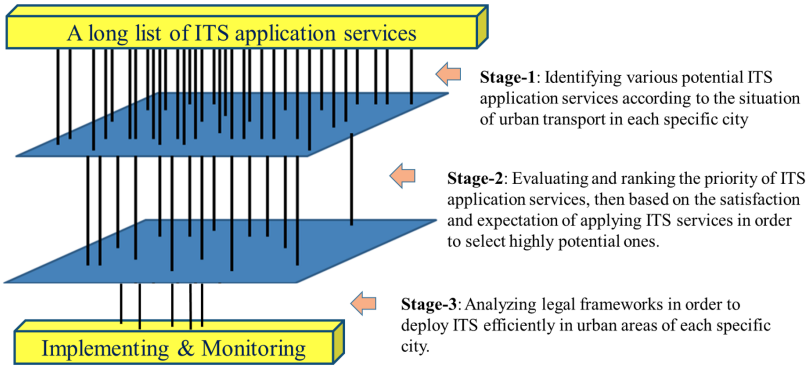

Figure 4. A three-stage framework for efficient deployment of ITS in urban areas

A three-stage framework to simplify the process of efficient deployment of ITS services in a specific city as shown in Fig. 4. The framework considers the specific transportation challenges and requirements of each urban area/city, taking into account factors such as traffic patterns, infrastructure limitations, environmental considerations, and future development plans. This proposed framework can assist decision-makers, planners, and transportation authorities in making informed decisions

regarding the most appropriate ITS services to implement. The framework would provide a structured approach for evaluating and comparing various ITS options, considering their potential impact, scalability, and compatibility with existing systems. By incorporating this method, it can ensure that the selected ITS services align with their unique needs and yield the desired outcomes in terms of improved traffic management, enhanced mobility, and sustainable transportation practices.

Stage-1 involves identifying and analyzing potential ITS applications and determining the requirements for their successful implementation. There are various services in applying for ITS, however, it is necessary to analyze the selection of highly feasible ITS services and determines the priority when deploying applications corresponding to each of urban types based on the following criteria [6]: (a) purpose and benefits achievement of ITS services; (b) traffic characteristics of each city; (c) ICT infrastructure of each city; (d) the existing transport system and the urban planning; and (e) the urban transport development strategy. The process also utilizes expert survey with questionnaire and/or interview manners.

The survey participants are required from various sectors related to management and operation of urban transport, such as state agencies, traffic police, research institutes, universities, private enterprises. The survey questionnaire is structured into three main parts to ensure comprehensive coverage of relevant topics. Part 1 focuses on gathering basic information of participants, including job positions, areas of expertise, years of working experience. Part 2 aims to determine the subjective perceptions of participants and their overall evaluation in order to identify critical problems regarding the existing transport conditions, including traffic congestion, road safety, public transport-related issues. The assessment survey of transport situation is utilized for identifying potential ITS services according to each specific city as mentioned in Stage-1. By understanding the current state of urban transport system, concerned problems can be identified where ITS could potentially provide significant improvements and benefits. Part 3 of the questionnaire is prepared to measure levels of ITS's awareness and knowledge of participants. Then, the level of satisfaction and expectation for applying ITS services is to be evaluated and orderly ranked from high to less necessity based on their understanding of current situations as illustrated in Stage-2.

The analysis of current legal frameworks associated with the ITS implementation in each urban area plays a crucial role in Stage-3. By examining existing legal frameworks, researchers and policymakers gain insights into the extent to which ITS implementation aligns with applicable laws, regulations, and standards. It helps identify any gaps or areas where the current legal framework may fall short in accommodating ITS technologies. Moreover, analyzing the legal framework provides an opportunity to evaluate the national and city governance structures surrounding ITS implementation. It examines the roles and responsibilities of various stakeholders, including government entities, transport agencies, and private sector participants, to ensure a practical and collaborative approach to implementing ITS technologies. Furthermore, the legal framework analysis serves as a foundation for policy development. It enables policymakers to identify areas where legal revisions or new regulations may be required to support the safe and efficient implementation of ITS. The findings help shape policies that promote innovation, ensure data privacy and security, address liability concerns, and establish guidelines for the ITS deployment in an efficient manner.

4. Survey results analysis and discussion

4.1. Survey background

The survey was conducted in Hai Phong city from December 13, 2021 to December 22, 2021. However, the survey process encountered significant challenges due to the complex nature of the COVID-19 epidemic, which affected the ability to collect survey questionnaires from the intended

participants. Despite these difficulties, efforts were made to reach out to individuals. The studied areas are limited in the city center and along main corridors of Hai Phong city as illustrated in Fig. 5.

