16TH ATRANS ANNUAL CONFERENCE

"TRANSPORTATION FOR A BETTER LIFE: TRANSFORMING TOWARDS DECARBONIZATION, SAFETY, AND SUSTAINABILITY "

ATRANS
Asian Transportation Research Society
สมาคมวิจัยวิทยาการขนส่งแห่งเอเซีย

IATSS
International Association of Traffic and Safety Sciences

1 September 2023
Chatrium Grand Bangkok
Thailand

PROCEEDINGS OF

ATRANS YOUNG RESEARCHER'S FORUM 2023

Organized by
Asian Transportation Research Society (ATRANS) and
International Association of Traffic and Safety Sciences (IATSS)

Welcome Message from the Chair of ATRANS Annual Conference & Activity Committee

Dear ATRANS Young Researcher's Forum 2023 Participants,

It is a pleasure to welcome you to the 16th ATRANS Annual Conference: Young Researcher's Forum (AYRF) 2023.

In this sixteenth year, ATRANS organized 1 day event in which AYRF 2023 Paper Presentation Session takes place on 1st September 2023 in the afternoon session of the annual conference, our main event. We received magnificent supports from reputedly well-known speakers coming from multidisciplinary area across the continent to share their knowledge, information and valuable experiences with the conference's delegates and the participants during this 1-day meeting event.

This year we are able to meet face-to-face making our event a significant place for academic gathering and discussion, regaining relationships, and networking as well as increasing engagement.

Thanks to the convenient, accessible, and affordable transportation system nowadays, we can travel anywhere around the globe. Nevertheless, even though transportation is capable supportive of the mobility needs of a society, we should consider a manner that is the least damageable to the environment and does not impair the mobility needs of future generations.

Hence, this year conference's theme is upon "Transportation for a Better Life: Transforming Towards Decarbonization, Safety, and Sustainability."

On behalf of ATRANS, I wish to express my sincere gratitude to the Young Researcher's Forum Committee and the staff who worked relentlessly to make the conference and ATRANS Young Researcher's Forum 2023 possible. I earnest hope that you all, will enjoy listening to the presentations, exchange knowledge and information, and have good times staying in Thailand.

Tuenjai Fukuda, Dr. Eng.

ATRANS Secretary-General, and

Chair of ATRANS Conference & Activity Committee

September 2023

Welcome Message from Vice-Chair of ATRANS Conference & Activity Committee

Dear Esteemed Attendees, Scholars, and Visionaries of the Future,

It is with immense pride and honor that we extend our warm welcome to each one of you for the 16th ATRANS Annual Conference, which is held at the Chatrium Grand Bangkok Hotel. This event symbolizes the dedication, passion, and collaborative spirit that has always been the hallmark of the Asian Transportation Research Society (ATRANS).

A special highlight this year is the ATRANS Young Researcher's Forum (AYRF) 2023. Recognizing the vigor, fresh perspectives, and innovative solutions brought by the young minds in our academic and professional communities, AYRF is a dedicated platform that is built to foster, encourage, and showcase their exceptional contributions. We believe that by connecting these researchers with leading experts and like-minded peers, we can ignite conversations that drive the future of transportation research. Our aim for AYRF 2023 is more than just an academic exchange. We are committed to providing an opportunity for budding researchers, scholars, and students to bring forth their research papers for international peer-review. This is not just an evaluation, but a pathway to mentorship, feedback, and collaboration. We understand the significance of presenting research on an international stage and the boost it gives to young academics, both in terms of career progression and personal growth.

We encourage our young researchers to approach this forum with an open mind. Immerse yourself in the vast wealth of knowledge, ask challenging questions, and build networks that will assist you throughout your research journey. To our esteemed attendees, we urge you to offer your insights, experience, and encouragement to the next generation of transportation researchers. Your expertise and feedback are invaluable tools that will help shape and refine their work.

We would like to express our gratitude to our sponsors, partners, and dedicated team members who worked tirelessly to make this event a reality. The unwavering support and belief in the vision of AYRF have been pivotal to its success. As we convene for this year's conference, let's remember that each research paper, discussion, and presentation could very well be the catalyst for transformative solutions in the realm of transportation.

Together, let's inspire and be inspired.

With warm regards,

Asst.Prof.Pol.Lt.Col. Waiphot Kulachai, Ph.D.
Vice-Chair of ATRANS Conference & Activity Committee
Suan Sunandha Rajabhat University
September 2023

Welcome Message from ATRANS Young Researcher's Forum Advisory Committee 2023

Dear ATRANS Young Researcher's Forum (AYRF) 2023 Participants

With utmost pleasure and gratitude, I extend my heartfelt welcome to the AYRF sessions of the 16th ATRANS Annual Conference, being held in Bangkok, Thailand, in the year 2023.

Our journey to this moment has been defined by resilience and shared endeavor, particularly in the face of the challenges posed by the global COVID-19 pandemic. The trials of the past years, with their encompassing lockdowns and constrained activities, serve as markers of our collective difficulty. While gradual restoration has taken place, it remains evident that not all aspects of our lives have reverted to their former state. A transformative shift in our way of life has redefined norms of travel. This paradigm shift within the domain of transportation, demanding a thorough reevaluation, underscores the conference theme: "Transportation for A Better Life." It is also of vital importance that we address the emerging concerns of safety and decarbonization—dominant factors that collectively define the sustainability of our society and our shared world. These multifaceted challenges necessitate intellectual and innovative research responses.

The AYRF sessions embody our commitment to encourage the fresh perspectives and energies of our young colleagues, providing them with a platform to present their ongoing or completed research endeavors and to engage with professionals and scholars who possess a wealth of experience in the field of transportation.

To the dedicated reviewers who have spent their valuable time reviewing and providing constructive comments to the young authors, your contributions are highly appreciated.

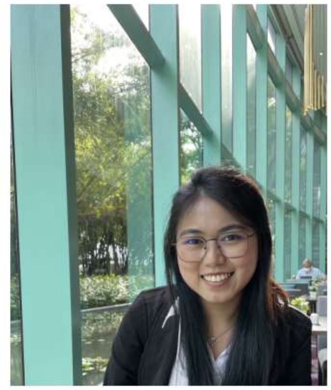
In conclusion, I extend my heartfelt wishes for the success of both the AYRF sessions and the comprehensive 16th ATRANS Annual Conference.

With deepest gratitude and anticipation,

Assoc.Prof.Dr. Varameth Vichiensan

Advisory Committee for ATRANS Young Researcher's Forum 2023

Welcome Message from President of ATRANS Young Researcher's Forum Committee 2023



Dear ATRANS Young Researcher's Forum (AYRF) 2023 Participants,

On behalf of ATRANS Young Researcher's Forum Organizing Committee, I would like to extend our welcome to all of the researchers, academicians, young scholars and students from global attending 16th ATRANS Annual Conference, held on 1 September 2023 at Chatrium Grand Hotel, Bangkok.

Transportation for a Better Life: Transforming Towards Decarbonization, Safety, and Sustainability was selected as a main theme of the conference this year and we believe that this event would bring a great opportunity for many young researchers to present the insight and significant research findings in the field of transportation. I would like to take this opportunity to sincere thanks to our admirable keynotes speaker for sharing their valuable knowledge and we hope every participant would gain research idea, inspiration, and motivation for upcoming research trends from many experts in this conference.

Wishing this annual event would be a place for networking with many researchers, scholars from various countries and we do hope that everyone will enjoy in this event. Lastly, I also would like to express my sincere appreciation to all our conference organizing committee for your hard work and continuous support towards ATRANS Annual Conference.

Sincerely,
Sandar Win
Chulalongkorn University
President of ATRANS Young Researcher's Forum Committee 2023

List of ATRANS Young Researcher's Forum 2023 Organizing and Scientific Committee

AYRF Organizing and Scientific Committee		
1	Ms. Sandar Win	Chulalongkorn University
2	Mr. Rattapon Thongpaen	Chulalongkorn University
3	Mr. Bundam Ro	Suranaree University of Technology
4	Mr. Sopanha Yim	Asian Institute of Technology
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7	Ms. Thitiya Phongklee	Kasetsart University
8	Ms. Sutthikarn Weluwanarak	Burapha University

List of Mentors of ATRANS Young Researcher's Forum 2023 Committee

AYRF 2023 Mentors		
1	Mr. Naruphol Niyom (AYRF Alumni and Mentor of ATRANS Young Researcher's Forum Committee 2017-2021)	PlanPro Corp., Ltd., (Transportation Consultant)
2	Ms. Suwishada Fukuda	ATRANS Secretariat for In-House Management
3	Ms. Narisara Pongpakdeeboribhan	ATRANS Secretariat for Academic Affairs
4	Mr. Wisuthiluk Pongpakdeeboribhan	ATRANS Secretariat for Academic Affairs

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International Advisory Committee		
1	Dr. Tuenjai Fukuda	Chair of ATRANS Annual conference & Other Activity Committee Advisory Committee of AYRF 2023
Local Advisory committee		
2	Asst.Prof. Pol.Lt.Col.Dr. Waiphot Kulachai	Vice-Chair of ATRANS Annual conference & Other Activity Committee Advisory Committee of AYRF 2023 Suan Sunandha Rajabhat University
3	Assoc.Prof.Dr. Varameth Vichiensan	Advisory Committee of AYRF 2023 Kasetsart University

List of the Paper Reviewers of ATRANS Young Researcher's Forum 2023

NO.	Reviewer Name	Organization
1	Prof. Dr. Atsushi Fukuda	Nihon University, Japan
2	Prof. Dr. Alexis M. Filone	De La Salle University, the Philippines
3	Prof. Dr. Pongrid Klungboonkrong	Khon Kaen University
4	Prof. Dr. Thaned Sathiennam	Khon Kaen University
5	Assoc. Prof.Dr. Chumnong Sorapipatana	Asian Transportation Research Society (ATRANS)
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14	Asst. Prof. Dr. Sittha Jaensirisak	Ubonratchathani University, Thailand
15	Asst. Prof. Dr. Phongphan Tankasem	Mahasarakham University
16	Dr. Passakon Prathombutr	Senior Executive Vice President, Digital Economy Promotion Agency (DEPA), MODES
17	Dr. Suwat Wanisubut	Former, Deputy Permanent Secretary, National Economic and Social Development Council (NESDC)
18	Dr. Rungsun Udomsri	Asian Transportation Research Society (ATRANS)
19	Dr. Pattarathep Sillapacharn	Department of Highways, Thailand
20	Dr. Sumet Ongkittikul	Thailand Development Research Institute (TDRI)
21	Dr. Puthipong Jaragasigorn	Thammasart University
22	Dr. Tuenjai Fukuda	Nihon University, Japan

Program of ATRANS Yong Researcher's Forum (AYRF) 2023
Paper Presentation Sessions

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TENTATIVE PROGRAM
16TH ATRANS ANNUAL CONFERENCE
"TRANSPORTATION FOR A BETTER LIFE: TRANSFORMING TOWARDS DECARBONIZATION, SAFETY, AND SUSTAINABILITY"
1 September 2023, 9:00 – 18:00, Chatrium Grand Bangkok Hotel

9:00 – 9:35 Opening Session Room: Chatrium Ballroom on 2nd Floor	
9:00 – 9:05 **Introducing and welcoming Message**	**By Dr. Passakon Prathombutr** SEVP / CTO of DEPA, MoDES and 1st Vice-Chairperson of ATRANS
9:05 – 9:15 **Welcome Message**	**By Mr. Nobuyuki Kawai** Executive Director, International Association for Traffic and Safety Sciences (IATSS)
9:15 – 9:25 **Opening Remark**	**By Dr. Chula Sukmanop** Secretary-General of EEC and ATRANS Chairperson
9:25 – 9:55 Keynote Lecture: **"Transforming Towards Decarbonization, Safety, and Sustainability in Transportation in Thailand"** **By Dr. Chula Sukmanop, Secretary-General of EEC, Office of Prime Minister and ATRANS Chairperson**	
9:55 – 10:00 **Group Photo Session**	ATRANS Chairperson, Board Members, IATSS, Invited Guest Speakers, VIP Guests are invited on stage for group photo
10:00 – 10:20	Coffee break

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10:20 – 12:00 Morning Session Session 1: "Transforming Towards Decarbonization, Safety, and Sustainability in Transportation Room: Chatrium Ballroom on 2nd Floor Moderator: Admiral Dr. Samai Jai-in, ATRANS Board Member	
10:20 – 10:40, 1st Speaker **"Smart Sharing City for Sustainable Society"**	**By Prof.Dr. Akinori MORIMOTO,** Dept. of Civil and Environmental Engineering, School of Creative Science and Engineering, Waseda University, Japan
10:40 – 11:00, 2nd Speaker **"Disaster Risk Reduction of Transport Infrastructure"**	**By Prof.Dr. Tomohiro ICHINOSE,** Dean of Faculty of Environment and Information Studies, Keio University, Japan
11:00 – 11:20, 3rd Speaker **"Pathways towards Decarbonization in Japan's Aviation Sector -Introduction of Recent Research Activities of JTTRI-"**	**By Mr. Akihiro TOMITA** Executive Director & Senior Research Fellow, Japan Transport and Tourism Research Institute
11:20 – 11:40, 4th Speaker zoom **"Decarbonization and Sustainability in Transportation: Global and Regional Perspective"**	**By Dr. Madan B. REGMI** Chief of Transport Research and Policy Section, UNESCAP
11:40 – 12:00	**Discussion, Q&A**
12:00 – 13:00	Lunch break at the Savio Buffet Restaurant on Ground Floor

Continued on next page

Program of ATRANS Yong Researcher's Forum (AYRF) 2023
Paper Presentation Sessions (continued)

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13:00 – 13:30 Special Lecture:
"AMATA Smart City: Adopted Yokohama Model and beyond"
By Mr. Vikrom Kromadit, Chairman of Amata Corporation Public Company and Chairman of the Amata Foundation
Room: Chatrium Ballroom on 2nd Floor

13:35 – 15:30, 1st Afternoon Session

13:35 – 15:30 Parallel Session 2A:
"Sustainability and Innovation Technology in Transportation and Logistics, (i.e., Active Transport, Smart mobility, EV, AV, Drone, etc.),"
Room: Chatrium Ballroom 1
Moderated by Assoc. Prof. Dr. Sorawit NARUPITI, Chulalongkorn University

13:35 – 14:00, 1st Speaker **"Convenient Walking, Safe Cycling" Active mobility for the healthy city"**	**By Mr. Silpa Wairatpanij, Manager,** Thailand Walking and Cycling Institute Foundation (TWCIF)
14:00 – 14:25, 2nd Speaker **"Smart City & Smart Mobility in 5G and AI Era"**	**By Dr. Passakon PRATHOMBUTR** Senior Executive Vice President of the Digital Economy Promotion Agency (DEPA), Thailand
14:25 – 14:50, 3rd Speaker **"Social Acceptability of Autonomous Vehicles: The Case of Japan"**	**By Prof. Dr. Akihiro NAKAMURA** Faculty of Economics, Chuo University, Japan
14:50 – 15:15, 4th Speaker **"Logistic Services Utilizing Drone & Flying Car: Trials in Japan"**	**By Prof. Dr. Atsushi FUKUDA** ATRANS Honorable Advisor, Nihon University, Japan
15:15 – 15:30	**Discussion, Q&A**
15:30 – 15:40	Coffee break

13:35 – 15:30 Parallel Session 2B:
"Road Traffic Safety, i.e., Infras & Engineering, Education, Enforcement, Data Analytic, AI and others"
Room: Chatrium Ballroom 2
Moderated by Dr. Witaya Chadbunchachai, WHO Expert Advisory Panel for injury Prevention and Control, Khon Kaen Hospital

13:35 – 13:55, 1st Speaker **"Spatio-Statistical Characteristics of Fatal Traffic Crashes in Bangkok: From the Viewpoint of IATSS Zero Strategies"**	**By Prof.Dr. Kenji DOI** Urban Transportation Planning, Division of Global Architecture, Graduate School of Engineering, Osaka University
13:55 – 14:15, 2nd Speaker **"Improving Multi-Agent Trajectory Prediction Using Traffic States on Interactive Driving Scenarios"**	**By Dr. Roy Debaditya** Institute of High-Performance Computing, A*STAR, Singapore
14:15 – 14:35, 3rd Speaker **"Policy Study on the innovation development guidelines to solve traffic and transportation problem"**	**By Dr. Surachet Pravinvongvuth** Chairman of Sub-committee, Transport Commission, House of Representatives. Thailand
14:35 – 14:55, 4th Speaker **"Sustainable Road Infrastructure Development for Smart Crosswalks"**	**By Dr. Songrit Chayanan** Deputy Director of Highways Safety Bureau, Department of Highways (DOH
14:55 – 15:15, 5th Speaker **"Enhancing Road Safety Culture and Education for Children in Thailand"**	**By Asst.Prof.Dr. Sittha Jaensirisak,** Chair of ATRANS Editorial Committee, Ubonratchathani University, Thailand
15:15 – 15:30	**Discussion, Q&A**
15:30 – 15:40	Coffee break

Program of ATRANS Yong Researcher's Forum (AYRF) 2023
Paper Presentation Sessions (continued)

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15:40 – 17:30 2nd Afternoon Session of ATRANS Young Researcher's Forum 2023 Paper Presentation Sessions	
15:40 – 16:30 Parallel Session 3.1A: **Topic (1) Resilient & Sustainable Transportation Planning,** **Room: Chatrium Ballroom 1 on 2nd Floor** **Chaired by Prof. Dr. Alexis M. Filone, De La Salle University, Philippines**	
15:40 – 15:52 Presenter 1 AYRF 2023-005 "The Prevalence of Small Streets and Its Influence on Car Ownership in Hanoi, Vietnam" Presents by **Mr. Ngo Trung PHUONG** Graduate School of Science and Engineering, Saitama University, Japan	**15:52 – 16:04 Presenter 2** AYRF 2023-017 "A Study on The Factors Affecting the Driver's Preference on The Toll Collection in Cavitex" Presents by **Mr. John Isac Tengco** Department of Civil Engineering, De La Salle University, The Philippines
16:04 – 16:16 Presenter 3 AYRF 2023-024 "A Systematic Assessment of Transportation-engineering-related Indicators through a Review of Sustainable Roadway Rating Tools" Presents by **Dr. Nam Hoai TRAN** International Civil Engineering Program, Duy Tan University, Danang, Vietnam	**16:16 – 16:28 Presenter 4** AYRF 2023-028 "Effects of Expressways on Condominium Prices: An Investigation of Condominiums in Metro Manila using Hedonic Regression Analysis" Presents by **Mr. John Francis Ong** Department of Civil Engineering, De La Salle University, The Philippines
16:30 – 17:30 Parallel Session 3.2A: **Topic (2) Public transportation and connectivity and Topic (4) Innovation Technology in Transportation including Smart Mobility, (ITS), EV, Autonomous Vehicles** **Room: The Chatrium Ballroom 1 on 2nd Floor** **Chaired by Assoc. Prof. Dr. Saroch Boonsiripant, Kasetsart University**	
16:30 – 16:42 Presenter 1 AYRF 2023-001 "Determinants of Continuance Intention to Utilize Electric Motorcycles for Students in Hanoi, Vietnam" Presents by **Ms. Ngoc Minh NGO** Faculty of Transport-Economics, University of Transport and Communications	**16:54 – 17:06 Presenter 3** AYRF 2023-004 "Sexual Harassment in Public Transport among Students in Developing Countries – The Case of Hanoi, Vietnam" Presents by **Ms. Mai Phuong NGUYEN** University of Transport and Communications
16:42 – 16:54 Presenter 2 AYRF 2023-002 "Facilitators and Barriers to Adopt Electric Motorcycles for Commercial Purposes – A Qualitative Study of Food Delivery Riders in Vietnam" Presents by **Dr. Minh Hieu Nguyen** University of Transport and Communications	**17:06 – 17:18 Presenter 4** AYRF 2023-015 "External Human Machine Interfaces between Autonomous Shuttle Bus and Pedestrians in Road Crossing Scenario" Presents by **Ms. Veeraya RAWEESUPPAISAN** Department of Mechanical Engineering, Faculty of Engineering, Chulalongkorn University
	17:18 – 17:30 Presenter 5 AYRF 2023-016 "Development of Decision-making and Local Planning for Autonomous Vehicle to Mitigate Pedestrian Crash" Presents by **Mr. Sedtawud Larbwisuthisaroj** Department of Mechanical Engineering, Faculty of Engineering, Chulalongkorn University
Remarks: Attention to the AYRF Presenters of Session 3.1A and 3.2A, after finishes all the paper presentation sessions please remain in the meeting room. We will have a closing ceremony and the presenters from Session 3.1B and 3.2B will join the closing session as well.	

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Program of ATRANS Young Researcher's Forum (AYRF) 2023
Paper Presentation Sessions (continued)

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15:40 – 16:20 Parallel Session 3.1B: Topic (3) Road Traffic Safety Room: The Chatrium Ballroom 2 on 2nd Floor	
Chaired by Assoc. Prof. Dr. Varameth Vichiensan, Kasetsart University	
15:40 – 15:52 Presenter 1 AYRF 2023-008 "Attitude, Motivation, and Engagement of High School Students toward Traffic Safety Education in Ho Chi Minh City, Vietnam" Presents by **Mr. Hoai Nguyen PHAM** Institute of Smart City and Management, University of Economics Ho Chi Minh City, Vietnam	**16:04 – 16:16 Presenter 3** AYRF 2023-020 "A Comparison of Driver Behavior at Intersections During Peak Hours: Paranaque City vs Subic City" Presents by **Mr. Christian Edward Rapatan Viado** De La Salle University, The Philippines
15:52 – 16:04 Presenter 2 AYRF 2023-009 "Survey on Bicycle Overtaking Maneuvers of Cars and Motorcycles in Bangkok" Presents by **Mr. Jun SAKURAI** Faculty of Information and Communications, Bunkyo University, Japan	**16:16 – 16:28 Presenter 4** AYRF 2023-029 "Degradation of the Retroreflectivity of Thermoplastic Pavement Markings in Bangkok Highways" Presents by **Assoc.Prof.Dr. Viroat SRISURAPANON** Department of Civil Engineering, KMUTT, Thailand
16:30 – 17:30 Parallel Session 3.2B: Topic (3) Road Traffic Safety, Topic (5) Digital Transformation in transportation and logistics, and Topic (6) Energy and Environment, e.g., Transport decarbonization Room: The Chatrium Ballroom 2 on 2nd Floor	
Chaired by Dr. Sumet Ongkittikul, Thailand Development Research Institute (TDRI)	
16:30 – 16:42 Presenter 1 AYRF 2023-031 "Understanding Problems of Design Standard of Roundabouts in Thailand Using Comparison of Standards" Presents by **Mr. Shogo ARAKAWA** Graduate School of Science and Technology, Nihon University, Japan	**16:54 – 17:06 Presenter 3** AYRF 2023-012 "May Electric Cargo Trucks Be Accepted in Developing Countries: A Case Study in Hanoi, Vietnam" Presents by **Nguyen Thi Nhu** University of Transport and Communications, Vietnam
16:42 – 16:54 Presenter 2 AYRF 2023-032 "Survey of speed humps and bumps in Bangkok and analysis of effects by probe data" Presents by Mr. **Hiroto SAKAI** Graduate School of Science and Technology, Nihon University, Japan	**17:06 – 17:18 Presenter 4** AYRF 2023-014 "Enhancing Food Security in Hanoi Logistics and Transportation Chain for Pork" Presents by **Mr. Do Mai Duong** University of Transport and Communications, Vietnam
Remark: **Attention to the AYRF Presenters of Session 4.1B and 4.2B, after finishes all the paper presentations please move to the Chatrium Ballroom 1 for closing session. For those who are already in the Chatrium Ballroom 1 please remain where you are.**	

Closing Session at the Grand Ballroom 1 on 2nd Floor	
17:30 – 18:00 Certification and Closing Remark by Dr.Chula SUKMANOP, ATRANS Chairperson	
17:30 – 17:40	Present Certification to AYRF 2023 Presenters and Best Paper&Presentation Awards By **Dr.Chula SUKMANOP, ATRANS Chairperson**
17:40 – 17:50	Present Certification to AYRF 2023 Student Committee Members By **Dr.Chula SUKMANOP, ATRANS Chairperson**
17:50 – 18:00	Closing Remark By **Dr.Chula SUKMANOP, ATRANS Chairperson**
19:00 – 22:00 Reception Dinner (by invitation only)	

SESSION 3.1A: AYRF 2033 RESEARCH PAPER PRESENTATION
From Paper ID: 2023-05, 2023-017, 2023-024, 2023-028

The Prevalence of Small Streets and Its Influence on Car Ownership in Hanoi, Vietnam

Topic number:1, Paper Identification number: AYRF2023-005

Ngo Trung PHUONG[1], Masahiko KIKUCHI[2], Aya KOJIMA[3], Hisashi KUBOTA[4]

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Abstract

The increasing prevalence of small, narrow, and dead-end streets in Asia which is considered to be the result of rapid urbanization but lack of comprehensive planning for road networks. This phenomenon has a negative impact on the urban landscape and influences people's traffic behavior. This study focuses on investigating the disparity in car ownership rates between two groups: individuals living on wide streets with easy car accessibility and those residing on small streets where cars cannot reach. The findings indicate significant differences in both car ownership rates and the intention to own a car in the near future between these two groups.