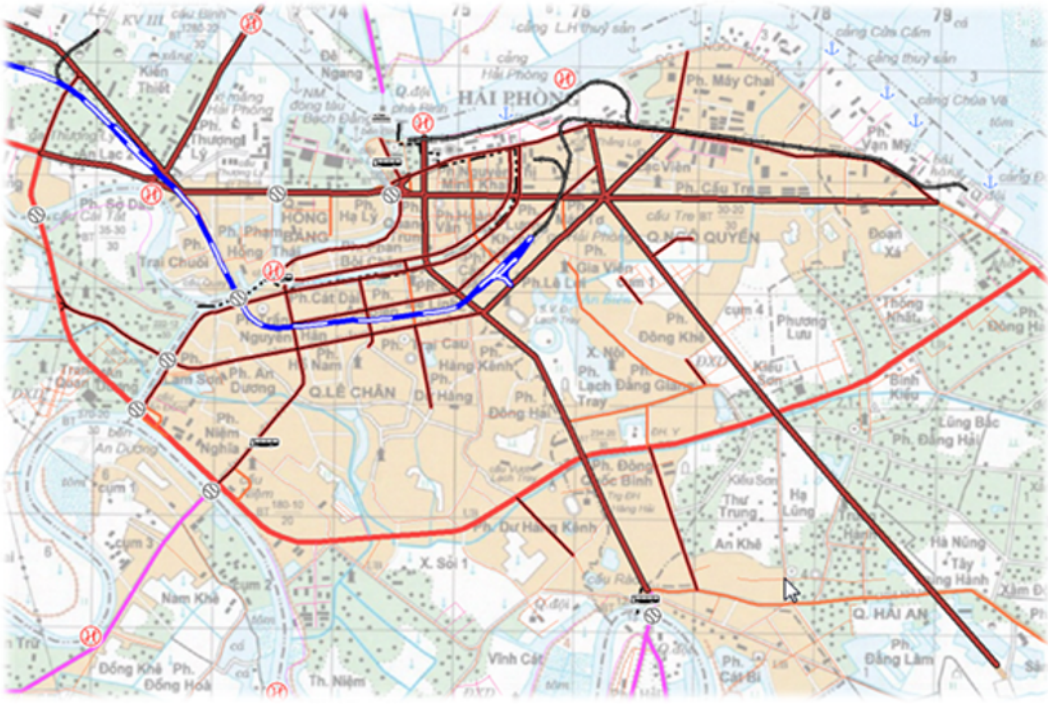

Figure 5. The studied areas of Hai Phong city
(Source: Hai Phong Department of Transport, 2022)

A total of 125 survey questionnaires were collected during the survey period from various respondents related to transportation operation and management, they are mostly from city state agencies, traffic police, research institutes, universities, private enterprises. It is noteworthy that the majority of survey participants had professional experience ranging from 5 to 10 years (28.8%), 10 to 20 years (30.4%), and more than 20 years (29.6%), as shown in Fig. 6. This indicates that the surveyed subjects possessed considerable work experience and a certain level of understanding regarding social and traffic-related issues.

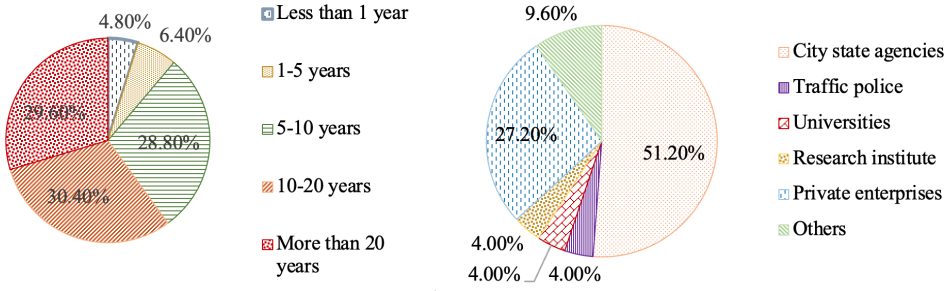

Figure 6. Working experience and working types of respondents

4.2. Assessment of the current transportation situation

Based on the analysis of survey results, the majority of respondents indicated that the current traffic of Hai Phong city is not in serious situation, including for the travelling by private cars. However,

there are several notable transportation issues in Hai Phong city that require attention, including inconvenient public transport, traffic congestion, parking problems, and traffic safety (Fig. 7). Among the identified problems, the inconvenience of public transport was highlighted by a majority of survey respondents (65.6%). This finding aligns with common challenges faced by developing urban areas like Hai Phong city, where the effectiveness of investment and development in the public transport system needs to be improved in order to ensure its convenience and reliability.