Keywords: Car ownership, Wide Street, Narrow Street

1. Introduction

1.1 Current Situation of Narrow and Very Narrow Streets in Hanoi, Vietnam

The rapid urbanization of developing Asian megacities is characterized by a distinct characteristic: the absence of well-planned and comprehensive road networks. Despite the parallel growth of urbanization and economic development, the expansion of public transport infrastructure lags behind. As a consequence of the inadequate road network planning, it is common to encounter traditional rural-style neighborhoods hidden behind towering high-rise buildings or bustling shopping centers [1], [2]. This situation commonly observed in Asian megacities, including Hanoi, has resulted in the emergence of two distinct types of neighborhoods. The first type comprises residents who live in wide, spacious streets conveniently located near the city center, allowing easy car access. On the other hand, the second type consists of individuals residing in small, narrow alleys and dead-end streets, which can only accommodate motorcycles and not larger vehicles. This division of neighborhoods has significantly influenced people's transportation choices due to the limited options available to the second group.

Fig. 1 Example of entrance from Wide Streets to Narrow Street

The disparity in mode choice between the two groups is evident and has caused inconvenience for those residing in narrow streets. While individuals living on wider streets have the privilege of using their cars for commuting directly from their homes, those residing in narrower streets face the challenge of being unable to drive their cars to their residences. As consequence, there is a clear difference in car use between the two groups as shown in Figure 1 and Figure 2.

Fig. 2 Example of Narrow Streets areas situation

For this study, the participants of the questionnaire survey were categorized into two groups based on whether they have the ability to use a car to access the street where they reside. The group consisting of individuals who can use cars on their street is referred to as the "*Wide Street*" group, whereas the group comprising individuals who cannot use cars on their street is referred to as the "*Narrow Street*" group. In the context of this study, "*Narrow Street*" refers to streets where car usage is hindered based on the potential for car use. Measuring streets solely by meters is challenging due to the presence of many special streets in Hanoi. While they are initially wide enough to accommodate cars, they progressively narrow, making it impossible for cars to proceed further. Such streets are categorized as Narrow Streets. Furthermore, the criterion for the potential for car use takes into account contextual factors such as roadside conditions and obstructions like utility poles, garbage, or motorbike parking. Even if a street meets the physical width requirements for car movement, these obstructions can impede cars from entering. Thus, using this criterion in conjunction with survey assessments, the streets under study were determined to qualify as Narrow Streets or Wide Streets. Figure 3 shows the representation example of the streets network in Ba Dinh district of Hanoi city in 2021 [3].

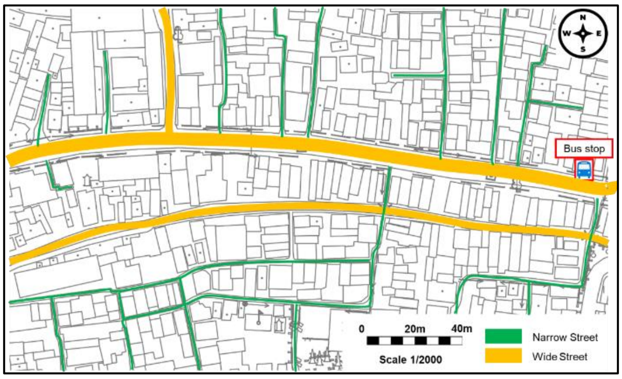


Fig. 3 Representational example of Wide Street and Narrow Street network in Hanoi

The issue of Narrow Streets poses a significant impact on people's transportation behavior, particularly with regards to the hindrance it creates in utilizing public transport. The limited capacity of Narrow Streets to accommodate vehicles larger than motorcycles acts as a major barrier to accessing public transportation for residents living on such streets. The infrastructure in these areas, including lighting systems, landscapes, and overall safety measures, is often inadequate. The confined spaces increase the risk of traffic accidents involving motorcycles, pedestrians, and other vehicles. Additionally, individuals, as well as their children, are in danger of incidents of theft and harassment when navigating through these complex and concealed streets, as discussed in the Livable Street book [4].

However, when considering the overall percentage of individuals owning cars as personal vehicles throughout the city, the drawback of being unable to use cars on Narrow Streets takes on a different significance. An important issue that arises from this factor is whether residents living on Narrow Streets exhibit lower intentions to own cars or, in other words, whether the prevalence of narrow and very narrow streets in Asian cities hampers the growth of car ownership rates. Building upon this hypothesis, the primary focus of this paper is to comprehend the disparity in car ownership rates between the two research groups: individuals residing on Wide Streets versus those residing on Narrow Streets.

1.2 The Problem of Hanoi's Increase in Car Ownership

The rise in car ownership is a prevalent trend observed in major cities across Asia. While the advantages of cars in developing cities are undeniable, it is crucial to address the negative consequences associated with their excessive use and dependence. Factors such as high per capita income, car-centric land development, and limited transportation alternatives contribute to concerns regarding public health. It is essential to recognize and address these issues to ensure a sustainable and healthy urban environment [5]. Numerous studies have demonstrated that this dependence on cars, as opposed to other modes of public transportation, leads to various adverse consequences. These consequences include the restriction of physical activity, an increase in sedentary behavior, elevated levels of pollution (both noise and air pollution), and a particularly high rate of road traffic accidents and casualties. The collective findings from various studies emphasize the detrimental impacts associated with prioritizing car dependency and underscore the urgent need to address these issues for public health, environmental well-being, and overall safety [6-7].

Meanwhile, as economic development progresses and individuals' income levels rise, there has been a notable surge in car ownership in Vietnam in recent years. Statistical data, as depicted in Figure 4, illustrates the increasing demand for car ownership among the Vietnamese population [8]. This is evident from the rising number of cars sold annually, observed from 2018 to 2021, and the projected trend extending to 2023. These statistics highlight the growing interest and inclination of Vietnamese individuals to own cars as their financial capabilities improve. In Hanoi, the number of vehicles has surpassed 7.8 million, including over 1 million cars, more than 6.6 million motorbikes, and more than 184,000 electric motorbikes. Additionally, there are approximately 1.2 million vehicles from provinces and cities that participate in traffic within the capital. The current population of Hanoi exceeds 8 million people (excluding approximately 1.2-1.5 million individuals who are regular visitors residing and working in the city). This indicates that, on average, approximately 1 out of every 8 people in Hanoi owns a car, which accounts for approximately 12% of the population. In terms of traffic infrastructure, Hanoi has a road network spanning over 23,000 kilometers. The ratio of land allocated for transportation compared to urban construction land stands at approximately 10.35%. Regarding public transportation, Hanoi has a bus network comprising 111 routes. These routes cover 30 districts and towns, reaching 411 out of 584 communes and wards, providing a coverage rate of 70.4% across the city. The bus network ensures essential connectivity between urban areas, residential clusters, hospitals, schools, and industrial zones. However, despite its coverage, the public transport system currently satisfies only 8-10% of the travel demand for the residents of Hanoi [9].

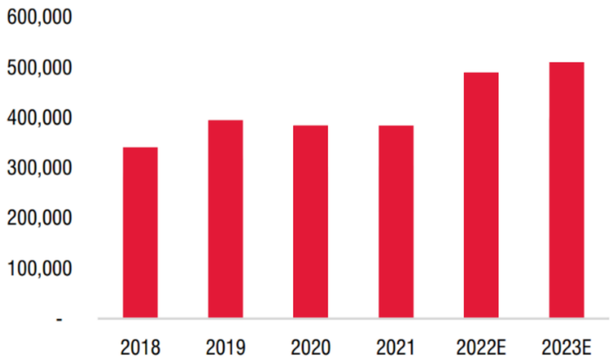


Fig. 4 Number of cars sold by years in Vietnam

The Vietnamese government has implemented several measures to control car ownership and reduce traffic congestion. These measures include high import taxes (importing a car into Vietnam can be quite expensive due to high import taxes and the tax rate varies depending on the type and value of the vehicle), registration fees (car owners in Vietnam are required to pay registration fees when purchasing a new car which are based on the vehicle's value and can be a significant expense), and a lottery system for car license plates. In urban areas such as Hanoi, regulations governing parking standards for apartment buildings are outlined in QCVN 04:2021/BXD (National technical regulation on apartment buildings) and construction law 50/2014/QH13 [10-11]. According to these regulations, for apartments, apartment complexes, or high-rise commercial housing with an average usable area of approximately 100m^2, it is required to allocate a minimum parking space of around 20m^2. For social housing units with an average usable area of about 100m^2, the regulations stipulate the necessity of providing a communal parking area of at least 12m^2. These standards aim to limit the demand for car ownership by people living in urban areas, where infrastructure for public transport has always been a priority for development.

2. Methodology

2.1 Questionnaire Design & Data Collection

The survey questionnaire was divided into two parts to gather information and gather opinions from Hanoians. The first part focused on obtaining basic personal information regarding the possibility of using a car in the street where they reside. The streets were categorized into two groups: Wide Street and Narrow Street.

The second part of the questionnaire aimed to collect data on car ownership among the respondents. For those who owned a car, they were asked about their parking arrangements, the associated parking fees, and the distance between their home and the parking area. On the other hand, individuals who did not own a car were inquired about their future plans for car ownership. They were provided with four options to choose from: (1) within the next 3 years, (2) approximately 3-5 years later, (3) after 5 years, or (4) no plans for car ownership.

From April to May 2022, a survey was undertaken in Hanoi to investigate the car ownership patterns among residents in the inner Hanoi area. The survey was conducted using both offline interviews and an online survey. Offline data was gathered by interviewing individuals in various locations, including bus stations, schools, banks, hospitals, and cafes. Simultaneously, an online survey was conducted using a Google Form, accessible to respondents through a provided link. A total of 306 valid responses were collected, with 169 respondents residing on a Wide Street and 137 on a Narrow Street, as depicted in Table 1.

Table 1 Summary of respondent's information

	Overall	Wide Street	Narrow Street
Number of respondents	306	169	137
(%)		55.23 %	44.77 %
Owning car (%)	15.69	21.30	8.76

Overall, the car ownership rate among the surveyed population in Hanoi was found to be 15.69%, which aligns quite closely with the statistics provided by the Hanoi Department of Transport indicating a car ownership rate of 12%. Notably, there exists a disparity in car ownership rates between the two groups, Wide Street and Narrow Street. Specifically, the Wide Street group exhibited a car ownership rate of 21.3%, whereas the car ownership rate significantly decreased to 8.76% among the Narrow Street group. The lower car ownership rate observed among residents living on Narrow Streets can be attributed to limited car accessibility in this particular group.

Moreover, Table 2 shows the proportion of car ownership situation between Wide Street compare to Narrow Street based on income criteria. The Income criteria was divided into two group including Low income group and High income group. The people who have monthly income lower than 12,000,000VND including no income, based on the per capita GDP of Hanoi in 2021, people in this group are defined as low-income group. The group higher monthly income than 12,000,000VND is a group of people with high income, who can afford to pay the cost of living in main road areas, convenient transportation, afford to own a personal car [12]. Overall, 15.69% of the surveyed population (48 individuals out of 306) owns cars. Among these car owners, 75% reside on Wide Streets, whereas a smaller proportion of 25% resides on Narrow Streets. Within the Wide Street group, only 6.25% are individuals with low incomes, while the majority (68.75%) comprises car owners with higher incomes. In contrast, among the Narrow Street residents, a notable 20.83% of car owners have low incomes, which is significantly higher compared to the mere 4.17% of car owners with higher incomes.

Table 2 The proportion of car ownership situation between two groups based on income criteria

	Wide Street	Narrow Street
Low income (%)	6.25	20.83
High income (%)	68.75	4.17
Total (%)	75	25

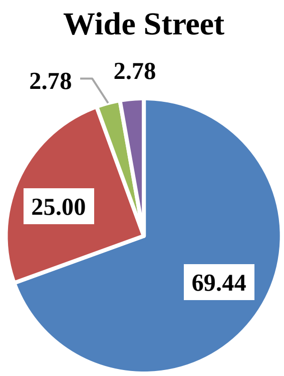
2.2 Data Analysis & Tools

A research model was developed to examine the car ownership status of two distinct groups: Wide Street and Narrow Street. The primary aim was to evaluate the disparity in car ownership prevalence between these two groups. To achieve this, an Analysis of Variance (ANOVA) model, a statistical tool designed to identify differences among means of experimental groups, was employed to detect variations in responses across these groups [13-14]. In this study, the ANOVA model was chosen to address the hypothesis regarding the variation in the inclination to own a car between residents of Wide Street and Narrow Street. The model assessed the mean distinction between the independent variable "living location" (comprising two groups: Wide Street and Narrow Street) and the dependent variable "car ownership" (comprising two groups: Owning a car and Not owning a car). Additionally, the study aimed to anticipate individuals' intentions to acquire a car. The analytical process was conducted using IBM SPSS Statistics program version 20.

3. Results & Discussion

3.1 Data Analysis & tools

There is a notable difference in parking challenges faced by individuals residing on Wide Streets compared to those living on Narrow Streets. The wider street areas generally provide more available parking spaces and are designed to accommodate vehicles conveniently. As a result, residents on Wide Streets may experience fewer parking difficulties due to the ample parking options available to them. On the other hand, individuals residing on Narrow Streets often encounter more pronounced parking issues. Due to limited space and narrower roadways, finding suitable parking spots can be significantly challenging. Lack of designated parking areas and the narrowness of the streets can lead to restricted parking options for residents in these areas.



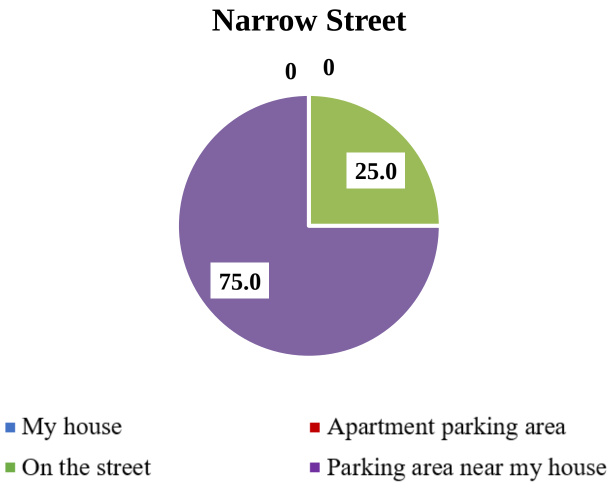


Fig. 5 Comparison in parking behavior of people living on Wide Street and Narrow Street

According to the survey results, individuals residing on Wide Streets reported fewer parking issues. A significant portion of respondents, specifically 69.44%, indicated that they park their cars at their homes (as depicted in Figure 5). This provides them with the advantage of not having to pay a monthly parking fee or travel to a separate parking area near their residence. Another common option among residents on Wide Streets is parking in the designated parking lots of their apartment buildings, with 25% of respondents choosing this option. However, the percentage of individuals who park their cars in parking lots near their houses is relatively low, accounting for only 2.78%. It is worth noting that parking on the sidewalk, chosen by 2.78% of individuals, is not recommended due to its adverse impact on the urban landscape. Overall, the data indicates that individuals living on Wide Streets have a higher tendency to park their cars at their homes, while a smaller proportion utilizes parking lots in their apartment buildings or nearby areas.

As depicted in Figure 5, a distinct difference can be observed in the choice of parking spaces between the Wide Street and Narrow Street groups. This disparity is primarily attributed to the constraints faced by individuals residing on Narrow Streets, where cars is impossible to enter. For residents living on Narrow Streets, their parking options are significantly limited. As a result, a substantial proportion of individuals, up to 75%, tend to park their cars in the parking lots situated near their residences. This preference can be attributed to the proximity and convenience offered by these nearby parking facilities. Furthermore, approximately 25% of individuals residing on Narrow Streets resort to parking their cars on the sidewalk near to their residences. It is important to note that parking on the sidewalk is generally discouraged due to the adverse impact it has on the urban landscape and pedestrian movement.

Furthermore, the average parking fee reported by the respondents is approximately 1,365,000 VND per month. Among individuals living on Wide Streets who have to pay for parking, the average fee amounts to around 1,510,000 VND per month. On the other hand, residents of Narrow Streets who park their cars in nearby parking lots pay an average fee of approximately 1,220,000 VND per month. In terms of the average distance between the parking area and their homes, the overall average is approximately 142.3 meters. For individuals residing on Narrow Streets, the average distance is slightly longer, with an average of approximately 145.8 meters from their car park to their residence.

3.2 The Relationship between Respondents' Place of Residence and Their Car Ownership

The result from Table 1 shows that there is a gap in proportion of car ownership criteria between Wide Street and Narrow Street group. Only 8.76% of respondents living on Narrow Street who are owning a car while this number in Wide Street jump to 21.30%. A hypothesis is put forward based on that result: is the degree of choice to have a car or not different between Wide Street and Narrow Street? Table 3 shows the details of distribution respondents between two groups living location and car ownership.

Table 3 Comparison between car ownership and living location of respondents

Living location	Car ownership situation		Total number	Mean	Std. Deviation	Std. Error
	Owning car (= 1)	Not owing car (= 0)				
Narrow Street	12	125	137	0.088	0.284	0.024
Wide Street	36	133	169	0.219	0.429	0.033

Table 4 Means difference of car ownership situation in each living location groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.305	1	1.305	9.482	0.002*
Within Groups	41.848	304	0.138		
Total	43.154	305			

Significant at $p < 5\%$.
df means degree of freedom.

As for mean difference between two living location groups, the One-way ANOVA analysis is conducted to identify whether a significant difference exists between choice to have a car or not of two targeted living locations.

Table 4 shows the statistically significant value at $p < 0.05$ which means that there is a mean difference in choice to have a car or not among Wide Street group and Narrow Street group.

3.3 Trends of Car Ownership of Two Groups Wide Street and Narrow Street

Based on the information presented in Table 5 and Figure 6, a notable difference can be observed in the car ownership intentions between the Wide Street and Narrow Street groups. Figure 6 highlights that a relatively high percentage of individuals residing on Wide Streets have plans to own a car within the next 5 years. Specifically, 27.82% plan to acquire a car within the next 3 years, while 29.32% plan to do so within 3 to 5 years. This percentage is higher compared to those who plan to purchase a car after 5 years (21.8%) or have no plans to buy a car (21.05%).

Table 5 Trends of car ownership of residential

Plan to afford a car (%)	Overall
Within 3 years	19.77

3-5 years later	21.32
After 5 years	28.29
No plans	30.62

In contrast, the trend among residents of Narrow Streets differs significantly. A substantial 40.8% of respondents from the Narrow Street group have no plans to own a car, which is nearly double the corresponding criteria of the Wide Street group (40.8% versus 21.05%). Additionally, 35.2% of individuals in the Narrow Street group plan to own a car after 5 years. The percentage of individuals planning to purchase a car within 3 years and within 3 to 5 years is relatively low, at 11.2% and 12.8%, respectively.

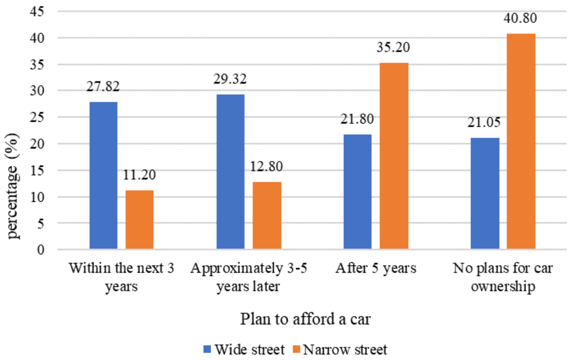


Fig. 6 Trends of car ownership of two groups Wide Street and Narrow Street

In general, there is a notable difference in car ownership plans between the two study groups. The Wide Street group comprises a significant number of individuals who are planning to own a car in the near future. In contrast, the Narrow Street group includes a higher percentage of individuals who have no plans to buy a car or plan to do so after a longer period of at least 5 years.

When considering the findings from Section 3.2 (related to the car ownership situation at present), it becomes apparent that the place of residence not only impacts the current car ownership status but also influences individuals' intentions to own a car in the future.

4. Conclusion

This study analyzed data from two distinct groups, "Wide Street" and "Narrow Street" to investigate the attitudes of Hanoians towards car ownership. The analysis revealed differences in factors related to car ownership based on residents' location. These factors encompassed not only the current car ownership situation but also the intention to own a car in the near future. Additionally, the study identified variations in parking behavior between the two groups, which can be attributed to limitations imposed by the accessibility of cars in certain areas.

The prevalence of Narrow Streets is a common issue not only in Hanoi but also in other cities across Asia, and it significantly impacts various aspects of urban transportation. This article has conducted research to examine and present the findings on how Narrow Streets affect the car ownership rates of individuals. While Narrow Streets may constraining the demand and intention for car ownership among residents, it is important to acknowledge that the intention to own a car is influenced by multiple factors, as indicated by previous studies. In the context of Hanoi, the prevalence of Narrow Streets seems to contribute to maintaining a lower level of car ownership due to city infrastructure. This stands in contrast to the United States, where every street is designed to accommodate cars, fostering greater accessibility and motivation for car ownership, thereby resulting in a higher share of car usage compared to other modes of transportation. In the future, if the factors that positively influence people's intention to own a car outweigh the impact of Narrow Streets, it may lead to an increase in car ownership rates in urban areas. As consequence, this could have negative repercussions on the overall transportation system of the city. To address this potential issue, it is crucial to conduct further research and implement appropriate policies to prepare for such a situation in the future. The implication of this research is detecting differences in car ownership intentions and related behaviors of two groups Wide Street and Narrow Street. Thereby providing more information for development strategists to be able to make appropriate policies for each target group based on the advantages and disadvantages of the current facilities of Hanoi and other cities which have similar properties. These policies should aim to mitigate the adverse effects of increased car ownership and promote sustainable and efficient urban transportation systems, especially public transport system.

5. Acknowledgment

A sincere thanks to Mr. Tran Anh Quan, Mr. Nguyen Van Duc and Mr. Tran Manh Hung for their assistance in carrying out this research survey.