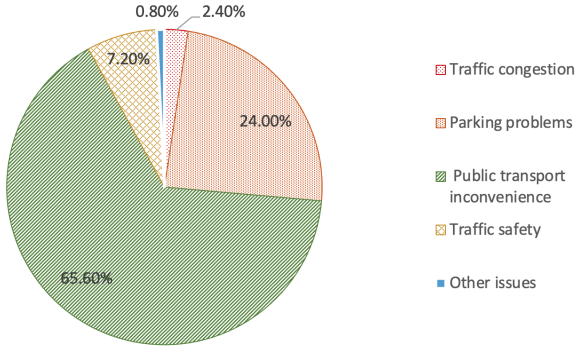

Figure 7. Assessment of transport issues in Hai Phong city

Regular congestions were identified in some main intersections (i.e. Cot Den, Tran Nguyen Han - Nguyen Duc Canh - Tam Bac, Quan Mau) as shown in Fig. 8, while serious traffic accidents were realized at Bui Vien street, Dinh Vu area (along NH.5), Vinh Bao commune area (along NH.10), as presented in Fig. 9. One of main reasons for traffic congestion are narrow streets in the city center and overloaded capacity of freight containers along national highways located in the city connecting to Dinh Vu and Lach Huyen habours (i.e., NH.5 and NH.10).

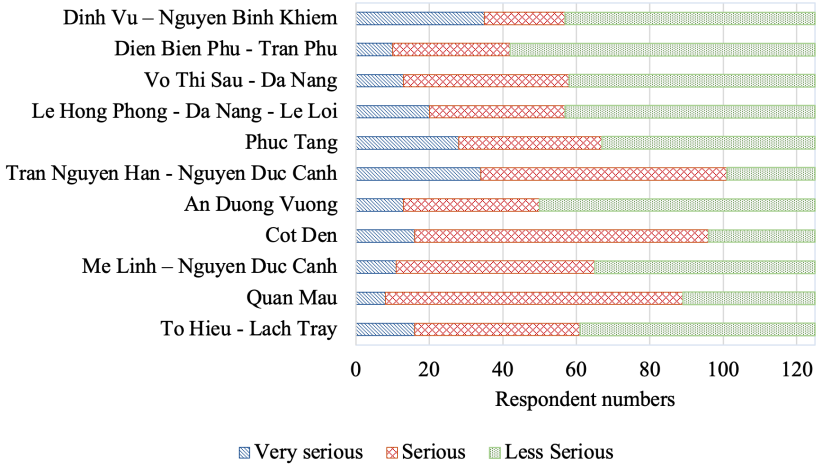

Figure 8. Assessment of traffic congestion at main intersections in Hai Phong city

These results suggest that although the current traffic situation in Hai Phong is generally manageable, there is a need to address the issues related to public transportation convenience and reliability. By focusing on enhancing the public transport system, including improving its accessibility, frequency, and quality, it is possible to alleviate the inconvenience experienced by commuters and promote sustainable transportation options in Hai Phong. According to the analysis results, a number of intersections that are assessed to have serious congestion are the intersection of Column Light,

the intersection of Tran Nguyen Han - Nguyen Duc Canh - Tam Bac, the intersection of Quan Mau intersection (Fig. 9). Moreover, according to the survey results, some areas that are considered to have serious traffic accidents are Bui Vien road, Dinh Vu area (at NH.5), Vinh Bao commune area, as shown in Fig. 10.