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A Study on The Factors Affecting the Driver's Preference on The Toll Collection in Manila-Cavite Expressway (Cavitex)

Topic number:1, Paper Identification number: AYRF2023-017

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Abstract

This study examines how drivers make decisions regarding payment methods at toll plazas and their perceptions of transaction time. A multinomial logit discrete choice model is employed to analyze the socio-demographic data and travel attributes obtained from surveys. The findings indicate that certain factors, such as transaction and queueing time, age, gender, income, and trip purpose, have a big influence on users' choices. Moreover, the study investigates the perceived transaction time ratings for cash and RFID users, revealing differences in how they perceive and agree on what constitutes an "average" transaction time. Additionally, factors affecting RFID implementation, including accessibility rate, ease of use, reliability and accuracy, congestion reduction, location of reloading stations, and system complexity, are examined. To enhance the RFID Toll Collection System, the researchers suggest investments in RFID tag technology, regular system calibration and maintenance, and gathering user feedback for continuous improvement.

Keywords: electronic toll collection, RFID, CAVITEX, discrete choice model, multinomial logit

1. Introduction

1.1 Background and Context

The Philippines is known for its conventional car-centric culture, which has led to transportation challenges, especially in Metro Manila. The heavy traffic congestion in the city has resulted in significant time and revenue losses, estimated at ₱3.5 billion per day in 2018 and projected to reach ₱5.4 billion per day by 2035 [1]. Additionally, the reliance on automobiles powered by petroleum products; and has led to the production of various pollutants, contributing to greenhouse gas emissions and negatively impacting public health[2][3][4].

To address the growing traffic volumes and improve urban mobility, the construction of expressways has been introduced in the Philippines. These expressways offer higher speeds and increased traffic capacity compared to existing road networks, promoting economic development and accessibility[5].

The implementation of cashless and contactless transaction systems, such as Electronic Toll Collection (ETC), has been introduced to streamline toll collection processes and reduce transaction times. The ETC system, first implemented in 2000, utilizes electronic transponders (E-Pass) to enable fee collection through electronic transmission, significantly reducing service times compared to cash payments[6][7]. The system has since evolved, with the introduction of radio frequency identification (RFID) stickers, namely AutoSweep and EasyTrip, for both public and private vehicles in the Philippines[8].

Fig. 1 CAVITEX Kawit Toll Plaza

Fig. 2 CAVITEX Parañaque Toll Plaza

Among the expressways in the Philippines, the Manila-Cavite Expressway (CAVITEX) plays a vital role in connecting Roxas Boulevard to Cavite, with various interchanges and toll plazas such as seen in Fig. 1and 2[9]. However, despite the availability of RFID systems and free installations, reports indicate persistent traffic congestion at CAVITEX toll exits, primarily caused by cash-paying drivers and unruly behavior[10][11]. This congestion not only affects traffic flow but also leads to revenue loss and adverse environmental and health impacts [1][3]. This is counterintuitive to the purpose of RFID technology, which aims to reduce transaction times and improve vehicular flow.

1.2 Statement of the Problem

The problem addressed in this study is the lack of understanding regarding drivers' preferences in choosing a toll collection system in CAVITEX, specifically between cash and RFID payment methods. This knowledge gap hinders effective policy-making, strategy formulation, and the improvement of traffic flow at toll plazas. Therefore, the study aims to analyze the factors influencing drivers' preferences and provide recommendations for enhancing the efficiency of toll collection and promoting the use of RFID systems.

1.3 Objectives

The main objective of this study is to analyze the drivers' preferences in choosing a toll collection system in CAVITEX. The specific objectives are as follows:

1. Identify the various factors affecting the preference of drivers in a toll collection system in CAVITEX based on driver attributes, travel attributes, and knowledge of RFID.
2. Design a Revealed Preference (RP) survey to determine the factors governing the driver's toll collection system preference.
3. Evaluate survey results using a discrete choice model of multinomial logit and descriptive analysis
4. Formulate and recommend ideas to the concerned authorities for strategy and policymaking in improving the traffic in toll plazas of CAVITEX as well as promoting the use of RFID payment systems.

1.4 Significance of the Study

The preference for manual toll collection systems and the resulting traffic congestion at toll plazas have significant implications for various stakeholders. The impact ranges from individual drivers experiencing reduced productivity and increased travel time to broader economic consequences affecting businesses reliant on efficient transportation. Additionally, the contradictory nature of persisting queuing issues despite the adoption of RFID technology highlights the need for a comprehensive understanding of drivers' preferences. This study's significance lies in developing insights into drivers' preferences, promoting the use of RFID systems to mitigate traffic congestion, and providing valuable analysis and resources for policymakers aiming to improve traffic flow, reduce road congestion, and enhance traffic safety.

1.5 Scope, Limitations, and Delimitations

This study assesses the preference of cash and RFID users regarding the toll collection system in CAVITEX. It focuses on driver attributes, travel attributes, and RFID knowledge and experiences. Data collection is limited to the toll plazas managed by the PEA Tollway Corporation (Kabihasnan, Kawit, and R-1) using distributed flyers and an online survey via Google forms. The use of flyers may result in limited sample size and self-selection bias. Respondents may exhibit response bias and cognitive factors. The study is time-constrained, limiting the assessment of temporal variations and long-term changes in the toll collection system of CAVITEX. Consider these limitations and delimitations when interpreting the findings.

1.6 Organization of the Paper

The study is organized as follows: Section 1 presents the concept of car-centrism and its possible implications in the content of the Philippines, the purpose of expressways, and the background of ETC. Section 2 provides an overview of significantly related literature discussing the purpose of RFID toll collection and the current condition of the technology in the Philippines compared to other countries. In Section 3, the conceptual and theoretical framework, along with the study procedure comprising mixed method research design, data collection process, setting, and participants were introduced. Results are divided into a two-part analysis of the discrete choice model (Section 5) and the descriptive statistics (Section 6). Section 7 presents further discussions and conclusions. Lastly, Section 8 exhibits the acknowledgment of individuals and organizations who provided support and assistance throughout this study.

2. Literature Review

ETC systems have introduced the feasibility of charging transportation based on the time of day, presenting multiple opportunities to influence travel behavior. ETC has significant implications for the movement of goods across the supply chain, as highlighted[12]. Compared to traditional charging systems, ETC offers several advantages such as improved service, reduced operating expenses, decreased infrastructure construction investment, enhanced vehicle traffic capacity, and the transition to paperless and cashless toll management[13].

The Philippines launched its first RFID-based toll collection system in 2014 at the Manila-Cavite Expressway (CAVITEX), owned by the Metro Pacific Tollways Corp (MPTC). The system utilized battery-less thin prepaid stickers to expedite transactions and reduce queueing at toll gates. During the COVID-19 pandemic onslaught in late 2020, the Department of Transportation (DOTr) issued Order 2020-012, mandating the implementation of mandatory cashless payments in all Philippine toll expressways to minimize human contact and prevent virus transmission[14]. Government officials and expressway representatives assured the public of their readiness for the cashless transition, scheduled to commence on December 1, 2020. However, difficulties showed up during the implementation process. The North Luzon Expressway (NLEX) operator's business permit was stopped by Valenzuela City Mayor Rex Gatchalian due to traffic congestion, and the Toll Regulatory Board (TRB) acknowledged the possibility of glitches[15]. Additionally, the senators approved Senate Resolution 596, which temporarily banned any highway cashless transactions[15]. Calls for the DOTr to change the rules in order to improve the implementation of contactless transactions were sparked by these challenges.

In order to determine the most suitable ETC strategy for India, a study was conducted[16] that took into account the country's unique infrastructure and socioeconomic factors. Discussions with toll authorities, operators, users, and expert research were used to examine thirteen crucial factors including cost, reliability, environmental impact, and congestion reduction. A study investigated the variables affecting server utilization and queue length at highway tollgates in Metro Manila[17] and took variables into account such as vehicular arrival rate, number of lanes, queue capacity, toll gate service times, and number of operational toll gates. It was discovered that slower service times and higher arrival rates during peak traffic hours had a substantial impact on the experience of road users.

The location of the tag and reader and the vehicle's speed affect RFID technology in toll collection systems. In order to identify the most optimal parameters for RFID-based toll collection, a study was carried out that tested three vehicle speeds as well as various tag and reader placements[18]. The results showed that mounting the tag on the windshield of the car and mounting the reader 7 feet above the ground on a signpost produced the best performance. On-vehicle installation of numerous tags at once improved signal strength and detection rates.

When analyzing the factors influencing drivers' choices between cash and cashless systems at expressway toll gates, preference surveys are needed. A study identified two approaches to transportation preference surveys: Revealed Preference (RP) and Stated Preference (SP) surveys. RP surveys gather data on consumers' firsthand experiences, while SP surveys involve experiments that assess respondents' preferences for different options. To analyze RP and SP survey data, discrete choice models (DCM) are commonly used[19]. A study highlighted the significance of DCM in understanding decision-making processes when individuals are presented with exclusive choices. Several studies have applied DCM in driver preference research [20]. For example, a study utilized the multinomial logit model (MNL) to examine drivers' preferences for variable message signs[21]. A study employed a mixed multinomial logit method (MMNL) to study stated preferences for speeding enforcement strategies in Hong Kong[22]. Likewise, a study used the mixed logit method (ML) to estimate passenger transfer penalties in Madrid [23]. Studies have conducted successful research in Transportation Engineering, emphasizing the mixed RP and SP survey as the most suitable method for determining results that are not yet available in a chosen study area[19][20]. This approach captures consumers' preferences for transportation services, which further predicts the travel demand and project revenue. It also identifies the influential factors shaping consumer preferences for different transportation options.

3. Methodology

The problem that this study tackles leads to the question of what variables affect the decision of cash user drivers in choosing their mode of payment as shown in Fig. 3. Three categories of variables that affect the preference of cash users in CAVITEX toll payment were considered. To collect data from the drivers, a proper survey design is required. In similar studies[19][24], a mixed RP and SP survey was used to analyze a driver's preference. In the study[24], it was stated that both SP and RP surveys can be used in preferences study. Since the study will focus only on discussing existing factors and the current experience of the respondents, it is deemed necessary to use only RP surveys.

Furthermore, the analysis of the collected data was based on discrete choice models that utilize the Random Utility Theory, which asserts that people (q) make decisions about different options (A_j) based on their utility (U_{jq}). The modeler assumes that the utility can be expressed as the product of two elements: first, a representative utility function (V_{jq}), measurable from characteristics (X) of the person, alternative, or choice situation, weighted by coefficients (β); and second, a random term (ε) for the difference between the representative and the real utility[21]. This is represented by the following expression:

$$U_{jq} = V_{jq} + \varepsilon_{jq} = \sum_k \beta_{jk} X_{jkq} + \varepsilon_{jq}$$
(1)[JT1]

The MNL model was used in this study since it was normally used to model the choices of people preferably with binary options. This multinomial logit formulation of travel demand models is computationally tractable and transparent in analysis. If the restricted behavioral assumptions of logit can be accepted, the logit formulation is likely to be preferred over other formulations in many demand modeling situations[25].

Equation 2 describes the multinomial logit formulation where X'_{nj} is a row vector of characteristics of an individual n and alternative j, θ is a column vector of constant parameters, δ_n is a random column vector whose components reflect the differences between the preferences of individual 'n' and the average preferences of individuals with similar observed characteristics, and ϵ_{nj} is a random function that reflects the additional impact of unobserved characteristics.

$$U_{nj} = X'_{nj}\theta + X'_{nj}\delta_n + \epsilon_{nj} \qquad (2)$$

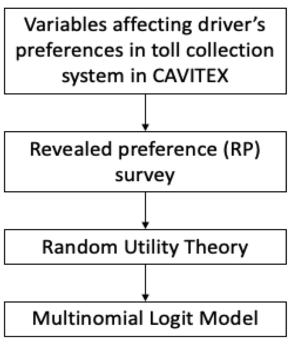

Fig. 3 Theoretical Framework

The approach taken to conduct research in this study was a mixed method design, which combines both quantitative and qualitative research methods. Specifically, a sequential transformative design was utilized to collect the qualitative data through RP survey to gain a better understanding of the respondents' preferences, while the quantitative data was obtained through data analysis, with the application of DCM and Descriptive Statistics. This preferred methodology, involving a mixed method design, was seen as suitable for this study due to its potential to identify patterns and trends among respondents, while also attaining in-depth knowledge about their experiences and preferences associated with their decision-making process.

The research was performed in Manila-Cavite Toll Expressway Project or CAVITEX, particularly along the operational Parañaque Toll Plaza, Kabihasnan Toll Plaza, and Kawit Toll Plaza within the R-1 segment. The expressway was chosen due to its adoption of RFID technology and diverse user population, which would develop relationships between their preferences and socioeconomic background. The respondents were required to be licensed non-professional or professional drivers in the Philippines who utilize cash or RFID at any CAVITEX toll plazas. The sample size was computed using the following Equation (3). As a result, the sample requires 108 Cash respondents and 277 RFID respondents.

$$Sample\ size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+\left(\frac{z^2 \times p(1-p)}{e^2 N}\right)} \qquad (3)$$[JT2]

The data collection process was conducted using a revealed preference survey containing driver attributes and trip attributes questions, open-ended questions and Likert-scale (distinctly designed for cash and RFID users) regarding their suggestions and preferences on the toll collection system. The surveys, designed for cash users, were distributed by the PEATC toll operators to the toll road users, who are passing through cash lanes at the designated locations. The respondents were given the option to answer the survey online via a QR code or website link or to hand over the completed forms at designated drop boxes located in the toll operator's booth. On the other hand, surveys designed for RFID users were handed out by the researchers stationed at the RFID reloading stations. The RFID respondents were given the same option of submitting their answers like the cash users. The data collection process was conducted over a span of approximately two months, from April 12th to June 27th, 2023.

The gathered data was analyzed using descriptive statistics, comprising measures of central tendency and variability, to determine the key characteristics, patterns, and trends of a sample. In addition, a discrete choice model software developed by Econometric Software, Inc. named NLogit Version 3 [JJC3]was utilized to model how choices are being made to visualize the factors that influence the choices of the respondents.

The study was performed with strict compliance to the Philippine Republic Act No. 10173 [JJC4][JJC5] (Data Privacy Act of 2012) for the protection of personal information, informed consent, handling of personal data responsibility, and imposed penalties for non-compliance. Additionally, the retention and disposal of data were mentioned. The access of data was restricted to the researchers of the study and any authorized parties from the Department of Civil Engineering in De La Salle University-Manila[JJC6][JJC7]. The respondents were given the freedom to be anonymous or provide their name. However, during the data analysis, all particular information was treated anonymously to ensure personal security.

The study was able to improve the overall reliability and validity through the application of triangulation of data sources wherein similar findings were obtained from multiple perspectives, some discrepancies were identified, and patterns and trends were examined across different sources.

4. Socio-demographics and Trip Attributes

The total obtained samples from the data gathering process are 388 validated surveys with 277 of them being RFID users and 111 to be cash users.

The minimum age for driving in the Philippines is 16 years old, contingent upon the driver having acquired a student permit and being accompanied by a duly licensed individual, whether classified as professional or non-professional. This minimum age varies across all permit categories: 16 for student, 17 for non-professional, and 18 for professional.

Based on the respondents' sociodemographic profiles, the majority of the RFID users were aged 20-24 years old, which accounts for 69.0%. On the other hand, the majority of the Cash users aged from 25-29 years old represent 26.1%.

Next, the gender was sorted into two classifications, which are male and female. Among the 277 RFID users, there are 176 male respondents and 101 female respondents, which comprise approximately 63.5% and 36.5%, respectively. For the Cash users, there are 71 male respondents and 40 female respondents, which account for 64.0% and 36.0%, respectively.

With regards to the occupation of the respondents, almost half of both RFID and Cash users are working in the private sector employees, which represent 44.4% and 42.3% of the sample, respectively.

Lastly, the majority of the RFID users' monthly personal income ranges between ₱21,914 to ₱43,828 (23.5%), while the majority of the Cash users earn below ₱10,957 (27.0%).

In the data collection process for the trip purpose of the users, respondents were given the option to select multiple trip purposes (Fig. 4). Most of the users' trip purposes are as follows: 233 out of 388 respondents for work; 183 out of 388 respondents for visiting friends and relatives; and 181 out of 388 respondents for going to their homes or place of residence.

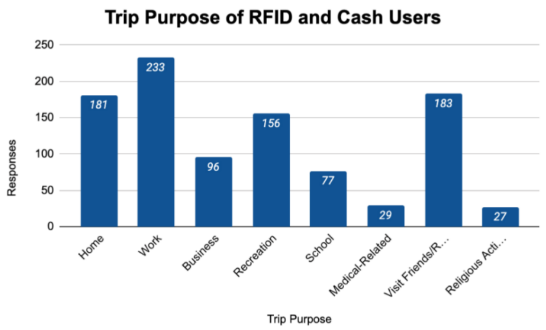

Fig 4 Trip Purpose of RFID and Cash Users

For the respondents' trip attributes, the city of origin or destination describes that the majority, or 53.8% of the 277 RFID users, are from Metro Manila. On the other hand, the majority of Cash users are from Cavite, comprising 69.4% of the 111 Cash users. The higher percentage of RFID users from Metro Manila could be by the region's large population and significant commuter traffic. For the users' frequency of CAVITEX use, the majority of the RFID users, or 26.4%, pass through at least once a week. On the other hand, 26.1% of the Cash users use CAVITEX at least 5 times a week, which suggests that they are more frequent users. For the time of usual CAVITEX use, it can be observed that most of the RFID users pass through from 06:00 AM to 11:00 AM. The higher percentage of RFID users during the earlier part of the day could be attributed to the fact that many individuals from Metro Manila are traveling during these hours in reaching their place of work or in attending their morning appointments.

5. Discrete Choice Modeling Results

A simple multinomial logit (MNL) discrete choice model was used to explain the choice of motorists based on their socio-demographic data and travel attributes obtained from the surveys. A systematical approach was done in building the utility model by trying different combinations of variables. In choosing the best model for the data, parameters such as pseudo-R2 value, Chi-squared value and p-values from the outputs were considered. Details of these variables are listed in the following table.

Table 1 Variable Descriptions

Variable Name	Description
INCOME	Monthly income
TOHOME	Trip purpose going home
FREQ	Frequency of travel
SERVFREQ	Service time over frequency of travel
PEAKHOUR	Travelling during peak hours
SERVPEAK	Service time during peak hours

A correlation analysis was conducted between the variables as shown in Table 2. The coefficients suggest that there is very weak correlation between the variables. These results ensures that statistical consequences of multicollinearity do not affect the coefficient output of the model.

Table 2 Correlation Matrix

	(1)	(2)	(3)	(4)
SERVFREQ	1			
INC	-0.0566	1		
TOHOME	-0.0455	0.1228	1	
PEAKHOUR	-0.0325	-0.0301	-0.0043	1

$$U(RFID) = ASCRFID + SERVPEAK * (service\ time\ over\ frequency\ during\ peak\ hours) + INCOME * (income) + TOHOME * (going\ home) \quad (4)$$

$$U(CASH) = SERVPEAK * (service\ time\ over\ frequency\ during\ peak\ hours) \quad (5)$$

Equations 5 and 6 represents the peak hour model with the coefficient output shown in Table 3. It can be observed that the model is significant given the Chi-squared value of 58.92[26]. It can also be said that the model performance is acceptable with an R-squared value of 0.27628[26]. Moreover, it was confirmed that income, travel purpose of going home, and the service time over frequency during peak hours affect payment method choice. This is indicated with their corresponding p-values less than 0.05 level of significance.

The coefficient of service time over frequency during the peak hour (SERVPEAK) serves as a disutility. This means that the longer the queueing time, people would less likely choose an option. Moreover, the model also implies that people with higher income tends to choose RFID payment over cash, the same with people whose purpose of travel is going back to their homes.

Table 3 Revealed Preference Logit Choice Model

No. of observations		276
R-squared		0.27628
Chi-squared		58.92385
Prob [chi-squared > value]		0.00000
Variable	**Coefficient**	**P[|Z| > z]**
ASCRFID	-0.454489	0.0639
SERVPEAK	-0.0427498	0.0479
INCOME	1.03999e-005	0.0043
TOHOME	2.07504	0.0000

Further, the model performance of the peak hour dataset was checked as shown in cross-tabulation matrices from Table 5.7.6. The rows represent the number of choices made by the sample population for each alternative, while the columns represent the number of times an alternative was predicted to be selected based on the model. A measure of the aggregate proportion of correct predictions can be derived from the table by summing the number of correct predictions (148 + 36) divided by the total number of observations (276) Thus, for the data, the model correctly predicted the actual choice outcome for 66.67% of the total number of cases.

Table 4 Contingency Table

	RFID	CASH	Total
RFID	148	46	194
CASH	46	36	82
Total	194	82	276
Percentage of Correct Prediction			66.67%

6. Driver Perception Analysis

The evaluation of the various factors affecting RFID implementation, namely the accessibility rate, ease of use, reliability and accuracy of RFID, congestion reduction satisfaction, location of reloading stations, and RFID system complexity were analyzed using descriptive statistics shown in Table 5.

The table provides an analysis of factors affecting RFID implementation, with mean values indicating the average satisfaction level for each factor. Factors like Accessibility Rate (4.47) and Ease of Use (4.41) show higher mean values, indicating general satisfaction.

Table 5 Analysis on the Various Factors affecting the RFID Implementation

Factors	Mean	Standard Deviation	Median
Accessibility Rate	4.47	4.02	5
Ease of Use	4.41	3.95	5
Reliability and Accuracy	3.81	3.40	4
Congestion Reduction	3.59	3.22	4
Location of Reloading Station	3.95	3.56	4
System Complexity	4.34	3.89	5

However, the relatively high standard deviations for these factors suggest varying opinions among respondents. Factors like Reliability and Accuracy (3.81) and Congestion Reduction (3.59) have lower mean values, indicating comparatively lower satisfaction. The standard deviations for these factors suggest less variability in ratings. The median values align closely with the means, representing a balanced distribution of ratings. Overall, the table highlights satisfaction levels and variations in perceptions of the factors influencing RFID implementation. The statistical values provide insights into the perceived strengths and areas of improvement for RFID implementation.

A satisfactory graph is also presented in Fig. 5 comparing each factors.

The factors that were only deemed as somewhat satisfactory are the reliability of the RFID system, congestion reduction, location of reloading stations, and system complexity. Given this, the RFID system needs improvement on the detection and identification of RFID tags, reduction of traffic congestion, having easily accessible reloading stations, and simplifying the RFID system's processes to reduce its complexity – all to ensure an efficient and convenient toll collection experience for the expressway users.

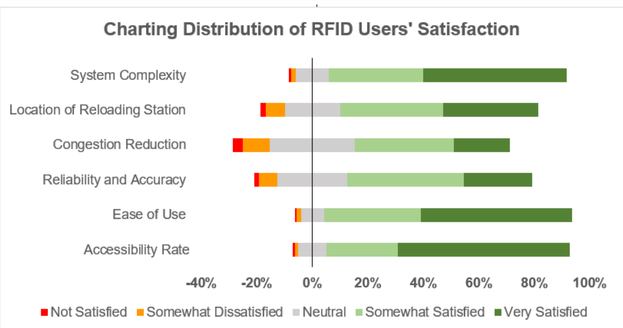

Fig. 5 Satisfactory Graph of Factors Affecting the RFID Implementation

Moving on, the perceived transaction time of both cash users and RFID users is also analyzed in the following table.

Table 6 Statistical Measurements of the Perceived Transaction Time of Cash and RFID Users

	Mean	Standard Deviation	Mode
Cash Users	3.68	3.14	4
RFID Users	4.23	3.70	4

Based on Table 6, cash users perceive the transaction time as slightly below average (mean of 3.68) with high variability (standard deviation of 3.14), while RFID users perceive it as slightly above average (mean of 4.23) with similar variability (standard deviation of 3.70). The mode of 4 indicates that "average" is the most common perception among both groups.