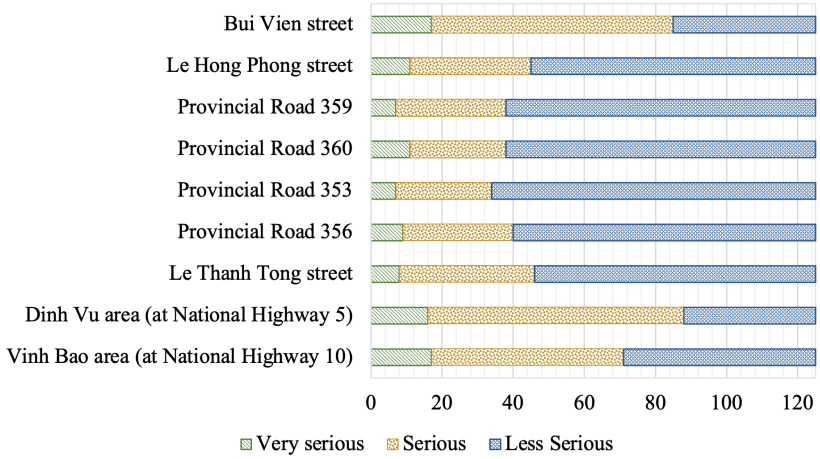

Figure 9. Assessment of traffic accidents in Hai Phong city

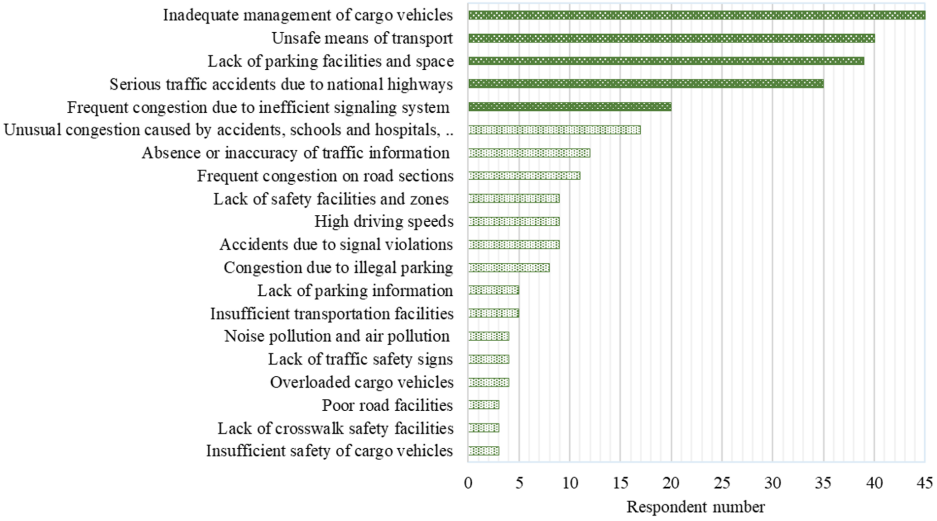

Figure 10. Assessment of transport problems in Hai Phong city

Regarding urban transport problems in Hai Phong city, out of the 21 issues raised, after analysis, there are five most severe problems as significantly emerged in Fig. 10. These include (1) inadequate management of cargo vehicles/containers; (2) the risk of causing accidents due to unsafe means of transport; (3) inconvenience caused by a lack of parking spaces and parking facilities; (4) potentially serious traffic accidents due to the narrow intersections and the overloaded capacity of cargo/freight vehicles on national highways in the city connecting to Dinh Vu and Lach Huyen harbors; and (5) frequent congestion due to inefficient signaling system. In addition, the survey result raises the issue for local traffic jams in crowded places as like schools and hospitals. These problems reflect the real situations regarding to traffic safety caused by cargo vehicles/ containers due to Hai Phong city as one of big harbor cities in Vietnam, especially Lach Huyen harbor is the biggest International Container

Terminal in Vietnam. In light of these circumstances, the implementation of ITS emerges as a vital solution that can offer advanced traffic management and control mechanisms to tackle congestion, optimize traffic flow, and enhance parking management. By leveraging ITS technologies, cities like Hai Phong can benefit from real-time traffic monitoring, intelligent traffic signal control, and efficient parking guidance systems. Additionally, ITS can facilitate the integration of different modes of transportation and improving the coordination of cargo vehicles/containers, reducing potential risks and further easing traffic congestion.

The survey also collected the evaluation from respondents regarding bus public transport in Hai Phong city. The respondents emphasized five significant issues as identified in Fig. 11, that are (1) poor accessibility including inadequate bus stops and shelters; (2) unreasonable transfers and increased travel time due to a lack of connecting bus routes; (3) passing through bus stops without stopping and irregular schedules; (4) long waiting time or irregular bus intervals; and (5) lack of/inconvenience of waiting facilities at bus stops. In the fact, these challenges can be improved by implementing ITS in order to enhance the efficiency and effectiveness of public transport system in Hai Phong city. ITS can help optimize bus scheduling, improve real-time information dissemination to passengers, enable better connectivity between different bus routes, and enhance overall system management. Additionally, ITS can facilitate the development of smart bus stops equipped with modern amenities, making the waiting experience more convenient for passengers. Implementing ITS in Hai Phong city would greatly contribute to alleviating the identified issues and providing a more seamless and user-friendly public transport experience for the residents.

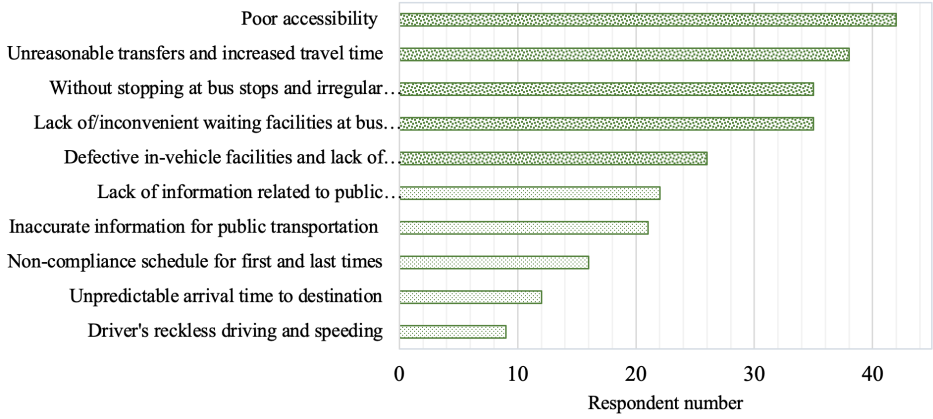

Figure 11. Assessment of bus public transport in Hai Phong city

4.3. Awareness and selection of ITS services

Based on the assessment of the current situation of urban transport in Hai Phong city, 22 potential ITS services are recommended as summarized in Table 1. According to the survey, a majority of respondents (52.0%) reported familiarity with ITS, indicating a level of awareness and knowledge. Most of ITS services for traffic management in Hai Phong city are currently implemented in a premilitary stage and unsatisfactory ratings, such as traffic flow control, emergency management, basic traffic information, automated traffic control. Furthermore, electronic payment services for public transport, parking fee collection, provision of trip information, traffic safety management for freight/cargo vehicles are not currently implemented in Hai Phong city.

In the survey, the level of satisfaction/expectation for applying ITS services was evaluated and orderly ranked from high to less necessity as presented in Table 1. Five essential ITS services were

selected as high priority for resolving problems of urban transport in Hai Phong city, that are in the order as follows: (1) traffic flow control; (2) traffic accident black-spot management; (3) provision of public transport information; (4) provision of integrated traffic information; and (5) traffic safety management for dangerous cargo/freight vehicles.

Table 1. Evaluation of satisfaction/expectation for applying ITS services in Hai Phong city

Group	ITS services	Selection (%)	Rank
Traffic management	Traffic flow control	81%	1
	Contingency management	34%	7
	Provision of basic traffic information	38%	6
	Traffic accident black-spot management	70%	2
	Automatic traffic control	30%	8
	Transportation administration support	12%	10
Public transport	Provision of public transport information	47%	3
	Public transportation management	10%	12
	Public transportation reservation	11%	11
	Semi-public transportation support (taxi, ferry, ...)	7%	18
Electronic payment	Electronic payment for transportation facility fee (parking, petrol, ...)	8%	14
	Electronic toll payment	8%	15
	Electronic payment for public transport fares (bus, taxi, ...)	8%	16
Traffic information	Integration and management of traffic information	6%	20
	Provision of integrated traffic information	42%	5
Travel information	Provision of pre-travel information	9%	13
	Provision of real-time travel information	6%	21
Vehicle and road	Safe driving assistance	13%	9
	Incident warning on road	7%	19
	Autonomous driving	2%	22
Freight/cargo transport	Traffic safety management for dangerous freight/cargo vehicles	43%	4
	Operation support for freight/cargo vehicles	8%	17