Moreover, RFID users have an average transaction time of 10.8 seconds, while Cash users have an average transaction time of 21.4 seconds, which suggests that RFID users have a faster transaction time because they pass through the toll booths without stopping, whereas Cash users complete their transactions longer due to the manual handling of cash that add extra seconds to their transaction time.

For the average waiting/queuing time on the other hand, 36.1% (100 respondents) among the 277 RFID users reported waiting times ranging from 3 to 5 minutes. Similarly, 30.6% (34 respondents) among the 111 Cash users, experienced waiting times within the same range. On average, RFID users had a queue/waiting time of 7.9 minutes, while Cash users had an average time of 9.8 minutes.

In addition to the statistical results, cash users and RFID users were asked to state specific reasons that would make people completely switch to cashless transactions.

Grouping their responses accordingly, it showed that the convenience and decongestion of RFID lanes will make cash users more inclined to switch to cashless payments if this will offer a more efficient and less congested transaction process compared to cash payments, to save time and avoid long queues at toll plazas. Furthermore, cash users may be more willing to switch to cashless payment if the RFID readers are reliable, ensuring seamless transactions and reducing concerns about compatibility or accessibility issues.

As for the RFID users, the major contributor was the smoother traffic flow, which was represented by the 236 responses. It was followed by RFID's high technology (151), motorists' frequent use of expressways (169), healthy safety purposes (86), and dislike of cash transactions (87).

7. Policymaking/Project Suggestions

The study's analysis of choice modeling and motorist perceptions has led to the identification of three key areas requiring improvement in the CAVITEX Toll Plaza collection system. These areas include enhancing the overall time spent at toll plazas, optimizing the RFID toll collection system, and promoting the transition of cash users to RFID technology. These recommendations are consistent with CAVITEX's present toll management policies, relevant literature, and comparable practices in other nations.

Improving the total time spent at CAVITEX toll plazas necessitates strategies to minimize both transaction and queueing times. Research indicates that enhancing toll plaza layout and configuration can yield substantial improvements, with simulation-based studies advocating for adjustments in toll booth numbers and lane setups[27][28]. Real-time traffic monitoring can aid in predicting traffic flow, allowing for proactive adjustments based on vehicle estimates near the plaza using discharge rates and travel times[29]. Adequate staffing during peak hours is crucial to ensure effective execution of capacity adjustments. Implementing variable pricing and dynamic toll fees has been successful in redistributing traffic throughout the day, as seen in studies on Metro Manila Skyway and mode-based research on dynamic toll pricing[30][31].

Enhancing the RFID toll collection system could involve adopting technologies from other countries, such as Japan and Poland's dedicated short-range communication (DSRC) or Taiwan's integration of automatic number-plate recognition (ANPR) with RFID[32][10]. Alternatively, prioritizing RFID system maintenance and calibration offers a cost-effective approach. Meanwhile, collecting user feedback effectively identifies service strengths and areas for development. Lastly, social media platforms for RFID advocacy can further encourage cash users to transition to cashless transactions, capitalizing on the growing influence of social media.[JJC8]

8. Conclusions and Recommendations

The researchers conducted a comprehensive study to analyze the preference of Cash and RFID Users regarding the toll collection system in CAVITEX. Through Revealed Preference surveys, Discrete Choice Model, and Descriptive Statistics, they identified key insights and areas for improvement.

The findings showed that most Cash users still prefer traditional payment methods due to established customs, reloading inconvenience, and infrequent expressway usage. However, these Cash users expressed a willingness to adopt RFID technology if improvements in RFID services, facilities, and decongestion of RFID lanes are evident. Stricter enforcement of the RFID system or discontinuation of cash toll collection emerged as motivating factors for Cash users to switch to RFID technology.

The study's choice modeling findings reveal that during peak hours, longer service time negatively affects option choice, but during off-peak hours, service time positively impacts choice, similar to queueing time. This could be due to less traffic, resulting in shorter queues. A 1% increase in service time during peak hours decreases RFID choice probability, while for Cash choice, a 1% service time increase decreases its probability. Comparing these, shorter service time favors RFID during peak hours. Based on these findings, three areas for CAVITEX Toll Plaza improvement were identified: 1) enhancing total vehicle time spent, 2) improving RFID toll collection, and 3) promoting RFID adoption. Suggestions include optimizing toll plaza layout, real-time monitoring, variable pricing, and dynamic tolling. These strategies reduce congestion, encourage off-peak travel, and enhance overall traffic flow. Enhancing RFID technology, regular maintenance, user feedback, and awareness campaigns are recommended to facilitate RFID adoption among Cash users.

Future research should consider incorporating different qualitative methods, such as interviews or focus group discussions, to gain a comprehensive understanding of factors influencing users' continued adoption of RFID technology. Additionally, combining Stated Preference surveys with Revealed Preference surveys can provide deeper insights into drivers' preferences and bridge any gaps between stated and actual preferences. Expanding the scope of the study to include other toll plazas and road networks would offer a broader understanding of drivers' preferences in different contexts. Furthermore, future studies could evaluate the effectiveness of interventions and policies aimed at influencing drivers' preferences for toll-collection systems.

By following these recommendations, future researchers can build upon this study's findings, contributing to a deeper understanding of driver preferences and informing policymakers and transportation authorities in optimizing toll collection systems, improving traffic flow, and promoting advanced payment technologies.

9. Acknowledgements

The researchers would like to express their profound gratitude to Dr. Nicanor R. Roxas, Jr. for sharing his knowledge and expertise about Statistics and Transportation Engineering throughout the study. We would also like to give recognition to PEA Tollway Corporation for their cooperation and assistance during the data collection process, particularly Mr. Eric Cimanes and Mr. Jose Gonzales.

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A Systematic Assessment of Transportation-Engineering-Related Indicators through A Review of Sustainable Roadway Rating Tools

Topic number:1, Paper Identification number: AYRF2023-024
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Abstract:

A sustainable roadway rating tool (SR^{2}T) typically includes diverse indicators to evaluate the sustainability performance of roadway projects. Implementing appropriate transportation engineering solutions has the potential to enhance the performance of roadway projects. However, scholarly work assessing the importance of transportation-engineering-related indicators (TEIs) in SR^{2}Tse is lacking. To address this gap, this study conducted a comparative analysis using the Normalized Indicator Score (NIS) to assess the priority of TEIs in five selected SR^{2}T. The findings revealed that among the chosen rating tools, Green Guides for Roads assigns the highest percentage of total points (37%) to TEIs, while the Greenroads tool allocates the lowest percentage of total points (16.2%) to TEIs. Regarding TEIs in roadway projects, pedestrian infrastructure, bicycle infrastructure, and traffic facilities are believed to significantly contribute to project sustainability, whereas freight transport, parking area, and roadway consistency are considered to have relatively lower impacts on project sustainability. This study offers valuable insights into transportation engineering practices and can aid practitioners in applying them to roadway projects. Future studies can use the common TEIs identified in this research as a foundation for developing new indicators tailored to the specific characteristics of new SR^{2}Ts.

Keywords: Sustainable roadway rating tool, transportation engineering, indicators, roadway project

1. Introduction

A country's economic development hinges greatly on its transportation infrastructure system, which is widely recognized as a critical catalyst for global sustainability. This is primarily due to the direct links between transportation projects and various disciplines, as well as their significant contribution to CO2 emissions [1]. Roadway transportation alone accounts for 90% to 95% of greenhouse gas (GHG) emissions in the global transport sector [2]. Consequently, many countries and regions have embraced sustainability principles and integrated them into sustainable roadway rating tools (SR^{2}Ts). These tools, such as Greenroads, Illinois Livable and Sustainable Transportation (I-LAST), Green Leadership in Transportation Environmental Sustainability (GreenLITES), and Infrastructure Voluntary Evaluation Sustainability Tool (INVEST), serve to evaluate sustainability performance in the transportation domain.

An SR^{2}T is a practical tool used to quantify and measure sustainability achievements in various phases of roadway projects: planning, designing, construction, operation, rehabilitation, and maintenance [3]. By serving as a guideline, it helps stakeholders assess the performance of road transportation projects and provides an overall standardized ranking for comparison with other projects. This hierarchical structure of an SR^{2}T consists of two layers - categories and indicators. A category represents a collection of optimal sustainability practices and activities called indicators or credits. These indicators are variables that enable the quantitative and qualitative assessment of roadway project sustainability, and each one is assigned a point value based on its impact on sustainability.

Transportation engineering plays a crucial role in roadway projects. It encompasses the planning, geometric design, and traffic management of roads, streets, and highways, as well as their networks, terminals, surrounding land, and connections with other transportation modes. To create transportation engineering-related indicators (TEIs) for a sustainability rating tool, assessing the significance of existing indicators in this category is essential. This evaluation involves both quantitative and qualitative comparisons across different rating tools, following the recommendation by Oltean-Dumbrava et al. [4]. The selected indicators from this process serve as the baseline for establishing or refining new indicators to suit specific conditions.

TEIs derived from the review process can meet international agreements and gain approval from competent international bodies, as suggested by the International Standards Organization [5]. Additionally, the indicators embedded in existing systems inherently meet essential criteria for selection, such as reliability, independence, and comparability [6].

However, it has been observed that there have been limited efforts to explore TEIs in current SR^2Ts. To address this gap, this study aims to conduct a comparative analysis of TEIs across existing SR^2Ts. This analysis represents the initial phase towards developing new TEIs for the adjustable sustainable urban road rating tool in the Southeast Asian context. The study has three specific research objectives: (1) identifying common TEIs in five selected SR^2Ts, (2) investigating existing practices related to EEIs defined in SR^2Ts, and (3) examining the treatment of TEIs in SR^2Ts and comparing their relative importance.

This research makes a distinctive contribution by determining the priority of TEIs integrated into existing rating tools, which can guide practitioners in selecting the most crucial TEIs for sustainable roadway projects. Through analyzing the existing TEIs, the current research contributes to the knowledge base of transportation engineering aspects concerning sustainable roadway projects and provides a set of common indicators that can aid in developing new rating tools. While the current research places a significant emphasis on the transportation engineering aspect, it's worth noting that the proposed research method holds the potential for application across various categories within the realm of SR^2Ts.

2. Literature Review

2.1. The Transportation Engineering in Roadway Projects

In recent years, transportation engineering has gained paramount importance due to the evolving nature of urban landscapes and the increasing demand for efficient and sustainable mobility solutions in roadway projects. Pedestrian infrastructure and bicycle infrastructure have garnered significant attention as cities strive to promote non-motorized modes of transportation for environmental and health reasons. Studies by authors like Handy et al. [7] emphasize the positive impacts of pedestrian-friendly designs on urban livability and public health, underscoring the need for safe sidewalks, crosswalks, and dedicated cycling lanes. Additionally, Ospina et al. [8] shed light on the importance of considering socio-demographic factors when planning bicycle infrastructure to ensure inclusivity and accessibility.

Traffic facilities remain crucial to transportation systems, impacting vehicular flow and road safety. Research by Qadri et al. [9] highlights the significance of intelligent traffic management systems in optimizing signal timings and reducing congestion. The work of Levinson and Wu [10] emphasizes the role of well-designed intersections in enhancing traffic efficiency and minimizing accident rates. Freight transport, a vital contributor to economies, faces challenges related to congestion, emissions, and last-mile delivery. Authors like Gonzalez-Feliu and Routhiers [11] stress the importance of efficient urban freight distribution systems and sustainable freight transportation practices. Parking areas are integral to transportation planning, with limited space and increasing vehicle ownership posing challenges. Shoup [12] advocates demand-based pricing strategies to manage parking demand and reduce urban congestion. Consequently, sustainability rating tools have integrated the TEIs as a major category contributing to roadway projects' sustainability performance.

2.2. Sustainable Roadway Rating Tools

Over the last ten years, progress has been made in evaluating sustainability accomplishments within road development initiatives, particularly in developed countries like the U.S., Canada, and the United Kingdom. These nations have introduced SR^2Ts, such as Green Guide for Roads, Greenroads, GreenLITES, I-LAST, and INVEST. These tools have attracted the interest of both industry professionals and academics. Moreover, their influence has expanded to other global regions, including New Zealand, Israel, South Africa, Saudi Arabia, and Taiwan [13].

In this framework, an SR^2T is a collection of indicators surpassing the established standard requisites [14]. Each indicator is assigned a numerical value indicating its significance and impact on enhancing road project sustainability. Additionally, the category layer in the hierarchical structure has been introduced to ensure a comprehensive representation of sustainability dimensions. While the rating tool generally revolves around the environmental, economic, and societal aspects, these facets are further divided into distinct classifications: materials & energy, environment & ecology, transportation engineering, and economy & society.

The establishment of an SR^2T is primarily dependent on local attributes, like available resources, technological options, agency objectives, and project nature [14]. This diversity stems from the notion of context-sensitive sustainability, indicating that a standardized rating tool cannot be universally applicable. According to Mattinzioli et al. [13], the absence of consensus on indicator prioritization in existing SR^2Ts mainly results from their suitability within diverse local settings and the preferences of rating tool developers. Therefore, a comparative analysis of indicators within each category among various SR^2Ts can offer deeper insights into indicators and their specific contributions to sustainability performance under particular circumstances. The information presented underscores the need to assess the significance of TEIs across notable SR^2T in relation to their contributions to roadway project sustainability. This emphasis on sustainability assessment is a focal point of the current study.

3. Research Methods

The current research employed a comparative study method, which involves exploring both the differences and similarities between analyzed objects while examining their relationships within their respective contexts [15]. This comparative study can be broadly categorized into descriptive and normative comparisons. The descriptive comparison seeks to describe distinct elements, similar elements under varying conditions, or a combination of both. This study's descriptive comparison of different SR^2Ts allows for an investigation into how TEIs were defined across them. On the other hand, the normative comparison aims to assess the priority of systems onTEEIs and identify the most significant TEIs that contribute to sustainable roadways. Therefore, comparing existing SR^2Ts based on the transportation engineering category will be an appropriate approach during the early stages of developing or enhancing TEIs for subsequent SR^2Ts.

The current research utilized a two-phase combined method for comparative analysis. Initially, the study examined five selected SR^2Ts through archive analyses to identify their respective TEIs. Subsequently, common TEIs were identified by grouping indicators with similar contents across these systems. In the second phase, the study compared the relative importance of these common TEIs using the Normalized Indicator Score (NIS).

3.1. Archival Analysis

In the initial phase of the comparative analysis, the researchers collected and stored archival data concerning TEIs. The focus was on five specific SR^2Ts: Green Guide for Roads, GreenLITES, Greenroads, I-LAST, and INVEST. These five were chosen because they meet three screening criteria: 1) system relevance, 2) timely updates, and 3) quantifiable indicators. SR^2Ts often comprise a range of different indicators. The first criterion allows researchers to select rating tools that contain TEIs. Secondly, several SR^2Ts have undergone adjustments since their original introduction. For instance, Greenroads has been significantly upgraded since its launch in 2009. Consequently, indicator requirements and corresponding scores can be customized to enhance system performance. Therefore, the chosen SR^2Ts should be currently in use. Thirdly, the indicator requirements must be quantifiable to compare TEIs across different systems. Utilizing the indicator scores enables the conduct of quantitative analysis.

In this research, content analysis was conducted using rating-system-related documents such as manuals, scorecards, and instructions (1) to identify TEIs and (2) to record their corresponding points. The process involved a thorough examination of indicator requirements, item by item, in each SR^2T, leading to the identification of TEIs and their respective categories. It is important to highlight that within SR^2Ts, identical requirements may be defined using different indicator terms and categories, reflecting the diverse intentions of developers. To minimize potential subjectivity in collecting related indicators, the author initially identified the original TEIs. Subsequently, the selected TEIs were cross-checked with colleagues.

Afterward, the corresponding scores for indicators/requirements were recorded to compare their priority between SR^2T and assess their contribution to sustainable roadway projects. It's important to note that the interpretation of existing indicators in different rating tools depends on the developers' understanding, leading to variations in how the same problem is described. Consequently, the original TEIs in selected SR^2Ts lack consistent definitions, making it impossible to compare the priority of these indicators. These observations highlight the need to define the group TEIs to facilitate a comparison of priority weights for transportation engineering in roadway projects. Two main concerns arise in this context: the identification and scoring of group TEIs.

Initially, nine TEIs were established by grouping existing ones or requirements with comparable contents. These nine indicators encompass various aspects of transportation engineering crucial for developing sustainable roadway projects. They comprise transportation facilities, pedestrian infrastructure, bicycle infrastructure, public transit infrastructure, freight transport, road traffic safety, roadway consistency, alignment, and parking areas. These indicators effectively capture the diversity and independence of each aspect within the field of transportation engineering.

Step 2 involves assigning the original TEIs/requirements scores to the relevant nine TEIs in each SR^2T. It is important to note that the content of existing TEIs in the five-selected SR^2Ts may perfectly match or partially overlap with those TEIs. To avoid double counting when assigning scores to group TEIs, only the score of specific requirements that suit the nine TEIs in the latter scenario is distributed instead of the overall score of indicators as in the former scenario. As an illustration, consider the PD10 indicator, which pertains to pedestrian facilities and holds a 3-point allocation within the INVEST. Consequently, this score was attributed to the TEI for Pedestrian Infrastructure. In a similar vein, the TP Credit 1 indicator, denoting Parking Management in the Green Guide for Roads, carries a 4-point value within the TEI for parking areas. Notably, certain prerequisite indicators, such as those associated with project consistency in the Green Guide for Roads, are designated a point value of '0'. After that, the scores of the nine group TEIs in each rating tool are determined by summing up the individual scores of the relevant original indicators. These scores serve as parameters for calculating the Normalized Indicator Score (NIS) to facilitate further comparative analysis of TEIs in the subsequent section.

3.2. NIS Determination

NISs serve as quantitative parameters that determine the ranking of various factors. These values were computed with the dual goals of assessing the preference of rating tools towards the transportation engineering aspect, as stated in Eq. ((*1*) and comparing the relative importance of TEIs across five-selected rating tools, as depicted in Eq. ((*2*). The first equation, NIS_1, represents the weight distribution of all nine TEIs in each rating tool, enabling differentiation of the focus on TEIs among SR^2Ts. Meanwhile, the second equation averages the proportions of each TEI across the five-selected tools. The value NIS_2 indicates the significance with which SR^2Ts treat different TEIs, and a larger NIS_2 suggests a stronger contribution to the sustainability performance of the roadway project. A higher NIS_1 value also implies a greater priority to transportation engineering in the corresponding rating tool.

$$\left(NIS_1\right)_j = \frac{\sum_{i=1}^{9} IS_{ij}}{TIS_j} \times 100\% \qquad (1)$$

$$\left(NIS_2\right)_i = \frac{1}{5} \times \sum_{j=1}^{5} \left(\frac{IS_{ij}}{TIS_j}\right) \times 100\% \qquad (2)$$

where, IS_{ij} represents the score of indicator i in rating tool j, $i = 1, 2, \ldots, 9$; $j = 1, 2, \ldots, 5$; TIS_j is the total indicator score of the rating tool j.

4. Results

4.1. TEI Overview

Through content analysis, the transportation engineering aspect of roadway projects in five selected SR^2Ts (Fig. 1) has been examined, resulting in the reclassification of existing indicators into nine common TEIs (Table 1). Table 1 shows that four TEIs—traffic facility, pedestrian infrastructure, bicycle infrastructure, and public transit infrastructure—are consistently present in all selected tools. Upon comparing the various TEIs, it becomes apparent that I-LAST includes the highest number of TEIs, followed by Green Guide for Roads, GreenLITES, Greenroads, and INVEST. None of the rating tools encompassed all nine TEIs. Consequently, further revised or new SR^2Ts can incorporate indicator requirements from the missing TEIs to comprehensively assess transportation projects in terms of transportation engineering.

Table 2 displays the aggregate maximum indicator points, NIS_1 value, and NIS_2 value assigned to each TEI. During the calculation process, existing indicators related to two or more TEIs were distributed equally among those common TEIs. For instance, the Greenroads indicator AL-5 encompassed two requirements: 1) pedestrian paths and sidewalks and 2) bicycle facilities. As a result, each TEI was allotted an equal number of points (one point, to be precise) during the calculation. TEIs may include either or both of the prerequisite indicators and awarded indicators. Prerequisite indicators, like the project-consistency-related indicators outlined in Green Guide for Roads (refer to Table 1), are obligatory for evaluating sustainable transportation projects and are assigned zero points (see Table 2).

4.2. TEI Content in Five-selected SR²Ts

4.2.1. Pedestrian infrastructure

Tumlin proposed enhancing the walking environment during road construction [16]. As a result, transportation engineers should allocate space for motor vehicles and prioritize areas for pedestrians. In line with this principle, the five chosen SR²Ts emphasize the importance of Pedestrian infrastructure as integral components of roadway projects. Unlike Greenroads and INVEST, the remaining three SR²Ts significantly emphasize promoting walking (Table 2). Notable pedestrian infrastructures, such as pedestrian paths, sidewalks, sidewalk structures, pedestrian facilities, recreational areas, and accessibility features, promote the walking environment

During the construction or expansion of sidewalks, allocating enough space in the road cross-section is crucial, providing at least 1.5 meters wide sidewalks on one or both sides. In downtown areas, it is more beneficial to design sidewalks at least 2–3 meters wide for arterial roads. Additionally, a minimum 3-meter-wide buffer zone should separate the sidewalks from the edge of the roads.

To enhance pedestrian comfort and safety, various facilities such as lighting, signals, crosswalks, and pedestrian islands should be incorporated. When installing lighting along sidewalks, it is advisable to keep it separate from streetlight poles to avoid light trespass issues. On high-traffic roads, at intersections, or pedestrian crossings, pedestrians should be protected from motorized vehicles by using bridges or underpasses.

Additionally, road recreation areas offer leisure opportunities to pedestrians, thus contributing to developing a pedestrian-friendly environment. As road projects come to fruition, it is essential to establish or upgrade recreational facilities like information or map kiosks, pocket parks, roadside overlooks, and picnic rest areas. Lastly, to enhance pedestrian accessibility in roadway projects, incorporating bicycle parking areas and public transit stops or stations within an 800 m range should be considered.

4.2.2. Bicycle infrastructure

Bicycles play a crucial role in sustainable transportation by reducing reliance on motorized transit, promoting a healthier lifestyle, lowering travel expenses, and mitigating the environmental impact of motor vehicles. In urban areas and residential zones, cycling is considered one of the most important modes of travel. All the selected SR²Ts explicitly address indicators related to bicycle facilities. The Green Guide for Roads and I-LAST allocate the highest weightage to this aspect, with 8.0% and 7.8%, respectively (refer to Table 2).

The selected SR²Ts emphasize that on-street bike lanes aim to create a safe and comfortable cycling environment. Roadways must be designed to accommodate dedicated bicycle lanes throughout their entire length. Including bridges or tunnels for cyclists and pedestrians at intersections is essential. Separating protected bicycle lanes from motorized vehicles using flexible plastic posts, concrete curbs, and buffers can be advantageous on high-capacity roads. During road reconstruction or maintenance projects, bicycle lanes can be reallocated through a road diet approach, reducing travel lanes to add a bidirectional center turn lane for motor vehicles and utilizing right-hand lanes for cyclists. Moreover, bicycle infrastructure effectiveness is enhanced through associated facilities like lighting, prioritized signals, colored pavements, wayfinding systems, and racks. These facilities ensure that short trips to and from parking areas or stations are safe and comfortable for bicyclists.

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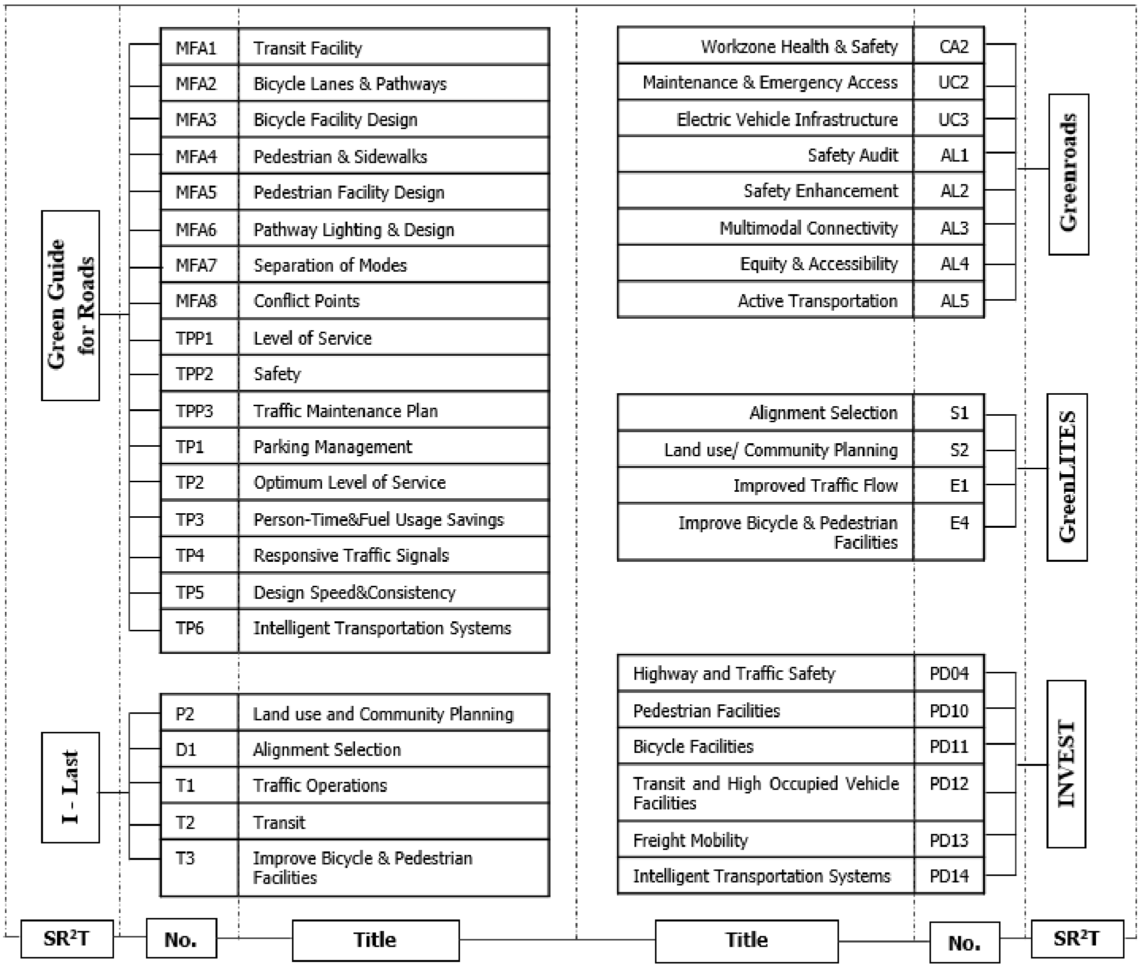

Note: MFA = Mobility For All; TPP = Transportation Planning Prerequisite; TP = Transportation Planning; P = Planning; D = Design; T = Transportation; CA = Construction Activitie; UC = Utilities &Control; AL = Access & Livability; S = Sustainable Sites; E = Energy and Atmosphere; PD= Project Development.

Fig. 1 Existing TEIs in five-selected SR²Ts

Table 1 TEIs incorporated into five-selected SR²Ts.

No.	TEIs	Green Guide For Roads	GreenLITES	Greenroads	I-LAST	INVEST	SR²T' s No.
1	Traffic facility	√	√	√	√	√	5
2	Pedestrian infrastructure	√	√	√	√	√	5
3	Bicycle infrastructure	√	√	√	√	√	5
4	Public transit infrastructure	√	√	√	√	√	5
5	Freight transport	-	√	√	√	√	4
6	Road traffic safety	√	-	√	-	√	3
7	Roadway consistency	√	√	-	√	-	3
8	Roadway alignment	-	√	√	√	-	3
9	Parking area	√	-	-	√	√	3
TEI's No.		7	7	7	8	7	

Table 2 Proportion of TEIs in SR²Ts.

TEI	Green Guide for Roads	%	GreenLITES	%	Green roads	%	I-LAST	%	INVEST	%	NIS_2
Total indicator score of SR²Ts	*100.0*		*276.0*		*130.0*		*245.0*		*171.0*		
Pedestrian infrastructure	13.0[a]	13.0[b]	31.0	11.2	2.0	1.5	13.0	5.3	4.0	2.3	6.7
Bicycle infrastructure	8.0	8.0	20.0	7.2	2.0	1.5	19.0	7.8	4.0	2.3	5.4
Traffic facility	6.0	6.0	17.0	6.2	5.0	3.8	9.0	3.7	5.0	2.9	4.5
Road traffic safety	3.0	3.0	-	-	7.0	5.4	-	-	10.0	5.8	2.8
Public infrastructure	3.0	3.0	6.0	2.2	3.0	2.3	8.0	3.3	5.0	2.9	2.7
Roadway alignment	-	-	13.0	4.7	1.0	0.8	13.0	5.3	-	-	2.2
Freight transport	-	-	2.0	0.7	1.0	0.8	2.0	0.8	7.0	4.1	1.3
Parking area	4.0	4.0	-	-	-	-	5.0	2.0	1.0	0.6	1.3
Roadway consistency	-*	-	4.0	1.4	-	-	2.0	0.8	-	-	0.5
NIS_1		37.0		33.7		16.2		29.0		21.1	

Note:
- a Sum of the highest existing TEI scores under each SR²T
- b Normalized weight (%) of TEIs in each SR²T
- \- Zero value
- * Roadway consistency is mandatory indicator, as outlined in Green Guide for Roads (refer to Table 1). Thus, it receives a zero-point allocation within this table.

4.2.3. Traffic facility

Traffic facilities, such as signals, signs, road markings, traffic barriers, guideposts, and reflectors, regulate and guide users to ensure a safe and efficient travel experience while optimizing traffic flow [17]. As a result, all five SR²Ts incorporate traffic facility-related requirements (Table 1). Among the five systems selected, GreenLITES assigns the most significant importance to traffic facilities, accounting for up to 6.2%, whereas INVEST gives the lowest priority, only 2.9%, as shown in Table 2.

Traffic signals play a crucial role in controlling traffic at intersections and crossings. They utilize various techniques, including full-actuated traffic signals, coordinated signal systems, signal phasing, and timing plans. These methods are crucial for managing active transportation and bus priority systems. Traffic signs and markings also indicate road conditions and potential hazards while reinforcing traffic laws and regulations. Examples include queue warning signs, truck rollover warnings, and low bridge signs. Moreover, intelligent transportation system devices can be deployed to complement traffic facilities. These devices include surveillance tools, traffic control mechanisms, road weather management systems, and electronic payment and pricing systems.

Electric vehicles represent an emerging technology that solves the CO_2 emission problem mainly caused by fuel-based vehicles. Greenroads recognizes and rewards projects incorporating features such as roadside charging stations or parking plots to encourage the adoption of electric vehicles.

4.2.4. Public transit infrastructure

Various forms of public transportation, such as single-deck buses, double-deck buses, trolleybuses, light rail, and metro, offer eco-friendly travel options. Jäppinen et al. [18] suggest combining public transit, cycling, and walking as a viable alternative to using private motorized vehicles. The five representative SR^2Ts address concerns related to public transit and emphasize the need for essential bus infrastructure during the road project's design stage. This infrastructure includes dedicated lanes, proper facilities for bus stops, and accessibility for other nonmotorized travel modes. I-LAST, Green Guide for Roads, and INVEST strongly emphasize these criteria (Table 2).

Bus lanes should be physically separated from other lanes in road design [19]. If bus lanes are not immediately required, designers can reserve space for future bus development using median strips. This approach is valuable because existing roads often face congestion issues, making modifying road dimensions later for dedicated bus routes challenging. Improving or constructing new bus stops is crucial to enhancing bus service quality and encouraging greater use of bus systems. Each bus stop should be equipped with essential facilities, including enclosed shelters, bus turnouts, lighting, seating, itinerary, and timetable information. These amenities contribute to commuter safety and convenience. Green Guide for Roads and INVEST specify that at least 50% of transit stops within road projects should have these facilities. SR^2Ts also highlight the importance of providing accessible facilities to pedestrians and cyclists, as discussed in the previous sections.

4.2.5. Roadway traffic safety

Traffic safety primarily pertains to ensuring the safety of roads, vehicles, speeds, and individuals, with a key focus on preventing accidents and minimizing the harm resulting from vehicle collisions [20]. Table 1 presents the traffic safety measures outlined in three SR^2Ts (Green Guide for Roads, Greenroads, and INVEST). Among these rating tools, INVEST places the highest emphasis on safety criteria, allocating 5.8% of the total points to these specific factors.

Safety audits are a top priority according to the traffic safety management requirements outlined in the relevant credits. Safety audits involve systematic inspections of new or existing road projects and must be carried out by third-party organizations. They aim to assess current and potential safety hazards throughout the project lifespan. Additionally, stakeholders should gauge user safety awareness before and after construction. Furthermore, during the construction stage, it is essential to implement safety measures, including conducting job hazard analyses and providing emergency facilities.

4.2.6. Roadway alignment

In road alignment design, which encompasses horizontal and vertical alignment, the overarching goals are to minimize costs and mitigate any negative impacts on nearby habitats arising from transportation projects. Opting for an inappropriate alignment can lead to environmental harm and substantial cost escalation throughout roadway project construction, maintenance, and vehicle operation stages. Notably, explicit sustainable measures for road alignment design have been specified among the evaluated systems, namely GreenLITES, Greenroads, and I-LAST. I-LAST, in particular, assigns a significant priority (5.3%) to road alignment indicators (Table 2).

The primary focus lies in safeguarding the current ecosystem surrounding roadway projects in the three previously mentioned tools. When choosing the alignment, this involves steering clear of fertile lands, undeveloped areas, and valuable socioeconomic resources like parks, residential zones, and historical sites. Furthermore, the indicators stipulate a specific distance that should be maintained between the constructed road and wetlands or water resources. Another crucial criterion emphasized in these systems pertains to designing a vertical alignment that ensures a balance between the cut and fill volumes of earthwork within the project boundaries.

4.2.7. Freight transport

For several decades, freight trucks have played a vital role in the haulage industry [21]. In urban areas, the breakdown of freight traffic could exacerbate issues concerning travel time, congestion, safety, and emissions. As a result, all the surveyed systems, except for Green Guide for Roads, address freight vehicle movement and propose solutions like coordinating dedicated truck lanes and establishing facilities at truck stops along the roadways.

Creating dedicated lanes exclusively for trucks and managing them can reduce travel time, improve safety performance, and decrease emissions. To segregate truck lanes from other traffic lanes, physical barriers or operational measures like rumble strips, signage, and paint stripping can be employed. Truck lanes are most beneficial on certain roads, such as major arterials, freeways, and streets, especially for traveling to and from central freight hubs like rail terminals, ports, and industrial zones. Regarding truck stops, rest areas or rest stops along the roadway system should be equipped with facilities such as truck ramps, pullouts, priority truck delivery, and priority signals.

4.2.8. Parking area

Despite the limited parking space designated for bikes, motorcycles, and cars on the road, this allocation can still help meet the parking needs in urban areas [22]. Therefore, relevant criteria are outlined in Green Guide for Roads, I-LAST, and INVEST to encourage road designers to include parking areas within the project boundary. Among these tools, the highest priority is given to the parking-related indicator in Green Guide for Roads.

In the mentioned SR^{2}Ts, there is a notable emphasis on parking areas, specifically focusing on park-and-ride lots. Park-and-ride lots are designed to facilitate commuters accessing public transit by offering parking spaces within a short distance of transit stops, typically less than 800 meters. Implementing these principles can enhance the efficiency of the transportation network, enabling seamless travel between residential areas and desired destinations. To ensure vehicle safety, it is crucial to equip parking lots with essential facilities, including theft-resistant bicycle stands, lockers, and adequate lighting. Moreover, in urban areas, regulating on-street parking along existing shoulders could help alleviate the high demand for parking.

4.2.9. Roadway consistency

Farzaneh et al. [23] claimed that project consistency refers to aligning transportation projects with existing plans, programs, or design standards in their respective localities. Failure to include a transportation project in the local or regional development program could result in delays or the withholding of funds by funding agencies. In Table 2, it is evident that three SR^{2}Ts provided instructions regarding project consistency; however, they assigned relatively low scores to these indicators compared to other criteria. This might be because project consistency is a fundamental requirement for any transportation project, leading rating tools like Green Guide for Roads to assign zero points to these indicators. According to the indicator instructions, highway project planning and design stages must adhere to the existing local and regional transportation plans and programs. For example, the federal air quality conformity regulation in the United States mandates that transportation projects align with a transportation plan conforming to the air quality target.

4.3. TEI Significant in Five-selected SR^{2}Ts

4.3.1. Comparison of all TEIs in each SR^{2}T

The results in Table 2 demonstrate variations in the prioritization of TEIs among the selected SR^{2}Ts. This discrepancy can be attributed to the fact that these rating tools were established independently by different developers, each in distinct spatial-temporal contexts. The determination of NIS_1 for all TEIs in each rating tool is as follows: Green Guide for Roads (37%), GreenLITES (33.7%), I-LAST (29%), INVEST (21.1%), and Greenroads (16.2%). Green Guide for Roads and GreenLITES exhibit the highest emphasis on the transportation engineering aspect. I-LAST also focuses significantly on TEIs during the project stages, constituting 29% of the total rating tool points. On the other hand, INVEST and Greenroads assign relatively lower importance to TEIs than the other three selected systems.

4.3.2. Comparison of each TEI across five-selected SR^{2}Ts

Based on the NIS_2 values provided in Table 2, TEIs were categorized into three priority levels: high, medium, and low, as shown in Fig. 2. The indicators related to pedestrian infrastructure, bicycle infrastructure, and traffic facility management in the first group obtained the highest NIS_2 values. These elevated values suggest that the indicators falling under these specific TEIs contribute significantly to the sustainability of roadway projects. Notably, the indicators shared in the priority level align with non-motorized travel, such as AL5 in Greenroads, PD10&11 in INVEST, and TP4 in Green Guide for Roads, as illustrated in Fig. 1. Consequently, these indicators can be regarded as exemplary sustainable practices for the transportation engineering of roadway projects.

The second group of factors, namely public transit infrastructure, roadway traffic safety, and roadway alignment, significantly influence the sustainability of road operation. However, they were given lower weightage compared to the previously mentioned factors. Within the third group, indicators like freight transport, parking area, and roadway consistency were considered to have a lesser impact on roadway sustainability. It is worth noting that project-consistency-related indicators were considered essential prerequisites for any transportation project or conventional road.

Consequently, developers either assigned no points or the lowest possible points to these indicators. Roadway projects should prioritize TEIs that carry substantial importance in the five selected rating tools to achieve high indicator scores.

In the last two groups, the feasibility of most TEIs is contingent on the specific conditions of the transportation projects. For instance, implementing a public transit system would be appropriate for certain roads within cities, while freight-dedicated lanes should be designated for major roads connecting to freight generators such as ports, airports, and rail yards.

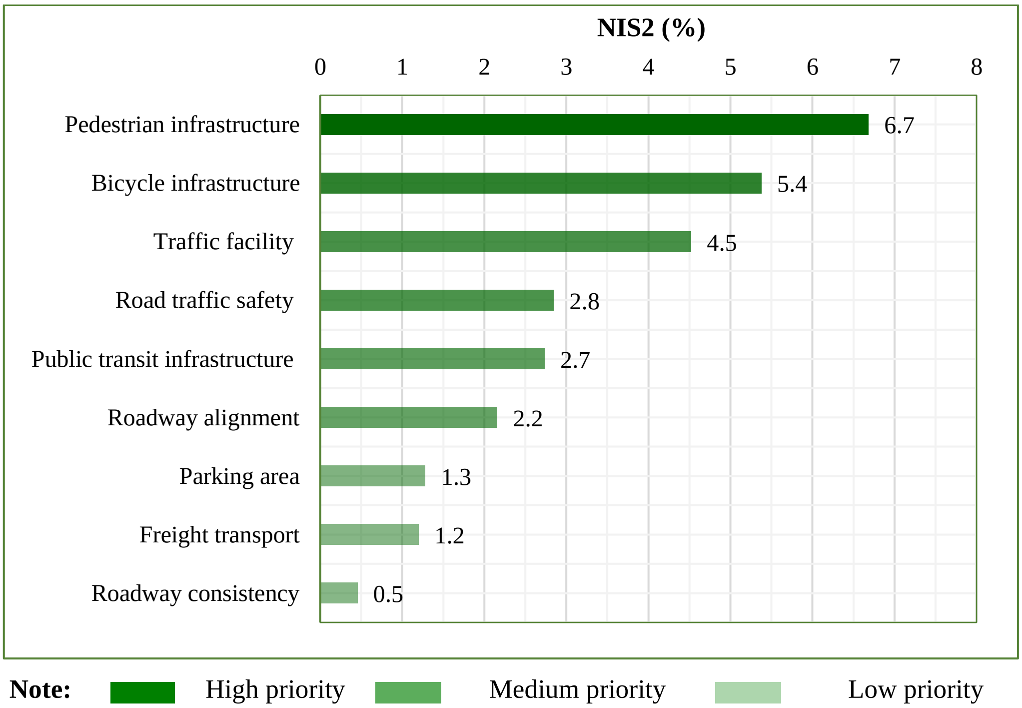

Fig. 2 TEI classification based on NIS_2 values

5. Conclusion

TEIs play a crucial role in measuring sustainability indicators for sustainable transportation development. Multiple SR^2Ts use these indicators to assess and certify the sustainability levels of various transportation projects. This study compared TEIs to determine their relative significance in the transportation engineering aspect of roadway projects. The results showed that among the five-selected SR^2Ts, Green Guides for Roads and GreenLITES assign substantial weighting scores to TEIs, accounting for 37% and 33.7% of the total system score, respectively. In contrast, Greenroads gives TEIs the least priority, only 16.2%.

Furthermore, indicators related to pedestrian infrastructure, bicycle infrastructure, and traffic facilities are prioritized over freight transit, parking area, and roadway consistency. Therefore, they are perceived to contribute more significantly to the sustainability of transportation projects. The high-priority indicators identified in this study could serve as the foundation for developing new systems or customizing existing ones to assess better and improve the sustainability of roadway projects.

This study aims to aid stakeholders involved in sustainable roadway projects, such as owners, design consultants, contractors, funding agencies, and research organizations. It provides valuable insights into transportation engineering measures. By utilizing the study findings, practitioners can identify appropriate transportation engineering measures based on their specific context or contribute to the sustainability of their roadway projects. Planners and designers are encouraged to implement the prioritized indicator instructions from rating tools, surpassing current environmental compliance standards during roadway design and construction. Public agencies in the transportation sector can also utilize the identified indicator requirements to enhance their existing technical specifications, guidelines, or manual designs.

Moreover, the results offered valuable information to SR^2T developers, improving their comprehension of the transportation engineering aspect. Consequently, these findings are expected to be highly beneficial in refining existing TEIs within current rating tools or establishing new indicators for future rating tools. Researchers can also adapt the methodology used in this study to analyze other categories within SR^2Ts. This allows for the potential expansion of knowledge and insights into sustainable transportation.

The forthcoming research topics are outlined below. Initially, it is essential to compare indicators associated with various sustainable aspects, including material and energy consumption, water resources, landscape and ecology, society, and economy. To gain practical insights, empirical research using a questionnaire survey can be undertaken to gauge participants' perceptions of the importance and challenges in implementing traffic-and-transportation-planning-related requirements for transportation projects. Lastly, tailored SR^2Ts can be developed to suit the unique contexts of individual roadway projects.

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Effects of Expressways on Condominium Prices: An Investigation of Condominiums in Metro Manila Using Hedonic Regression Analysis

Topic number: 1, Paper Identification number: AYRF2023-028

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Abstract

The effect of expressway expansion and transportation systems on condominium prices have emerged as a topic of interest for real estate stakeholders and urban planners. Although several studies have been conducted on the impacts of transit development on properties, limited research has focused on the effects of automotive transportation facilities such as elevated expressways. This study aims to evaluate the impact of proximity to elevated expressways on condominium properties in Metro Manila, Philippines. This paper utilizes data scraping techniques to speed up the data collection process and obtain as many samples as possible. A hedonic approach was used to study the relationship between transportation facilities and condo prices, including various condominium attributes to determine the best model in estimating the price of condominium units. The results of this study suggest that proximity to elevated expressway entry ramps has a statistically significant effect on condominium prices. For the entire study area of Metro Manila proximity to Skyway entry points had an inverse relationship in which a 1% increase in meter distance to entry points resulted in a 0.046% decrease in the price of the condominium. However, after further analysis, it was found that the positive effect of proximity to entry ramps was only up to a certain distance. Afterward, proximity would have a negative effect on the prices of condominiums. Whereas, proximity to transit stations was found to have a positive effect on condominium prices among the several datasets.

Keywords: Condominium property, Hedonic Regression, Rail transit, Expressway, Proximity, Value Capture, Metro Manila

1. Introduction

Population density plays a pivotal role in determining how cities are structured and organized. It influences the spatial arrangement of different components within an urban environment. In the case of Metro Manila, it is considered one of the most densely populated cities in the world with 21,765 persons per square kilometer [1]. This puts a strain on infrastructure, as limited spaces and overburdened networks struggle to accommodate the needs of a dense population. As population density rises, the demand for housing increases as well [2]. Metro Manila has a scarcity of land area as it only covers 619.54 square kilometers. As a result, there is pressure to maximize its land usage. With this, condominiums can pose a potential solution to this issue. It provides efficient land utilization that allows the construction of multiple units within a single building which can accommodate a large number of residents.

Due to the overwhelming demand, these developments have spread to the fringes, with new condominiums being built in Quezon City, downtown Manila, Makati, and Ortigas. It is projected that in 2023, the condominiums in Metro Manila will reach 27,380 units, which is an increase of 20.5 percent from 2020 [3]. As the number of these developments rises, companies tend to build more luxurious and high-end infrastructures that cater to the more affluent segment of the population. According to Statistica[4], the average selling price per square meter of condominiums in Metro Manila amounted to 225.29 thousand pesos in 2022. As a result, many Filipinos, particularly those with low incomes, cannot afford these condominiums. Subsequently, they are forced to seek alternative housing options outside the metropolitan area.

Understanding the variables that affect condo prices becomes crucial in addressing this issue. The price of condominiums is significantly influenced by elements including location, amenities, structure, and the general real estate market. By studying these variables, policymakers and urban planners can identify potential areas to explore and regulate. Policies may also be implemented based on the results of this study as the government may create regulations that can encourage the development of affordable housing alternatives. This can be accomplished by granting developers to construct condominiums at a modest price. Additionally, more diversified urban planning may be produced that promotes a mixed-income environment and an inclusive urban landscape. With this, families and individuals with lesser incomes may take advantage and possibly access opportunities that come with living in the metro.

Lastly, the results of this study can help the government to invest in the improvement of public transportation systems that link outlying areas to major districts. By enhancing transportation options, commuting becomes more desirable, efficient, and cost-effective. This can mitigate the effects of limited housing options within the city.

The following sections provide an overview of the paper's content. In Section 1, the problem setting of the research is addressed. Section 2 includes the Review of Literature, which encompasses relevant studies and sources cited in relation to this study. Section 3 outlines the methodology employed by the study. Lastly, Section 4 discusses the results and provides an overall conclusion to the paper.