Firstly, implementing a traffic flow control system is crucial to alleviate frequent congestion at road intersections with traffic lights. This solution dynamically controls vehicle traffic based on real-time conditions, reduces travel time, and enhances overall road utilization efficiency. Secondly, the city should prioritize managing and mitigating frequent traffic accidents at intersections and main corridors. This can be achieved by implementing a traffic accident black-spot management system. By promptly detecting and responding to potential road safety threats, this solution aims to improve traffic safety, ensuring that drivers can navigate these areas safely and effectively. Thirdly, a comprehensive public transport information system should be established to address issues such as long or irregular waiting times for buses, inadequate transit services, and a lack of passenger information facilities. This system would provide crucial information to passengers, including bus routes,

transit information, real-time transit schedules, and bus arrival times. By providing this information, passengers can make informed decisions, enhancing their overall transit experience. Fourthly, an integrated traffic information system should be implemented to tackle congestion at road sections with traffic lights and localized traffic congestion in crowded areas such as schools and hospitals during specific periods. This solution would enable data linkage and management of traffic-related information, facilitating rational decision-making for commuters. By providing comprehensive and integrated traffic information, individuals can choose optimal departure times, transportation modes, and routes, improving traffic flow and reducing congestion. Lastly, a specialized system for traffic safety management in order to address the risks associated with overloaded cargo vehicles and containers travelling on national highways (i.e. NH 5 and NH 10) in the city connecting to Dinh Vu and Lach Huyen harbors. This system would collect operational information on these vehicles, enabling systematic management and timely response in the event of accidents. By minimizing the risks posed by such vehicles, the overall safety of road users can be significantly improved.

By implementing these recommended ITS solutions in Hai Phong city, the local authorities can effectively tackle congestion, enhance traffic safety, provide reliable public transport services, offer comprehensive traffic information, and improve the management of dangerous freight/cargo vehicles. These advancements in the city's transportation infrastructure would contribute to smoother traffic flow, increased safety, and a more sustainable and efficient transportation network overall.

Promoting public transport as the primary mode of urban transportation has been recognized as a fundamental approach to achieve global greenhouse gas (GHG) emissions reduction targets and enhance the quality of life in pursuit of sustainable development, along with the transition of e-mobility toward sustainable transport in Vietnam [22]. Thus, in order to develop and improve the public transport system in Hai Phong city, the study proposes the application of smart mobility services based on survey results and references. The suggested smart traffic services include motorcycle sharing, on-demand bus travel, and e-ticket card payment service deployment and expansion. However, it is important to understand that smart traffic systems should be considered as important complements to traditional traffic engineering and organization approaches rather than substitutes for traffic policies and institutions. Without proper institutions and policies, the effectiveness of smart transportation systems, especially those involving private sector participation, may be limited. In addition to the proposed smart transport services, to ensure the effective deployment of ITS, consistency with the national system architecture is necessary to ensure compatibility and suitability for future upgrade or expansion plans

4.4. Legal requirements for efficiently deploying ITS

In recent years, Vietnam has begun implementing ITS, yielding highly positive initial outcomes. The Ministry of Transport has established a comprehensive ITS application roadmap. This roadmap aims to standardize ITS nationwide, develop traffic control centers across the North, Central, and South regions, and establish fully integrated ITS systems. Major cities like Hanoi, Ho Chi Minh city, and Da Nang have already implemented various ITS projects, while urgent efforts are underway to incorporate ITS into the expressway system. Additionally, several traffic monitoring systems for management purposes have been successfully deployed. Looking ahead, the period from 2021 to 2025 will focus on solidifying the legal framework for the management model, operating and maintaining the ITS system, and establishing a National ITS Management Center to interconnect ITS centers throughout the entire expressway network nationwide.

National and city-level plans and policies underscore the importance of integrating information technology advancements into transport operation and management in Hai Phong city, focusing on

modernizing the urban transport system through technological applications. Notably, on November 23, 2020, the People's Committee of Hai Phong city approved Plan 270/KH-UBND, which outlines the implementation of applying information technology in transport operation and management, primarily targeting the road sector. The main objectives of this action encompass the application of information technology to enhance the efficiency of state agencies' direction and administration in the transport industry, facilitate improved services for transport users and agencies, establish a robust data infrastructure to support operation and management functions, ensure road traffic safety through ITS applications, foster collaboration, and develop specialized human resources in information technology while researching and implementing advanced technologies within the transportation industry.

Currently, the management and operation of urban transport in Hai Phong city is being carried out mainly by the Department of Transport and the Traffic Police. Therefore, to deploy ITS services in an efficient and integrated manner, it is necessary to legally establish a city-based center to perform the integrated functions of urban transport operation and management. Fig. 12 shows the coordination diagram between the Department of Transport and the Traffic Police for the establishment of City Transport Operation and Management Centre (CTOM).