2. Literature Review

The hedonic pricing model is a popular technique that was utilized by most existing studies in terms of determining the impact of the proximity of various structures on property prices, as shown in Table 2.1. The structures of note are public transportation facilities that include railway stations [5][6][7][8], bus stops, highways or expressways [9][10], or any combination of the three [11][12][13]. Other studies have also utilized the hedonic pricing model in assessing the impact of the construction of an infrastructure by comparing the prices of properties in a before and after study [14][8]. Karlsson [15], though not explicitly stating the model, also used the hedonic pricing model in examining the impact of transportation improvements on housing prices. Regardless of the purpose of the application, the attributes that were used on their models were similar across all the studies examined. These are mostly composed of the structural attributes, neighborhood attributes, and accessibility attributes of the structure being evaluated. In terms of the price to be designated as the dependent variable in the hedonic function, studies either utilize sales transactions over a period of time [5][6][14] or the asking price of the properties at a specific point in time [7][11][12]. Most of these studies obtained their data from their respective local government agencies and through real estate companies, which granted them access to the location and several structural attributes. Dewita et al. [16], who examined the effect of transport costs on housing affordability, conducted surveys via questionnaires and face-to-face interviews to obtain data necessary for their study. A combination of both data acquired from existing databases and through interviews was observed in the study of Gallo [17], who used multiple linear regression as their analysis tool of choice. These studies also used Geographic Information System (GIS) to geocode the prices, measure distances, and map the locations.

Aside from the Hedonic Price Modeling as their main approach, other studies utilized other approaches in determining the impact of transportation on housing prices. Chwiałkowski & Zydroń [18] conducted a preliminary spatial analysis using QGiS and MS Excel software in obtaining the descriptive statistics of their variables after dividing their study area into groups based on their distance from bus stops. Due to the numerous limitations and disadvantages of using Ordinary Least Squares (OLS) in estimating the parameters of a linear regression model, Dorantes et al. [19] also included the use of the spatial lag model (SLM) and SEM in their study to take into account the spatial nature of the data. This was done to combat possible spatial dependence and spatial heterogeneity. A similar study was conducted by Guan et al. [20], who used OLS and SLM in the context of Manhattan, New York City.

3. Methodology

3.1 Study Area

The study area covers twelve cities in Metro Manila namely, Pasay, Makati, Quezon City, Manila, Muntinlupa, Taguig, Paranaque, Caloocan, Pasig, Las Pinas, San Juan, and Marikina. The expressway spans over 39.2 km, connecting the North Luzon Expressway and South Luzon Expressway. Stage 1 starts from Buendia in Pasay to Bictuan in Paranaque, Stage 2 starts from Bicutan to Alabang in Muntinlupa, and Stage 3 starts from NLEX up to Buendia in Makati. Skyway has a total of 27 entry points across Metro Manila, as shown in Fig. 1.

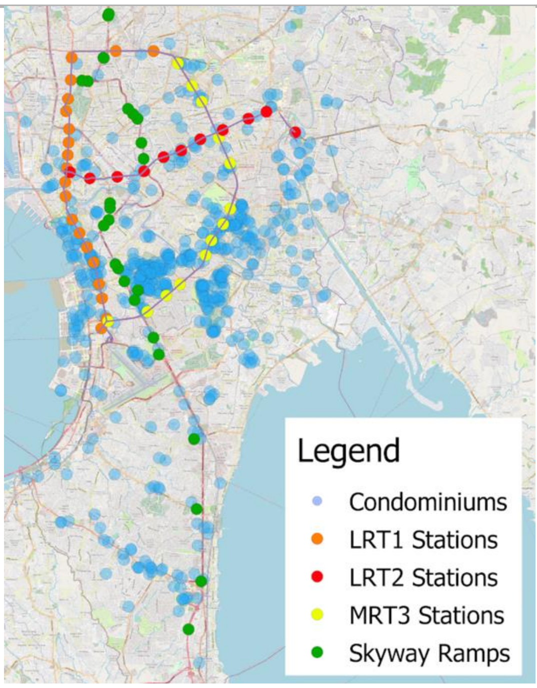

Fig. 1 Metro Manila Study Area (QGIS and OpenStreetMap)

Skyway is surrounded by different types of properties. To the South, in Paranaque and southward, there are mostly subdivisions, warehouses, company offices, and some clusters of mid-rise condominiums. On the other hand, the properties around Makati City consist mainly of commercial properties and condominiums of varying sizes. Unlike the clustered condominiums in the southern cities of Metro Manila, the condominiums along this part of Skyway are more spread out. Moving further North, the surrounding properties become predominantly residential with fewer condominiums, some commercial real estate, and warehouses.

3.2 Data Sets

Condominium data will be analyzed collectively as data cluster sets. Regression analysis will be conducted separately for each city to determine the effects of different attributes on condominium prices. Another regression analysis will be conducted for the entire study area to assess the impact of structural and locational attributes on condominium prices as a whole. To explore the effects of these attributes further, the dataset was grouped based on cities with direct access to different transportation facilities. Cities with access, regardless of degree, to the Skyway Stage 1 and 2, LRT 1, LRT 2, and MRT 3 stations were clustered, and Ordinary Least Squares (OLS) analysis was performed on these data.

3.3 Variables Used

For this study structural and locational attributes were used as independent variables for the hedonic regression analysis. Structural attributes used include the developers reputation and the floor area of the condominium in meters squared. The developer's reputation is based on an article by Investasian [21] on the 10 best developers in the Philippines. The variable Dev_rep is a dummy variable wherein if the condominium unit was developed by one of the top 10 developers, Dev_rep would be equal to 1. Otherwise it would be equal to 0. Locational attributes include shortest path distances to commercial and or business districts and transportation facilities such as train stations and Skyway entry ramps. While dummy variables for the presence of a hospital, church, school, college, and mall within 1km of the condominium.

For shortest path distances, the distances to the nearest LRT1 station, LRT2 station, MRT3 station, Nearest Station, Skyway Entry/Exit ramps, and commercial or business district was taken. While dummy values were used for the variables Church_1000, Hostpial_1000, Mall_1000, School_1000, and Uni_1000. Wherein the dummy variables would be equal to 1 if the facility is within 1000 m or 1 km from the condominium unit. The summary of the independent variables used in the regression analysis is summarized in the table below.

Table 1 Input Data and Attribute Description

Category	Attribute/ Variable	Operational Description
Dependent Variable	P	Price of Condominium Unit per Floor Area (PhP.)
Structural	Dev_rep	Developer Reputation (Categorical)
	Floor_area	Lot Size of the Condominium Unit (sq. m.)
Locational	Station_SPD	QGIS Shortest Path distance to closest rail transit station (m.)
	Skyway_SPD	QGIS Shortest Path distance to nearest expressway ramp (m.)
	DIST(CD)	QGIS Shortest Path distance to nearest Central Business/Commercial District (m.)
	Church_1000	Number of Churches within 1000 m distance (count)
	Hospital_1000	Number of Hospitals within 1000 m distance (count)
	Mall_1000	Number of Malls within 1000 m distance (count)
	School_1000	Number of Schools within 1000 m distance (count)
	Uni_1000	Number of Colleges & Universities within 1000 m distance (count)

3.4 Hedonic Price Model

Hedonic modeling is a widely used analytical tool in nonmarket valuation. This considers the significant decision of the household and confers different characteristics not solely based on the structure but with the consideration of different amenities and disamenities. Hedonic models decompose heterogeneous assets of the property and assign separate values as they shape the perceived utility [22]. In this manner, the extent to which these attributes or variables affect the property price can be estimated. While several forms of the hedonic pricing model exist, with respect to how data is manipulated before conducting the regression analysis, there is no existing theoretical basis as to which form should be used in a regression [22][23]. Linear, semi-logarithmic, inverse logarithmic, and logarithmic functions were the most commonly used forms based on existing literature. Since each set of data varied uniquely, each of these functions were utilized in determining the best-fit model for the various dataset that were considered. The basic form of the Hedonic Price Model is expressed in Eq. 1, with the other function forms differing in how they treat the data, either by obtaining the natural logarithms of the dependent variable, independent variables, or a mix of both.

$$Y = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \boldsymbol{X}_1 + \cdots + \boldsymbol{\beta}_i \boldsymbol{X}_i + \varepsilon \quad (1)$$

Where,
Y = Final Prize
X = Characteristic Attributes
$\boldsymbol{\beta}_1$ = Regression Coefficients
ε = Error

Moreover, regression analysis determines the contribution value of each attribute in the given model. It places value on each contributory factor and thus identifies how the price changes when a specific characteristic is modified. In this process, the significance and correlation of each attribute in the condominium price are determined. The interaction of each variable, as well as the entire framework of the study are summarized in Fig. 2.

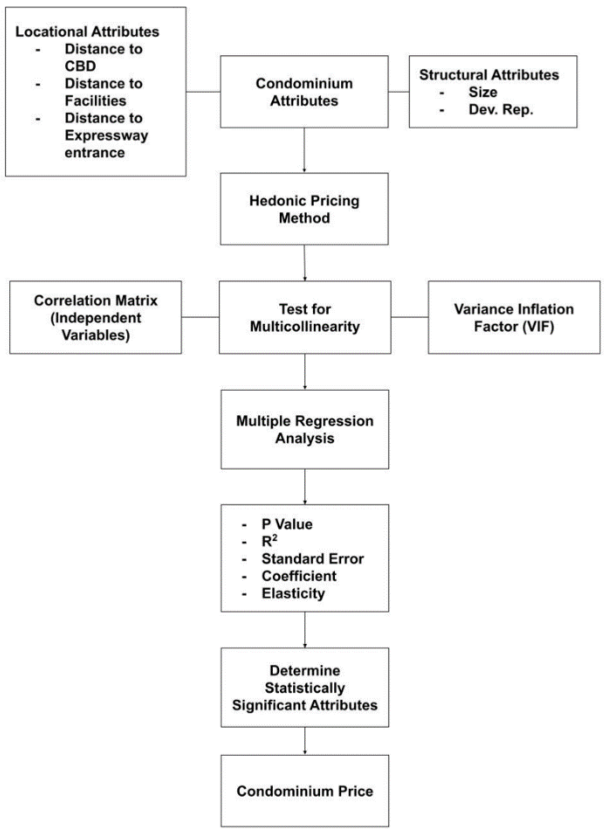

Fig. 2 Theoretical Framework

2.5 Descriptive Statistics

According to descriptive statistics of the entire study area, the average price of condominiums are 15,392,836.80 PHP, while the average floor area of condominiums is 73.320 m^2. Moreover, 48% of the condominiums in the data set are constructed by one of the top ten developers. In regards to the locational attributes the average distance of condominiums from the rail station (LRT1/LRT2/MRT3), skyway entry ramps, and commercial and business districts are 3109.469 m, 4233.904 m, and 1859.378 m respectively. The percentage of condominiums that are within 1km of a Church, Hospital, Mall, School, and College are 95%, 33%, 66%, 99%, and 74% respectively.

The acquired data were also grouped into four data sets; Skyway, LRT1, LRT2, and MRT3. The number of observations for each group is 388, 172, 218, and 278 respectively. The summary of the descriptive statistics can be seen in Table 2.

Table 2 Descriptive Statistics of Input Variables

Variable	Description	Entire	Skyway	LRT1	LRT2	MRT3
Price	Price in PHP	15392836.8	17829154.84	7964906.209	10602472.83	17252901.21
Floor_area	m^2	73.320	59.514	49.586	48.743	78.765
Station_SPD	m	3109.469	3689.311	3159.790	2787.676	2322.730
Skyway_SPD	m	4233.904	1975.770	3805.657	338.559	3340.927
DIST (CD)	m	1859.378	1398.193	2094.994	2036.745	1515.472
Dev_Rep	Dummy	0.480	0.501	0.430	0.390	0.510
Church_1000	Dummy	0.950	0.232	0.970	0.980	0.980
Hospital_1000	Dummy	0.330	0.479	0.460	0.400	0.420
Mall_1000	Dummy	0.660	0.442	0.530	0.490	0.750
School_1000	Dummy	0.990	0.124	0.970	1.000	0.980
Uni_1000	Dummy	0.740	0.450	0.850	0.080	0.820
n	596	596	388	172	218	278

The data gathered from the study and the processes, results, and conclusions that stem from it are used purely for academic and research purposes. The entities that submitted the listings to Lamudi were not included in the set of data that were obtained. Despite being acquired from readily available sources, proper steps were taken to prevent unauthorized access so as to abide by proper research ethics and data management.

4. Results and Discussion

4.1 Entire and Transportation Facilities Models

Tables 3 and 4 summarize the best models obtained from each scenario. Four models were created for each scenario utilizing different functional forms. For most of the models, with the exception of LRT1 and MRT, the logarithmic function yielded the best model. All five models show significant overall F tests as seen from the tables below, indicating that the models are acceptable.

Table 3 Best Fit Model Regression Results (Enter Method)

Variable	Coefficients				
	Log	Log	Linear	Log	Linear
	Entire	Skyway	LRT1	LRT2	MRT
(Constant)	13.919***	13.125***	2706457.867	13.132***	5517133.075
Floor_area	1.033***	0.999***	137688.748***	1.095***	267637.931***
Station _SPD	-0.032*	-0.039	-459.036**	-0.020	-223.779
Skyway_SPD	-0.042*	0.073**	531.253**	-0.036	31.765
DIST (CD)	-0.184***	-0.21***	-326.06*	-0.158***	-44.510
Dev_Rep	0.063*	0.084**	984454.068*	0.143**	4784120.526***
Church_1000	0.102	0.164*	2159519.206	0.120	2197170.658
Hospital_1000	-0.093**	-0.082*	6484.709	-0.036	-2626053.873
Mall_1000	0.136***	0.143**	429636.418	0.106*	2046035.713
School_1000	-0.245	-0.245	-3045166.392*	-0.012	1863191.914
Uni_1000	-0.053	0.049	-1476953.525*	-0.142**	-2861633.046**
n	596	388	172	218	278
Adjusted R^2	0.789	0.807	0.673	0.707	0.778

Table 4 Best Fit Model Regression Results (Backward Method)

Variable	Coefficients				
	Log	Log	Linear	Log	Linear
	Entire	Skyway	LRT1	LRT2	MRT
(Constant)	13.58***	12.926***	2244594.113**	12.829***	-6911328.353***
Floor_area	1.032***	1.006***	138302.688***	1.1***	269396.189***
Station _SPD	-	-0.045**	-526.189**	-	-
Skyway_SPD	-0.046**	0.091**	592.189**	-	-
DIST (CD)	-0.19***	-0.208***	-398.095**	-0.17***	-
Dev_Rep	0.063**	0.092***	1168832.073**	0.148***	4676622.558***
Church_1000	-	0.16*	-	-	-
Hospital_1000	-0.086**	-	-	-	-3175700.125**
Mall_1000	0.126**	0.148**	-	0.119**	*
School_1000	-	-	-1645926.816**	-0.129**	-
Uni_1000	-	-	-	-	-
n	596	388	172	218	278
Adjusted R^2	0.798	0.807	0.673	0.71	0.78

The results of the best model of the OLS of the entire study area, this case being the log form, reveals 6 significant attributes. These attributes include 2 that are structural while the remaining 4 are locational. The model is characterized by having an adjusted R-squared value of 0.789, obtained by examining a total of 596 condominium listings and their corresponding attributes. The results, along with the models of other forms, are summarized in Table 5, while Table 4 contains the details regarding the significant attributes of the best-fit model.

Table 5 Entire Study Area Model Summary

Entire	Enter Method (All Variables Included)			Backward Method (Best Model)		
Functional Form	Adjusted R-Squared	Sig	F	Adjusted R-Squared	Sig	F
Linear	0.723	0.000	156.432	0.723	0.000	311.768
Semi-Logarithmic	0.728	0.000	175.092	0.725	0.000	262.263
Inverse Semi Logarithmic	0.596	0.000	98.674	0.596	0.000	176.577
Logarithmic	0.790	0.000	224.267	0.789	0.000	371.106
n=596						

The OLS model reveals which attributes contribute to the price of condominium units across the various dataset groupings presented. Floor area and developer reputation were the two structural attributes that had an impact on the price. These are rather self-explanatory as the floor area of a property often dictates the price. This is not only limited to condominium units but to all land properties in general. This is also supported by literature as most of the ones that reviewed floor area yielded a high significance in the said attribute with a positive direct relationship to the price [24][29][30]. This also applies to all the other dataset groups as all of them, in their best-fit model, revealed floor area as one of the significant attributes that contributed to the price with a positive relationship to the price. The results imply that a 1% increase in floor area will result in a 1.032% increase in the price of the condominium unit. The other structural attribute examined was the reputation of the developer of the condominium. This was represented by a dummy variable that indicated whether a condominium was developed by an established company, which was ranked in the top 10 by some metric, or not. Results showed that this was often a significant factor in determining the price. This is supported by a similar study [24] that also took into account developer reputation. It can be said that condominiums with reputable developers have the capacity to command a premium depending on the audience that they cater to. In addition, these developers often strategically place their properties at or near commercial or business hubs, which may further influence their prices. This is also consistent throughout all the datasets. These two attributes are statistically different from zero at 99% and 95% confidence levels respectively as indicated by their p-value in Table 5.1.2.

In terms of locational attributes, these consisted of two types, shortest path distances to certain highway facilities or locations and number counts of a particular urban facility within a certain distance. In the case of the entire study area model, there were two of each that were considered significant attributes. The results revealed a negative correlation between the distance to the closest expressway ramps and the condominium prices at a p-value that was considered to be significant at 0.038 implying a 1% increase in meter distance the condominium unit is to Skyway entry ramp its price will decrease by 0.046%. This would indicate that the greater the distance from the expressway ramp, the cheaper the prices, which was in line with the hypothesis of the study and is supported by some studies such as the case in Thailand which recorded a 0.1% increase in property value per 1% increase in proximity [7], with the general subject matter having mixed results when examining literature, with some indicating that there is no correlation [10][25]. A positive impact on price indicates that the accessibility to those facilities garners a price premium and is enough to offset the potential disamenity effects. The other significant distance attribute measures the shortest path distance from condominiums to the closest commercial or business district. This is usually an attribute that greatly contributes to the price of properties as proximity to CBD minimizes or negates the need for travel most of the time while having access to a wider range of facilities compared to those outside of it. This is supported by the results of the study and by the results of previous studies [25], in which the coefficient of this attribute is one of the largest behind the floor area at -0.19. This trend is also found among the majority of the dataset groups. Similar to the shortest path distance to the expressway ramps, a negative coefficient indicates that the price decreases as the distance from the condo to commercial and business districts increases, which is in line with the expected results. It implies that a 1% decrease in meter distance to commercial or business districts will result in a 0.19% increase in the price of the condominium unit. In terms of the number count attributes, hospitals, and malls were the urban facilities that were revealed to be significant for this group. At a radius of 1000 m, hospitals were found to have an inverse relationship which is supported by the study of Peng & Chiang [26] who found that a disamenity effect is present as a function of the distance to the hospitals. Malls can be likened to commercial districts due to the range of facilities that they offer. They are also highly valued by people in the country specifically due to how they are seen as leisure spots and as places of convenience [31].

Examining the Skyway model, much of the significant attributes and their relationship with the condominium price remained consistent with the results of the entire study area model. One of the notable differences has to do with the direct relationship that exists between the price and distance to the expressway ramps. Unlike the previous model, this indicates that the price increases the further the expressway ramp. The results imply that a 1% increase in meter distance to the Skyway entry ramp will result in a 0.099% increase in the price of the condominium unit. As mentioned, this is also within expectation as literature on the topic has yielded inconsistent results. It is perhaps by focusing and isolating these cities with direct access to the expressway that its impacts on the price are magnified hence the drastic change in coefficient. Regardless, the distance to expressway ramps was still found to be statistically different from zero at a 95% confidence level.

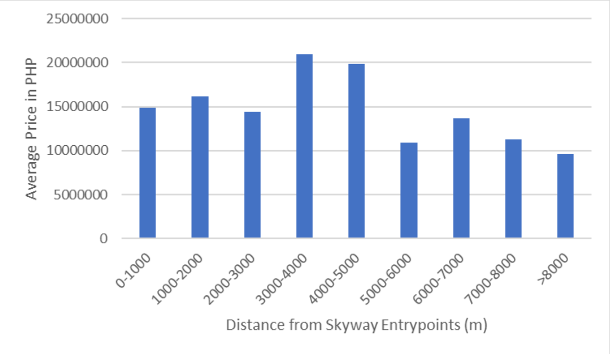

Fig. 3 Average Condominium Price at 1 km Intervals from Skyway Entry Ramp

Analyzing the prices of condominiums based on their distance from the expressway entrance ramp it is found that the prices of condominium units are highest within 3 km to 4 km away from expressway entry ramps as seen in Fig. 3. This possibly indicates that proximity to Skyway entry ramps only has a positive effect on condominium property prices up to a certain distance. Afterward, proximity to these ramps has a negative effect on condominium prices.

This model also managed to capture the effect of the proximity to the nearest rail station with a p-value of 0.038. This implies that condominiums within these cities could have been strategically placed with rail commuters in mind to raise property value, be it at a relatively lesser degree as shown by its coefficient. With a negative coefficient, and similar to the previous cases, there is a price premium in units that are closer to the rail stations. The results imply a 1% increase in meter distance to the transit station will result in a 0.079% decrease in the price of the condominium unit. This is consistent with several other pieces of literature on the topic [7][27] [28][29].

The effect of churches was also revealed in this model; it was found to be one of the heaviest contributors to the price with a coefficient of 0.166 at a 90% confidence level implying a 0.166% increase in price if the condominium is within 1km of a church. This may be due to the demographic of the country being mostly Roman Catholic, which encourages people to attend mass every Sunday. Hence, proximity to churches would eliminate or minimize the need to travel far.

In the case of the rail models, it is found that proximity to transit stations has a positive effect on the prices of condominiums. For the rail models, the beta coefficient of the distance to stations for the enter method is all negative implying that increases in distance to transit stations result in a decrease in the price of the condominium. However, among the three models, the distance to transit stations variable is only statistically significant for the LRT1 model. The results imply a 1% increase in meter distance to LRT1 stations results in a 0.209% decrease in the price of the condominium unit. However, the results of this model contradict the findings of another study conducted in 2018 by Salvame [24] who also investigated the effects of proximity to the nearest station and prices of condominiums along LRT1 Metro Manila. Whereas proximity to the nearest LRT station and the developer's reputation resulted in a price premium for this study, the research conducted by Salvame [24] had opposite results for both. The discrepancies between the two could be attributed to several differences between the independent variables and the number of samples used in the regression analysis. The reliability of both models should also be mentioned as what Salvame had deemed his best model had an R-squared value of 0.854 in contrast to 0.673. It could very well be the case that none of the models, and the OLS in general, can reliably explain the LRT 1 possibly due to the high variability of the dataset.

5. Conclusion

This study utilizes the hedonic pricing model to determine the potential impacts that proximity to expressway ramps might have on the condominium prices along the region of Metro Manila. This was achieved through the combination of utilizing web scrapers in extracting the basic structural information of condominium listings from a real estate website, Lamudi, and through QGIS in plotting and extracting locational data from OpenStreetMap. To explore the impact of these attributes on condominium prices, the dataset was further clustered based on the cities through which the Skyway (the main expressway of interest) passes, cities with different rail transit services such as LRT 1, LRT 2, and MRT 3, and analyzed on a per-city basis. Ordinary Least Squares (OLS) regression was employed to uncover the relationship between these attributes and the condominium prices.

The results of the study indicate that the most influential attribute of condominium price is the floor area. It was found to have a significant relationship and positive effect on the price for all of the models. While the developer's reputation was also found to have a statistically significant relationship and positive effect on price for all models except for Taguig. For locational attributes, the shortest path distance to skyway ramps shows a significant relationship in the entire study area, skyway, LRT1. The relationship between the distance to skyway ramps and price varies between models with the relationship being inverse for the entire model. While direct for the other models. For the best model of the entire study area, the results imply a 1% increase in meter distance from the condominium unit to Skyway entry ramp; its price will decrease by 0.032%. Whereas for the Skyway Stage 1 & 2 model, the results imply a 1% increase in meter distance from the nearest Skyway ramps resulting in a 0.099% increase in price. On the other hand, the Skyway, Skyway Stage 1 & 2, and LRT1 models featured the shortest path distance to the nearest rail station as a significant determinant of condominium price. The results imply a 1% increase in meter distance from the nearest station results in a 0.039%, 0.079%, and 0.209% decrease in the price of the condominium unit. They all have an inverse relationship with the price and its impact increases as the scope of the model decreases, while the effects of proximity to Skyway entry ramps are mixed.

The findings of this study indicate that proximity to transportation facilities has a statistically significant effect on the prices of residential properties such as condominium units. while the effect of proximity to elevated expressway entry ramps are mixed, the effect of proximity to rail stations are found to be positive in different models. Ultimately, these findings can help both transport planners and policy makers. Transport planners can use results of the study to cater to the needs and demands of people. The results of the study suggest that higher property prices near transportation facilities. Thus, this may warrant additional investment in these transportation infrastructures to meet the demand for the transport facility and reduce traffic congestions. Furthermore, policymakers can implement measures to ensure that affordable housing options are available in areas with good transport access. This can include inclusionary zoning, which requires developers to reserve a percentage of units as affordable housing in exchange for development rights or by limiting the prices of residential properties. By providing affordable housing options in desirable areas, in this case near transport facilities. Lawmakers can help address the potential gentrification and displacement risks associated with rising property values.

For future studies, the researchers recommend increasing the number of attributes considered. This expansion should include neighborhood attributes that describe the surroundings of a condominium and the demographic characteristics of the area. Additionally, including structural attributes would provide valuable insights into the physical features and qualities of the condominium itself.

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SESSION 3.2A: AYRF 2033 RESEARCH PAPER PRESENTATION
From Paper ID: 2023-01, 2023-002, 2023-004, 2023-015, 2023-016

Paper ID	Paper Entitled	Presented by
AYRF 2023-001 Page 45-54	"Determinants of Continuance Intention to Utilize Electric Motorcycles for Students in Hanoi, Vietnam"	**Ms. Ngoc Minh NGO** Faculty of Transport-Economics, University of Transport and Communications
AYRF 2023-002 Page 55-66	"Facilitators and Barriers to Adopt Electric Motorcycles for Commercial Purposes – A Qualitative Study of Food Delivery Riders in Vietnam"	**Dr. Minh Hieu Nguyen** University of Transport and Communications
AYRF 2023-004 Page 67-75	"Sexual Harassment in Public Transport among Students in Developing Countries – The Case of Hanoi, Vietnam"	**Ms. Mai Phuong NGUYEN** University of Transport and Communications
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AYRF 2023-016 Page 83-92	"Development of Decision-making and Local Planning for Autonomous Vehicle to Mitigate Pedestrian Crash"	**Mr. Sedtawud LARBWISUTHISAROJ** Department of Mechanical Engineering, Faculty of Engineering, Chulalongkorn University

Determinants of Continuance Intention to Utilize Electric Motorcycles for Students in Hanoi, Vietnam

Topic number: 4/6, Paper Identification number: AYRF2023-001

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Abstract

Electrification of private motorized vehicles is a major objective, in addition to the expansion of public transit, which supports the development of urban mobility. Based on an Extension of Expectation Confirmation Theory (ECT), the aim of this study is to investigate the influential factors of continuance intention to use electric motorcycles. Partial Least Squares Structural Equation Modelling (PLS-SEM) and the data of 394 students in Hanoi obtained in August 2022 are used to empirically evaluate the suggested conceptual framework. The findings demonstrate that perceived usefulness and satisfaction directly support the continuation intention, but perceived usability and expectation confirmation have a beneficial impact in a more indirectly manner. While individuals who live in rural areas appear to have a stronger intention to continue riding electric motorcycles, female students, on the other hand, often have a lower intention. With over 65% of the variation in continuance intention being explained by independent constructs, the model has strong predictive potential. Based on the results of the influencing factors, the authors provide practical implications for encouraging the usage of electric bikes among students.

Keywords: Electric motorcycles, Hanoi, Expectation confirmation, Hanoi, Sustainable development

1. Introduction

Natural catastrophes like floods and extended periods of intense heat that occur with increasing frequency are the main causes of critical environmental issues. Transportation is one of the main causes of greenhouse gas emissions, which raises temperatures on the planet over time [1]. This highlights how crucial it is to reduce pollution in transportation. Habits play a crucial role in people's choice of transportation modes [2]; therefore, green travel habits must be established in order to change the mobility that depends on fossil fuels. However, adult travelers have such ingrained travel behaviors that changing them requires effort and expense, not to mention unanticipated outcomes [3]. Students are more likely to engage in pro-environmental actions as a result of their extensive exposure to awareness-raising initiatives and the real-world observation of the catastrophic effects of climate change [4]. Students may be assumed also have limited financial resources, which causes them to choose public transportation or free or inexpensive options like cycling or walking [5]. Early adoption of green travel behavior is observed to carry over completely or partially into later life. As a result, promoting environmentally friendly transportation among students is a step toward developing sustainable urban transportation.

Due to their maturity in physical and mental capacity, university students are more independent when it comes to picking travel modes than pupils (school students), who often rely on transportation based on their parents' recommendations or decisions [7] Additionally, students must travel to school, (part-time) jobs, and recreational locations, which have complicated relationships with the travel demand. Therefore, using public transportation, walking, or riding a bike are not the best choices. Bus schedules and catchment areas, particularly in cities of developing countries (e.g., Hanoi), may be limited, and there may be a long waiting period. In contrast, active transportation requires significant physical effort and is unsuitable for medium- to long-distance travel, which may result in fatigue and inconvenience for users upon reaching their destinations. Moreover, while students would have a strong sense of self-demonstration, public transport and active transport may be associated with a lower social status [6]. Consequently, students may desire to have a private motorized mode. As a result, pupils could want access to a private motorized mode. Vietnamese cities are not an exception to the numerous empirical studies that have documented students abandoning public transportation in favor of driving or riding motorcycles, which are financially reasonable and suitable for various trips types (i.e., both short- and long-distance trips for recreational and utilitarian purposes) with little difficulty in seeking parking space [4,7,8]. The rising levels of student's desirability to use personal vehicles are undoubtedly concerning for researchers, practitioners, and transportation authorities. The concept of electrifying private motorized modes has gained increasing traction as a response to this issue. While wealthy nations have made significant efforts to encourage the use of electric vehicles on college campuses, developing nations, particularly those that rely heavily on motorbikes, have worked to encourage the use of electric motorcycles among students.

Understanding the factors that influence the choice of a travel mode is essential for proposing effective strategies to encourage its adoption, as it is a fundamental principle. The majority of previous studies on students' preferred modes of transportation have focused on conventional modes including cars, public transportation, and active transportation. There is a lack of understanding regarding the factors that influence the adoption of electric motorcycles. Furthermore, earlier studies have mainly focused on established nations while paying little attention to developing nations.

Hoping to fill the abovementioned gaps in part, this study aims at investigating the influential factors of continuance intention to use electric motorcycles based on an extension of Expectation Confirmation Theory (ECT). Partial Least Squares Structural Equation Modelling (PLS-SEM) and the data of 394 students in Hanoi obtained in August 2022 are used to empirically test the suggested conceptual framework.

The reminder of this paper is structured traditionally. This paper is divided into five sections. Before Section 3 gives a brief overview of techniques for data collection and analysis, Section 2 discusses the ECT constructs and posits research hypotheses. Results and in-depth discussions are presented in the next part. Our conclusions are drawn in the final section.

2. Formulation of Conceptual Framework

The current research focuses on continuation intention, which is the intention to continue utilizing or recycling a system. Yang et al. indicate that an individual who declares a continuing usage for an activity or purpose is said to have a continuation intention [9]. A person is said to have a continuation intention when they express a continued usage for a certain action or goal. Similarly, preparing to decide to acquire a specific good or service from the same business after assessing one's current situation and predicted circumstances is known as a continuation intention or repurchase intention.

According to the review of [10], Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM), and Theory of Reasoned Action are the most often mentioned theories for travel behavior analysis (TRA). However, this article uses ECT, a newly developed theory that has been used to investigate post-purchase behaviors like continuance intention [11–13]. Four constructs - Expectation Confirmation, Perceived Usefulness, Satisfaction, and Behavioral Intention - make up the original version of ECT. We include Perceived Ease of Use to the ECT in order to more thoroughly examine the desire to continue using e-motorcycles. We then analyze the constructs that have been taken into consideration and provide a conceptual framework based on a mix of research hypotheses.

**** Perceived usefulness***

According to Davis's definition [14], perceived usefulness is the extent to which a person thinks employing a specific technology will improve his or her ability to accomplish a job. This is taken from the definition of "useful," which is "able to be used advantageously". According to the Technology Acceptance Model, perceived utility is assumed to influence behavioral intention. The impression of the advantages of using electric vehicles has been demonstrated to have a significant impact on both the intention to use an electric vehicle and the desire to continue using one [15]. According to the original version of ECT, satisfaction is thought to be shaped by perceived usefulness. The user will be happier with a product if it is more useful. The existing study has generally indicated that perceived usefulness directly affects satisfaction and usage continuation intention [16].

**** Satisfaction***

The user's level of state and feeling is satisfied when results from utilizing a product are compared to the user's initial expectations [17]. As a result, satisfaction involves past purchasing patterns. Another way to describe customer satisfaction is their emotional response to a certain product usage experience. Customer happiness has undergone extensive examination in marketing research since it is a crucial antecedent of loyalty. The process of looking for alternatives might start when a customer is unhappy with a service. Numerous contexts, including websites, e-learning services, and transportation, empirically verify the major role of satisfaction to continuance intention [13].

**** Expectation Confirmation***

The user has expectations about the components that make up the product quality that the producer can provide before ever utilizing the product. The user's genuine perception of the product's performance will be formed after utilizing it. According to ECT, a person's happiness is positively impacted by confirmed expectations, which show that person has achieved the expected advantages because of using a good or service. Users can verify their initial expectations by contrasting what they anticipated before and after utilizing the product. The following three scenarios are possible [18]. The user will feel satisfied if their expectation is fully confirmed and their real perception matches them exactly. The confirmation will be favorable, and the user will be thrilled if the real perception exceeds the expectation. In contrast, if the confirmation is negative and the real impression is lower than the expectation, the user would be dissatisfied (disappointed). Prior studies have found higher confirmation and higher levels of satisfaction [17].

Because a product's initial usefulness is not concrete and may be updated continuously based on a comparison between expectations and actual experience, ECT further proposes that perceived usefulness is influenced and adjusted by confirmation expectation. According to [19], users will not value a product's perceived usefulness or convenience if it is not as useful as they previously thought. However, if it is worth more than was anticipated, people will value it (more) highly. The positive link between expectation confirmation and perceived usefulness is well demonstrated [20].

**** Perceived Ease of Use***

Perceived ease of use is defined as how much effort is required to use a particular product [14]. It should be simple to approach or utilize to prevent the user from rejecting a product or service [21]. Numerous research revealed a positive relationship between perceived ease of use and intention to continue. If an electric device's operations are easy to operate, users will be more likely to buy it. Additionally, an easy-to-use and control electric car is regarded as being more beneficial, according to the Technology Acceptance Model. This is acceptable because the user will have to invest a lot of time learning how to utilize each function and appreciate the usefulness at a lower level if they have trouble understanding the functions of each component that will affect the interaction of the vehicle [22].

**** Control variables***

Numerous studies have shown that socio-demographic factors significantly influence the travel mode choice of students. According to a Mexican study, female students are more likely to use public transportation than male students [7]. According to a research carried out in Hanoi [4] older students and those from higher-income families are more likely to move from taking the bus to riding motorcycles. The bus is frequently used by students who reside in urban areas with high street density [23]. Personal characteristics including age, gender, and income can be helpful predictors of intentions to use electric vehicles, as discussed in highly cited reviews of the topic [24,25]. However, the impacts may differ depending on the research environment. So, it stands to reason that the intention to continue using electric motorcycles for students may be influenced by control variables such as gender, age, income, and locality.

**** Conceptual framework***

Eight hypotheses are offered to create the theoretical foundation for this paper based on the discussions outlined above, as follows.

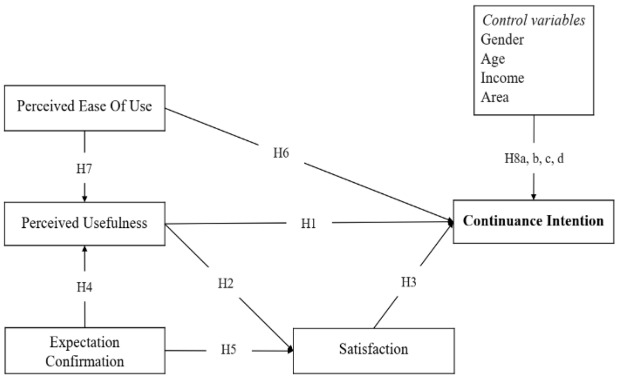

Fig 1. Proposed conceptual framework.

H1. Perceived usefulness is positively associated with continuance intention.

H2. Perceived usefulness is positively associated with satisfaction.

H3. Satisfaction is positively associated with continuance intention.

H4. Expectation confirmation is positively associated with perceived usefulness.

H5. Expectation confirmation is positively associated with satisfaction.

H6. Perceived ease of use is positively associated with continuance intention.

H7. Perceived ease of use is positively associated with perceived usefulness.

H8a, b, c, d. Control variables including gender, age, income, and area are significantly associated with continuance intention.

3. Data and Methods

3.1 Data

A systematic, three-part questionnaire was created in accordance with the conceptual framework outlined in the subsection. An overview of the research was presented in the first section. Participants' sociodemographic information was gathered in the second section, and responses to a variety of attitudinal statements were the subject of the third section. Six items that were modified from [26] were used to measure perceived utility and perceived ease of use. Expectation confirmation and satisfaction were assessed using 6 items modified from [17]. Continuance intention was evaluated utilizing 3 statements based on [17] (see *Table 1*).

Table 1. Indicators of considered constructs.

Code	Indicators
PEOU	***Perceived Ease of Use***
PEOU_1	Learning how to ride e-motorcycles is an easy task
PEOU_2	It is not difficult for me to become skillful at utilizing e-motorcycles
PEOU_3	My interaction with an e-motorcycle does not require much mental effort
PU	***Perceived Usefulness***
PU _1	I can reach almost anywhere by e-motorcycles
PU _2	E-motorcycles can improve my travel efficiency (e.g., saving fuel costs)
PU _3	E-motorcycles can improve my living quality
PU _4	Overall, an e-motorcycle is useful for me
EC	***Expectation Confirmation***
EC_1	My experience with riding my e-motorcycle is better than what I expected
EC_2	The benefits of using an e-motorcycle are more than I expected
EC_3	Overall, most of the expectations from using an e-motorcycle are confirmed
Satis	***Satisfaction***
Satis_1	I believe I make a wise decision on using an e-motorcycle
Satis_2	I am satisfied with my e-motorcycle
Satis_3	I am happy with my choice of e-motorcycle for daily travel
CI	***Continuance Intention***
CI_1	E-motorcycles will continue to be one of the most important modes for my travel
CI_2	I will continue using e-motorcycles
CI_3	I plan to keep using e-motorcycles

The survey was initially written in English before being translated into Vietnamese. To construct the final version, which was utilized for the official poll, certain pilot tests were conducted.

3.2. Survey

Vietnam's capital city of Hanoi served as the site of the data collection for this study. Despite having the second-highest population, the city has the greatest area. Residents primarily utilize bikes for transportation, while the (low) rate of vehicle use rises dramatically [27]. Walking and cycling are infrequent and mostly used for transit to and from school and for recreation [28,29]. Electric motorcycle adoption is on the rise in Hanoi, as demonstrated by Le et al. [30].

Hanoi is an educational center to the north. Nguyen and Pojani [4] investigated how students from Hanoi traveled during the COVID-19 era. However, electric motorcycles were not considered as the study concentrated on assessing factors influencing students' decisions to choose and discontinue using public transportation under the influence of COVID-19.

The widespread use of COVID-19 vaccines has allowed nearly all daily activities in Hanoi to return to normal (as the pre-pandemic time). As a result, we were able to conduct in-person interviews with students. We conducted surveys at Thuongmai University, National University of Civil Engineering, University of Foreign Trade, and University of Transport & Communications to compile a diversified sample. We spoke with students face-to-face throughout our interviews. After completing the survey, each participant received 20,000 VND (about $1) as a token of appreciation for their support. We received 402 responses in total at the survey's conclusion. The final sample of 394 replies, which qualified for testing the suggested framework, was created by removing incomplete and untrustworthy forms.

Table 2. Sample descriptions (N=394).

Variable	Value	Fre.	%
Gender	Male	170	43.15
	Female	224	56.85
Monthly household income	Less than 20 million VND	286	72.59
	≥ 20 million VND	108	27.41
Live in urban districts	Yes	210	53.3
	No	184	46.7
Age		19.604*	1.085**

** refers to mean; ** refers to standard deviation*

Table 2 demonstrates that more female students (57%) were interviewed. The average age was 19.6 (standard deviation: 1.085), with a range of ages between 18 and 23. The majority of participants (about 73%) came from families with lower monthly incomes (under 20 million VND). A little over half of the respondents (53%) resided in metropolitan areas.

3.3. Methods

In academics, structural equation modeling (SEM) has been the method of choice for analyzing conceptual frameworks [31]. Partial Least Squares Structural Equation Modeling (PLS-SEM), an upgraded method of SEM, has recently gained significant popularity among transport experts [32]. PLS-SEM [17] has been employed in a number of earlier investigations that utilized ECT, including this one. For investigations built on extensions of well-known theories, PLS-SEM is strongly advised [33–35]. Thanks to the bootstrapping technique, PLS-SEM has the benefit of not requiring a large sample with a normal distribution [36]. A rule of estimating the minimum size of sample of using PLS-SEM is that the number of observations should be at least equal to 10 times of the maximum number of inner or outer paths to a construct in the framework. Therefore, 394 observations are enough for this investigation. In this study, PLS-SEM was carried out using SmartPLS 3.0, a commercial professional software.

Confirmatory Factor Analysis (CFA) for measurement models and Structural Equation Modeling (SEM) for structural models are the two key tests that make up the PLS-SEM results. The outcomes of these two steps and considerations of influencing factors are presented in the following portion of this study.

4. Results and Discussions

4.1 Results of CFA

CFA is a popular method of factor analysis in social science for determining if measures of a component are consistent with existing understanding of the nature of that construct. To make sure the appropriateness and dependability of CFA results, three criteria must be checked. All indicators' factor loading should be at least 0.708 [37] and Cronbach's Alpha and Composite Reliability should also be at least 0.7 [37]. The average variance extracted must also be greater than 50%. All indicators and constructs met the criteria, as shown in Table 3.

The extracted average variance values needed to be at least 0.5 in order to determine the convergent validity [38]. All identified constructs achieved a satisfactory level of convergent validity, as anticipated.

Table 3. Confirmatory Factor Analysis results.

Variables		**FL**	**CA**	**CR**	**AVE**
Expectation Confirmation	EC_1	0.889	0.858	0.913	0.778
	EC_2	0.876			
	EC_3	0.882			
Continuance Intention	CI_1	0.879	0.860	0.914	0.781
	CI_2	0.866			
	CI_3	0.905			
Perceived Ease of Use	PEOU_1	0.864	0.865	0.917	0.788
	PEOU_2	0.855			
	PEOU_3	0.941			
Satisfaction	Satis_1	0.921	0.886	0.929	0.814
	Satis_2	0.886			
	Satis_3	0.900			
Perceived Usefulness	PU_1	0.764	0.886	0.921	0.746
	PU_2	0.891			
	PU_3	0.881			
	PU_1	0.911			

Using the Fornell-Larcker criterion, the discriminant validity—which considers the degree of statistical difference between two factors—was assessed. As shown in *Table 4*, each latent construct had an AVE that was higher than the values of the inter-construct correlations for both that construct and other measured constructs, indicating good discriminant validity [37].

Table 4. Fornell-Larcker criterion

Variables	CI	EC	PEOU	PU	S
Continuance Intention (CI)	***0.884***				
Expectation Confirmation (EC)	0.733	***0.882***			
Perceived Ease of Use (PEOU)	0.282	0.319	***0.887***		
Perceived Usefulness (PU)	0.723	0.770	0.380	***0.864***	
Satisfaction (S)	0.733	0.669	0.296	0.666	***0.902***

4.2. Results of SEM

The direct effect findings supported hypothesis 1, 2, 3, 4, 5, and 7 *(Fig 2)*. Particularly, continuing intention and satisfaction were both strongly associated with perceived usefulness. While anticipation confirmation aided in perceived utility and satisfaction, satisfaction increased the continuing intention. Hypothesis 6 was rejected because the relationship between perceived ease of use and the continuing intention was minor. Perceived usability was found to strongly contribute to perceived usefulness, as predicted by the hypothesis (H7). The strong connections of continuation with gender, area, and age were found to support hypotheses 8a and 8d, but H8b and H8c were rejected since continuance intention was not influenced by age or income. Living in urban regions and being a woman were associated with lesser continuance intention.

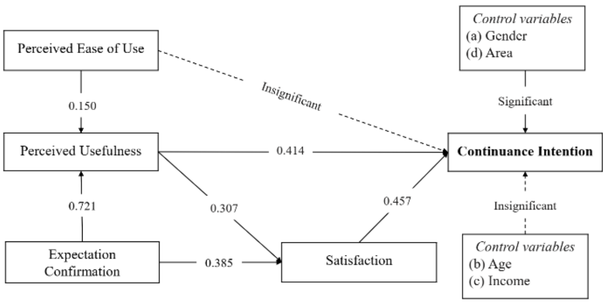

Fig. 2 Results of testing research hypotheses.

Regarding indirect effects, satisfaction played a role in the beneficial influence of perceived usefulness on continuation intention. However, satisfaction and perceived usefulness, served as a complete medium through which the favorable effect of expectation confirmation on the intention was transmitted. Like this, perceived usefulness entirely mediates perceived ease of use's beneficial effect on continuation intention.

Table 5. Results of indirect effects

Paths	**Indirect Effects**		
	β	*Std.*	*p*
PU -> CI	**0.169**	0.053	0.002
EC -> Satis	**0.267**	0.069	0.000
PEOU -> CI	**0.087**	0.032	0.006
EC -> CI	**0.600**	0.048	0.000
PEOU -> Satis	**0.055**	0.023	0.017

The biggest influences on continuation intention, as measured by the sum of direct and indirect effects, were expectation confirmation (β=0.600) and perceived utility (β=0.583). The less significant indicators were perceived ease of use (β=0.087) and contentment (β=0.457).

According to [37], standardized root means square residual (SRMR) and the Normed Fit Index (NFI) were used to evaluate the model's fit. In this study, the NFI value was greater than the cut-off value of 0.823 and the SRMR value was 0.048, which was below the 0.08 threshold. As a result, the suggested framework provided a satisfactory match for the data [39].

This study employed the cross-validated redundancy (Q^2) value and the coefficient of determination (R^2) value to evaluate the structural model's capacity to predict outcomes. The R^2 values for continuing intention, perceived usefulness, and pleasure in Table 6 varied from 0.504 to 0.651, indicating a reasonable level of predictive power (0.5-0.75) [37]. The Q^2 values for these constructions, however, were higher than zero, ranging from 0.403 to 0.496. (i.e., the required minimum level). So, for all endogenous components, the derived model demonstrated respectable predictive relevance [37]. The construct with the greatest values of R^2 and Q^2 was continuation intention.