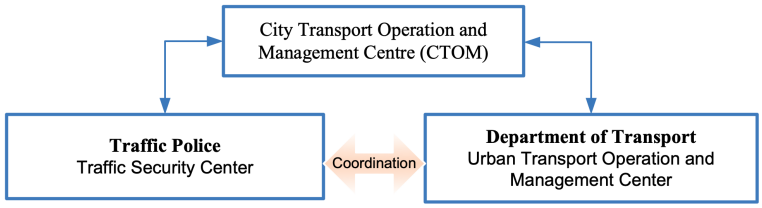

Figure 12. The coordination diagram for City Transport Operation and Management Centre (CTOM)

Table 2. Functional responsibilities for transport operation and management in Hai Phong city

No	Functional responsibilities	A city-based center (CTOM)	
		Department of Transport	Traffic Police
1	Planning for traffic organization	+	o
2	Operational management and control of traffic lights	+	o
3	Providing real-time traffic information	+	o
4	Management of public transport, taxis, and urban parking	+	o
5	Traffic monitoring through cameras	+	+
6	Warning, enforcement, penalty and traffic safety	o	+
7	Responding to emergency situations	+	+
8	Management and monitoring of cargo/freight vehicles and containers/heavy trucks	+	o
9	Traffic infrastructure management	+	o
10	Traffic data collection	+	o

Note: (+) Main responsibility; (o) Data sharing and coordination.

The central model of CTOM can be centralized or disaggregated according to the layout, but it is necessary to ensure the coordination, integration and sharing of information and data. Table 2 shows a number of functional responsibilities and integrated coordination under CTOM between department centers of the Department of Transport and the Traffic Police.

5. Conclusions

The paper has developed a methodology for deploying ITS application services efficiently in urban areas, which has three stages from identifying potential ITS services, evaluating and ranking the priority of ITS application services, analysing legal requirements as well identifying any gaps or areas where the current legal framework may fall short in accommodating ITS technologies.

A case study in Hai Phong city was presented where expert surveys were conducted to assess the current transport situation, evaluate satisfaction and expectation regarding applying ITS services. Five major problems of urban transport were identified, i.e. (a) inadequate management of cargo vehicles/containers; (b) the risk of causing accidents due to unsafe means of transport; (c) inconvenience caused by a lack of parking spaces and parking facilities; (d) potentially serious traffic accidents due to the narrow intersections and the overloaded capacity of cargo/freight vehicles on national highways in the city; and (e) frequent congestion due to inefficient signaling system. Regarding public transport, five most concerned issues are (i) poor accessibility including inadequate bus stops and shelters; (ii) unreasonable transfers and increased travel time due to a lack of connecting bus routes; (iii) without stopping at bus stops and irregular schedules; (iv) long waiting time or irregular bus intervals; and (v) lack of/inconvenience of waiting facilities at bus stops.

The survey showed that ITS services have been currently implemented in a premilitary stage and unsatisfactory ratings in Hai Phong city and a majority of respondents have a considerable level of awareness and knowledge. For their satisfaction/expectation of applying ITS services, there are five priority services in the order as follows: (1) traffic flow control; (2) traffic accident black-spot management; (3) provision of public transport information; (4) provision of integrated traffic information; and (5) traffic safety management for dangerous cargo/freight vehicles. In order to deploy ITS services in an efficient and integrated manner in Hai Phong city, the City Transport Operation and Management Centre (CTOM) needs to be established to perform the integration of functional responsibilities between the Department of Transport and the Traffic Police. These proposed ITS applications aim to improve the efficiency and effectiveness of the transportation system in Hai Phong, addressing the identified challenges and enhancing overall mobility. The findings from this study can serve as a valuable reference for other cities with similar characteristics, aiding in the effective implementation of ITS alongside smart city initiatives.

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References

[1] Alanazi, F. (2023). Development of smart mobility infrastructure in Saudi Arabia: a benchmarking approach. *Sustainability*, 15(4):3158.

[2] Tung, T. M. (2019). Sustainabilization of Hanoi mobility approached from new residential areas: Will it be a city without motorbike? *Journal of Science and Technology in Civil Engineering (STCE) - HUCE*, 13(1):89–99.

[3] Long, B. H., Ban, H. D., Hiep, D. V. (2019). Implementation of motorcycle-related policies in Vietnam: More failures and less successes. In *Proceedings of the 13th International Conference of the Eastern Asia Society for Transportation Studies (EASTS)*, Sri Lanka.

[4] Hang, N. T. L., Hiep, D. V., Ban, H. D. (2019). Traffic culture of motorcycle users in Vietnam: A study for evaluation after 10 years of official deployment. In *Proceedings of the 13th International Conference of the Eastern Asia Society for Transportation Studies (EASTS)*, Sri Lanka.

[5] Schafer, A., Victor, D. G. (2000). The future mobility of the world population. *Transportation Research Part A: Policy and Practice*, 34(3):171–205.

[6] Hiep, D. V. (2017). Solutions for applying intelligient transportation systems to operation and management of urban transport in Vietnam. *Journal of Science and Technology in Civil Engineering (STCE) - HUCE*, 11(5):66–74. (in Vietnamese).

[7] Miles, J. C. (2014). Intelligent transport systems: overview and structure (history, applications, and architectures). *Encyclopedia of Automotive Engineering*, 1–16.

[8] Mangiaracina, R., Perego, A., Salvadori, G., Tumino, A. (2016). A comprehensive view of intelligent transport systems for urban smart mobility. *International Journal of Logistics Research and Applications*, 20(1):39–52.

[9] Xiong, Z., Sheng, H., Rong, W., Cooper, D. E. (2012). Intelligent transportation systems for smart cities: a progress review. *Science China Information Sciences*, 55(12):2908–2914.

[10] Yokota, T., Weiland, R. J., Yamagata, H. (2005). Approaches for Introducing Intelligent Transportation Systems into Developing Countries. *Transportation Research Record: Journal of the Transportation Research Board*, 1910(1):72–81.

[11] GAO (2016). *Intelligent transportation systems - urban and rural transit providers reported benefits but face deployment challenges*. Report to the Committee on Transportation and Infrastructure, House of Representatives. United States Government Accountability Office, USA.

[12] FHWA (1999). *ITS benefits: Continuing successes and operational test results*. FHWA-JPO-98-002, Federal Highway Administration, USA.

[13] KEC (2016). *Intelligent transport systems*. Korea Expressway Corporation (KEC).

[14] Hiep, D. V., Hung, T. M., Sau, B. V., Tung, L. T., Tuan, N. A. (2021). Evaluation for the trend of utilizing the "Park and Ride" solution in order to reduce motorcycles entering into the center of Hanoi city. *Journal of Science and Technology in Civil Engineering (STCE)-HUCE*, 15(7V):57–67. (in Vietnamese).

[15] Hiep, D. V., Hung, T. M., Han, H., Tuyen, N. V., Huy, V. V. (2020). Cause analysis and remedy scheme of traffic organization and management to reduce congestion during rush hour surrounding the entrance gate of schools in Hanoi urban areas. *Journal of Science and Technology in Civil Engineering (STCE)-HUCE*, 14(4V):67–76. (in Vietnamese).

[16] Hiep, D., Huy, V. V., Kato, T., Kojima, A., Kubota, H. (2020). The effects of picking up primary school pupils on surrounding street's traffic: a case study in Hanoi. *The Open Transportation Journal*, 14(1): 237–250.

[17] Hiep, D. V. (2017). Research on application of parking demand management solutions for central business districts in Vietnam. *Journal of Science and Technology in Civil Engineering (STCE)-HUCE*, 11(3):50–58. (in Vietnamese).

[18] Hai, T. H., Hiep, D. V. (2012). Application of intelligent transportation systems in Vietnam: challenges and opportunities for sustainable transportation. In *The 5th ATRANS Symposium on "Transportation for A Better Life: Preparing for ASEAN Integration*, Bangkok, Thailand.

[19] Hiep, D. V., Trel, E. (2017). Public transport authority as an efficient solution for sustainable urban transport development: A case study in Hai Phong city. *Journal of the Eastern Asia Society for Transportation Studies*, 12:356–374.

[20] World Bank (2004). *Technical note 3: Innovative approaches to the application of ITS in developing countries*. The World Bank, Washington DC., USA.

[21] Hiep, D. V. (2017). *Intelligent transportation systems for urban areas*. Construction Publishing House, Ministry of Construction, Vietnam. (in Vietnamese).

[22] Hiep, D. V., Tran, N. H., Tuan, N. A., Hung, T. M., Duc, N. V., Tung, H. (2023). Assessment of electric two-wheelers development in establishing a national e-mobility roadmap to promote sustainable transport in Vietnam. *Sustainability*, 15(9):7411.