Table 6. Evaluation of structural equation model.

	R^2	Q^2
Continuance Intention	0.651	0.495
Perceived Usefulness	0.613	0.447
Satisfaction	0.504	0.403
SRMR for model	*0.048*	
NFI for model	*0.823*	

4.3 Discussions and Implications

This article is the first to investigate students' continued intention to utilize electric bikes. The suggested conceptual model based on ECT is appropriate as evidenced by the high-level R^2 value of 0.651 for continuing intention.

This study supported the literature's consistent reporting [26]. Of a positive relationship between perceived usefulness and intention. This article focused on the significance of how existing users now view the usefulness of e-motorcycles for continuing to use this mode since perceived usefulness was determined to be the 2nd largest important element of intention. Expectation confirmation was also shown to be a source of perceived utility. It may be inferred that respondents were more inclined to rate the benefits of e-motorcycles more highly when their expectations were met or even exceeded by practical experience, corroborating earlier results [40].

Perceived ease of use did not directly influence the continuing intention, contrary to our original anticipation and some earlier data [41]. This may be explained since after students rode e-motorcycles and were accustomed to them, they stopped thinking about how easy (or difficult) it would be to use them. Perceived ease of use had a negligible effect, which was consistent with some other studies [22]. Due to a direct positive correlation between perceived ease of use and perceived usefulness, it is interesting to note that the influence of perceived ease of use was mediated on the intention via perceived usefulness. Particularly, the perceived utility of an e-motorcycle increases with the ease with which it may be ridden. This discovery validated the prior report [42].

As predicted, satisfaction was discovered to be a factor in the purpose. It is commonly recognized that having higher levels of satisfaction increases one's likelihood of continuing [17]. According to our research, perceived utility, and expectation fulfillment both contribute to pleasure. As a result, using the advantages and upholding the expectations of e-motorcycles is essential to winning over current users.

Despite just having direct impacts, expectation confirmation was the most powerful predictor of the desire to continue. This suggests that perceived utility and satisfaction, which are two major direct factors influencing continuation intention, are primarily shaped by expectation confirmation.

Even though most of our findings were consistent with earlier theoretical conclusions, it is important to remember that prior to the completion of our study, the literature was unable to confirm the associations between the intention to continue using an e-motorcycle and its perceived usefulness, perceived ease of use, fulfillment of expectations, and satisfaction. As a result, our work has made significant advances in the analysis of green travel mode selection.

We discovered that female students were more likely to have a lower intention to continue using e-motorcycles than their male colleagues. This conclusion came as more or less of a surprise given that women have been found to prefer and utilize electric motorbikes and electric bicycles more frequently [30]. The straightforward design of e-motorcycles, together with the high-level of fashion consciousness among young women, might be one cause [43]. The recent trend of frequently flooded roads in metropolitan areas, which might damage the engines of e-motorcycles, may be to blame for people there having lesser intentions to stay there.

According to the factor-specific results, various policy implications were made to enhance the desire to continue using e-motorcycles. To change how customers see e-motorcycles, the value of these vehicles must be better illustrated. Although practical experience serves as the primary foundation for appraisal, knowledge also matters. In fact, some recent study demonstrates that information might aid in fostering the impression of utility [44]. Short training courses can be created and freely offered to boost the perceived ease of usage. If the promoter wants to increase the number of new e-motorcycle adopters, a product trial (e.g., encouraging students and potential buyers to try e-motorcycle for free) may be a good tactical way.

Manufacturers and merchants should assess user happiness and determine the causes of dissatisfaction. By employing this approach, they can implement strategies to increase satisfaction, thereby boosting users' intention to continue using e-motorcycles.

Understanding user expectations is crucial in addition to evaluating satisfaction. High expectations from consumers regarding e-motorcycles may worsen expectation confirmation and satisfaction. It is important to address this scenario by adjusting consumers' expectations through comprehensive explanations and real-world experiences.

Gender and place of residence should serve as the basis for developing tailored activities and solutions, as they are connected to the primary objective of user retention. For example, since female students and those living in metropolitan areas were more likely to have a low intention to continue, they should receive greater attention.

5. Conclusions

The continuation of student usage of electric bikes is crucial for the development of sustainable urban and transportation systems. According to this study, perceived usefulness, satisfaction, and expectation confirmation all have favorable effects on continuation intention. The objective was inadvertently promoted by perceived usability. Students who live in urban areas appear to have a stronger desire to continue riding electric bikes, but female students are likely to have a lower intention. There have been suggestions for practical applications to encourage the use of e-motorcycles among students.

The current study is one of the first to look at the use of electric motorcycles. It is nonetheless constrained by several factors. First off, while the sample size was sufficient for PLS-SEM analysis, it was not necessarily representative of Hanoi's student body. Second, prior studies have revealed a wide range of influencing factors, many of which were too numerous to be covered in this research, such as perceived risk. Third, the circumstances affect how influential factors behave. The results of this study might not entirely translate to other contexts in this manner. On the basis of the expansion of the study and improved data gathering techniques, more research is thus required.

6. Acknowledgment

The authors would like to give many thanks to the organizers of the ATRANS conference that is a useful avenue for young researchers.

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Facilitators and Barriers to Adopt Electric Motorcycles for Commercial Purposes – A Qualitative Study of Food Delivery Riders in Vietnam

Topic number: 4/6, Paper Identification number: AYRF2023-002

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Abstract

In contrast to the ample literature of utilizing electric vehicles for conventional transportation, the understanding about the influential factors of adopting electric vehicles for commercial purposes has been rather limited. For providing deep insights into the real-world problem regarding accounting for the potential of shifting from conventional motorcycles to e-motorcycles among food delivery riders (FDRs), the present study is conducted qualitatively to reveal both facilitators and deterrents to the FDRs' intention to adopt e-motorcycles in emerging countries. This research relies on the qualitative data collected in in-depth interviews with ten FDRs in Hanoi in May 2023. The findings suggest that the supporting and deterring factors can be divided into 2 groups: a working-related group and a personal group. Working factors refer to the variables that are linked closely to working performances in the stories of FDRs while personal factors involve the individual perceptions and beliefs of the respondents around e-motorcycles but are not linked to the working topic. Although the latter group plays a role, the former one has a stronger effect because (e-)motorcycles are not only a transportation mode but also a working vehicle. As such, in order to persuade FDRs to accept e-motorcycles, it is critical to demonstrate the suitability of e-motorcycles for the technical demands of working purposes and offer more financial support. As well as this, relieving the stigma and improving the social image of this mode are essential. Most importantly, this paper's findings can serve as the literature for formulating the theoretical frameworks to quantitatively explore the determinants of adopting e-motorcycles for professional riders.

Keywords: Electric motorcycles, Food delivery rider, Qualitative, Hanoi, Green logistics

1. Background

Transportation is responsible for a significant contribution to the total greenhouse gas (GHG) emissions over the world. The statistics indicate that transport makes up 16.2% of the global GHGs while road transport accounts for 11.9% [1]. Emissions come from the burning of petrol and diesel from all road modes, including cars, trucks, vans, buses, and motorcycles. There is therefore growing interest in the transition from fossil fuel-powered vehicles to electric alternatives from both academics and practitioners. Among many considered topics related to electric vehicles (e.g., technological advancement in the battery, economic and environmental assessment, safety, development and trends of electric vehicle markets), the acceptance of these modes has been scrutinized in both developed and developing countries because an understanding of the influential factors is critical for the formulation of timely and effective strategies that aim at boosting their popularity, especially where their market share remains minor [2,3]. So far, the greatest amount of scientific effort has been invested in uncovering the supporting and deterring factors of the adoption of electric passenger cars [4,5]. Besides, a large body of the literature focuses on the determinants of two-wheeled vehicles such as e-bicycles and e-motorcycles. More research on the investigation and the use or the intention to use e-bicycles is published as it is seen as an alternative to cycling on medium/long distances with less physical effort required [6]. Another reason is related to the desire to promote the e-bike sharing services in cities [7]. Whereas, studies on e-motorcycles are fewer and most of which have been done in motorcycle-dependent regions such as Taiwan [8,9].

However, the literature on the adoption intention of electric vehicles is imperfect. In fact, the vast majority of existing analyses have based on the responses of conventional people; whereas, as highlighted by Pelletier et al. [10], the potential of electric vehicles for the distribution of goods has received much less attention. To put it another way, in contrast to the emergence of research on green urban/city logistics, research on commercial contexts has been minor. Generally, the shares of e-cars, e-motorcycles, and e-bicycles are insignificant in most parts of the world; meanwhile, electric freight transportation modes such as e-vans and e-trucks are even rarer. A number of technical reports indicate the examples of deployment of electric vehicles for goods distribution, most of which are set in developed economies in Europe and North America with the participation of famous brands and enterprises such as FedEx, Coca-Cola, UPs, Hertz, and Stapes [10]. Developing countries, particularly Asian ones like Vietnam, Malaysia, Taiwan, and China have recently witnessed the proliferation of food delivery services provided by the giant companies such as GrabFood, Dahmakan, LINE Man, and Meituan Waimai [11,12]. As a coin has two sides, besides the ability to reduce shopping and dining trips, the dramatic increase in the number of food delivery motorcyclists has posed new threats to the environment. Hence, encouraging these motorcyclists to use e-motorcycles is increasingly attracting the attention from both researchers and policy makers. To the best of our knowledge, little is known about the potential of switching from conventional motorcycles to e-ones for last-mile delivery in an urban environment. It is important to note that an understanding of the predictors of e-motorcycle use in general can only be transferred to the delivery driver's context to some extent since e-motorcycles for the latter are a working tool rather than a conventional travel mode. Therefore, investigating the factors affecting the intention to accept e-motorcycles as a mode of food delivery for riders is a burning need and a research gap, too.

For a new topic with little extant understanding, qualitative studies are highly recommended to analyze and interpret texts and interviews for discovering meaningful patterns of the relationships between variables [13]. The application of a qualitative approach for this study is sound because it can provide deep insights into the real-world problem regarding accounting for the intention to adopt e-motorcycles among FDRs. The qualitative findings can act as an important starting point for large-scale quantitative analyses.

Based on the above-mentioned discussions, the present study is conducted qualitatively to reveal both facilitators and deterrents to the FDRs' intention to adopt e-motorcycles in emerging countries. This research relies on the qualitative data collected in in-depth interviews with ten FDRs in Hanoi in May 2023.

Compared to conventional riders who only use motorcycles for travelling, FDRs run motorcycles for completing delivery missions. Under the working pressure, FDRs are more likely to engage in risky riding behaviors such as running the red lights, speeding, and neglecting turning signal and thus more inclined to experience crashes and injuries [11]. While FDRs carry food, taxi motorcyclists carry passengers. Based on some previous studies, taxi motorcyclists are less likely to perform risky riding behaviors when transporting a passenger [14].

The rest of this paper is structured as follows. The next part describes the research design, data collection together with analytical methods. Subsequently, results are provided in section 3 before they are discussed in section 4. The last part closes this article with some conclusions and research limitations.

2. Research Design and Methods

2.1 Setting

Vietnam – a South East Asian country shapes S-letter and is divided into three parts: Northern part, Middle part and Southern part. The Hanoi capital is located within the Red River Delta of Northern Vietnam and is the second-largest city (3,359.82 km^2 and 8.33 million persons). Until November 2022, Hanoi has a total of 7.78 million means of transport with 1.06 million cars, 6.54 million motorcycles, and only 0.18 million electric motorcycles. Traffic jams and air pollution in the city are alarming and increasingly complicated [15].

Fig. 1 Delivery riders using conventional motorcycles in Hanoi.

Fig. 2 Delivery riders using electric motorcycles in Hanoi.

The food delivery market in Vietnam has boomed for five years with the competition from enterprises: GrabFood, ShopeeFood, Gojeck, Baemin, Loship, and Ahamove. GrabFood is the leading company that hold the share of about 45% in 2022. The overwhelming majority of FDRs run conventional motorcycles (Figure 1). In line with the recent trend of the use of e-motorcycles, app-based food delivery companies (e.g., Grab and Gojek) have signed pilot contracts with e-motorcycle producers, such as Datbike - a Vietnamese brand. Consequently, a number of FDRs begin utilizing e-motorcycles (Figure 2).

2.2 Survey and Analytical Methods

For gaining a rich understanding of the whys and the wherefores of the acceptance (or not) of e-motorcycles, the data of the present research were based on in-depth face-to-face interviews with FDRs in Hanoi during May 2023. Interviewing is one of the proper data-collection approaches for study on belief, attitudes, and opinions [16]. It is appropriate for measuring the underlying latent factors of the choice for new modes. In-depth interview can enable the collection of sensitive and detailed information because respondents might feel more comfortable to share their thoughts, opinions, and expectations [17].

In order to recruit respondents, we came to department stores to randomly invite FDRs to participate 20-minute interviews within the off-peak (working) time windows (i.e., 8h30-10h30 and 14h00-16h00). The interviews were carried out in relatively private and silent places, such as a restaurant. And they were recorded based on the acceptance from the respondents. During the interview process, a respondent was repeatedly asked for elaborate his/her reasons for choosing and not choosing to switch e-motorcycles. At the end of the interview, his/her background profile were requested. Each respondent was received 50.000 VND (about 2 USD) for their support. Finally, the qualitative data of ten riders were gathered.

As regards the analytical method, we followed [13]. The recordings of interviews were carefully re-listened to make transcripts. Then, notes were added alongside the transcripts in order to create preliminary themes. Subsequently, the transcripts were re-read rigorously to decide the final themes/groups based on the similarities, differences, and frequency within the statements.

As regards the sample's characteristics, Table 1 shows that most FDRs interviewed were male and younger than 30 years old. These age- and sex-based distributions are congruent with the characteristics of delivery rider population in Hanoi [18]. Only a small percentage of those surveyed – 2 out of 10 – were born in Hanoi. The remaining were those who moved to the city from other provinces. The majority of the respondents worked at the medium or (very) high levels. Partly because of being at the age of still going to school, several participants only work as a part-time job. The residence of participants was diversified perhaps because homes or rents in urban areas are typically more expensive not to mention the frequent occurrence of orders outside the urban area. In fact, with a motorcycle, getting from non-urban areas to metropolitan areas for them was not (too) challenging. The survey found that 7 out of 10 respondents were using motorcycles with manual transmission, which is cheaper than automatic ones. Among the 10 participants, two had prior experience in using e-motorcycles as a try (rather than a consistent use). As such, their perceptions and beliefs of e-motorcycles were expected to be insignificantly different from those of the remaining respondents.

Table 1 Sample description

ID	Sex	Age	Born in Hanoi	Working hours per day	Living area	Motor-cycle type
Par_1*	M	19	Y	Low	UB	MT
Par_2	M	25	N	Medium	UB	AT
Par_3	M	44	N	Medium	NU	AT
Par_4	M	20	Y	Low	NU	MT
Par_5*	M	26	N	High	UB	MT
Par_6	M	24	N	Very high	UB	MT
Par_7	M	22	N	Low	UB	MT
Par_8	F	28	N	Medium	UB	AT
Par_9	M	34	N	Very high	NU	MT
Par_10	M	21	N	Medium	NU	MT

*Note: "M"=male; "F"=Female; "Y"=Yes; "N"=No; "Low"=Less than 6 hours; "Medium"= 6-8 hours; "High"= over 8-10 hours; "Very high"= over 10 hours; "UB"= Urban district; "NU"= Non-urban district; "AT"= Automatic transmission; "MT"= Manual transmission; * Refers to the participants who had previous experience in using e-motorcycles but as a try and they currently are using conventional motorcycles.*

3. Results

This section presents the themes or main groups of factors influencing the choice of e-motorcycles for FDRs. We found that there are 2 groups (Fig 3).

- The first group (i.e., working factors) refers to variables that are closely linked to working performances in the stories of FDRs.
- The second group (i.e., personal factors) involves the individual perceptions and beliefs of the respondents around e-motorcycles but are not linked to the working topic.

3.1. Barriers

B1. Working factors

B1.1. Cost

B1.1.1. Purchasing cost

The majority of the FDRs interviewed mentioned that the upfront cost involved in the purchase of an e-motorcycle is a barrier to adoption. In their opinion, the price is excessive given the e-motorcycle's features. They can definitely get a gasoline motorcycle at a lower cost.

> *"As you know, e-motorcycles are too expensive for a beginner like me" - Par_7.*
> *"30 to 40 million VND huh? I think it's worthless. I found it to have no outstanding features. I can buy a gasoline motorcycle that has the similar features and of course with a cheaper price" – Par_4.*

Some respondents indicated that buying a second-hand e-motorcycle is a possible solution; however, they ignored it because the price of an old e-motorcycle is still high, even higher than a conventional one.

> *"I've seen a few second-hand e-motorcycles but its quality was not as expected. And the price is not much lower" – Par_2.*

B1.1.2. Maintenance and repairing cost

Most interviewees said that e-motorcycles are expensive to maintain and repair. Since e-motorcycles allegedly employ "Future Technology", there are not many repairing facilities. And because not all mechanics can work with e-motorcycles, the related cost is typically high. The fact that much equipment for e-motorcycles is imported is another justification offered by the riders. Equipment's price is raised because of this. Despite being so expensive, it is not available.

…"Maintenance and repair fee for e-motorcycles is equal to half of my salary" – Par_1.

B1.2. Limited range

Range refers to the maximum distance that e-motorcycles can travel on one single charge of the battery. It is difficult for the riders to adapt when they are limited to a certain range. They rely on how far the motorcycles ride. To ensure that the running distance is the best possible, they must constantly be thinking and calculating, leading them to feel annoyed. Some riders worry that the range is a barrier to working more.

"100km? Try to think. Every 2 days, I have to charge 4-6 hours to go. Is it more time consuming compared to refueling? And 100km is not enough for me to work 2 days" – Par_10.

B1.3. Performance

B1.3.1. Limited top speed

The participants take much care of the speed because it is closely related to the delivery time. Slow speed means slow delivery time. That's why it affects riders a lot. Especially for FDR, when the speed of the motorcycles has to "race" with the cooling time of the food.

… "Our work requires fast. So I find the speed of the tram sometimes unresponsive."… - Par_4.

B1.3.2. Unreliability

The respondents said that they distrust e-motorcycles because it may not meet the operating figures advertised by the manufacturers. There are instances where e-motorcycles malfunction for no obvious cause and the manufacturer is unable to provide an explanation. This reinforces their perception that e-motorcycles are unreliable.

…"I find that the manufacturer claims that they use anti-bottle battery technology. But I see that many people go for more than a year; the battery has already degraded." – Par_5.

Furthermore, there is no scientific proof that e-motorcycles can run steadily and dependably under intensity high.

B1.3.3. Charging time

The time to charge the battery is another barrier mentioned by FDRs. It is relatively long and if they forget to charge, there is no way work tomorrow.

"I think my memory is good enough to charge the battery daily. And with a long charging time, if I forget charging, I have to pay by a day off. It is really bad!" – Par_10.

B1.3.4. Reduced battery capacity

Battery deterioration with time affects negatively not only the range and the speed but also e-motorcycles' acceleration. The e-motorcycle's dropped acceleration results riders in the impression that it is slowing down and that its engine is no longer as powerful as it once was. Deteriorated batteries can also cause the "virtual battery" phenomena - the screen shows that the battery is still there, but when going, the power is cut off. If this issue arises when they are delivering, it is risky since it affects severely their work and possibly causes traffic accidents.

… "I think e-motorcycles' batteries are the same as cell phone batteries. It will also degrade over time" – Par_5.

B1.4. Limited carriage capacity

FDRs' worries also include carriage capacity. They believe that e-motorcycles' design does not leave enough room for the delivery bag. In addition to food delivery, some riders also take other deliveries or transport passengers. As a result, they consider the design and tonnage of e-motorcycles to be inappropriate for them.

… "You see, such a small design, how many goods can it carry?" – Par_8.

… "I think the motor of an electric motorcycle is not strong enough to carry heavy goods or people. But if it does, it will definitely consume a lot of energy" – Par_6.

B1.5. Lack of safety

The primary fear of safety amongst riders is the nature of battery to explode during an accident/impact or extreme weather conditions causing fire. They are concerned that a battery explosion can occur given the high temperatures (40 to 50 degrees) and the relentless intensity of activity.

... "I think e-motorcycles battery will be like cell phone battery. It may explode if the temperature is too high." – Par_7.

Another safety-related issue indicated was the lack of noise. E-motorcycles are nearly "silent". Therefore, this silence is felt unsafe by users, as the riders does not realise the vehicle's speed unless the driver looks at the speedometer. It is worth noting that riders tend to judge speed using the engine noise as looking at the speedometer is particularly distracting. The lack of noise also makes it difficult for other road users to know their presence. The risk of an unexpected accident is high. Some said that these e-motorcycles are quite heavy (due to the battery) but unstable, so it would be more or less difficult to control when turning, particularly for those using a manual transmission motorcycle.

"E-motorcycles are too silent. Sometimes I don't realize someone is riding beside me." – Par_9.

B2. Personal factors

B2.1. Stigma (manager and co-workers)

According to the responses, there were hardly any transportation companies that entered into contracts with users of e-motorcycles in the past. Currently, companies have some policies for signing contracts with e-motorcycle riders. However, companies seem not to believe in the operation of e-motorcycles.

"Don't believe what the media say. They (business) are just polishing their name. Management will not like you to ride an electric motorcycle because they believe that electric motorcycles are not efficient" – Par_7.

The interviewees also reported that they felt isolated when they went to work. They often have to listen to the disparaging words of their co-workers about their work with e-motorcycles. Their co-workers often talk about the limitations of e-motorcycles and completely deny their strengths in front of them, even though they have explained these characteristics many times.

"Riding an electric motorbike will become a topic of discussion among colleagues around. That is too bad" – Par_8.

B2.2. Social norms

The majority of riders declared to receive advice to purchase a gasoline motorcycle from their significant persons (e.g., family members, friends, and co-workers) when they are considering purchasing a new vehicle.

"When it comes to buying a motorcycle, my family immediately thinks of gasoline motorcycles." – Par_6

B2.3. Poor image

Several respondents said that the "futuristic design" of e-motorcycles is inappropriate for the current context. As such, e-motorcycles has a disadvantage of "technological immaturity". Along with that, the image of electric motorcycles in Vietnam is overly advertised, making them aversions. They contended that the recent growth in e-motorcycle technology cannot be compared to the decades-long evolution of gasoline motorcycles.

"I don't know how people feel. But I see the motorcycle design not beautiful" – Par_2.

B2.4. Environmental unfriendliness

Surprisingly some FDRs asked emphasized the environmental unfriendliness of e-motorcycles. They argued that the process of producing batteries and electricity is not environmentally friendly. So using electric vehicles will indirectly pollute the environment.

"As far as I know, the production process of electric motorcycles is not environmentally friendly at all" – Par_4.

3.2. Facilitators

F1. Working factors

F1.1. Reducing gasoline-dependence

F1.1.1. Gasoline price fluctuation

Nine of ten respondents stated that since the price of electricity is quite stable, they do not need to worry about it. Meanwhile, gasoline prices change unpredictably and are sometimes very expensive. Such gasoline prices make it difficult for them to make a profit. There are instances when the cost of gas is so high that some respondents must take a temporary leave from work.

"Do you remember June last year? The price of gasoline is nearly 30 thousand VND per liter. I go to work without profit" – Par_9.

F1.1.2. Lack of gasoline

Another fuel-related issue, which was also mentioned by the interviewers, is dependence on gasoline. When there is a shortage of gasoline, common issues are a restricted supply to purchase, a 20-30 minute wait in line to purchase, or even no

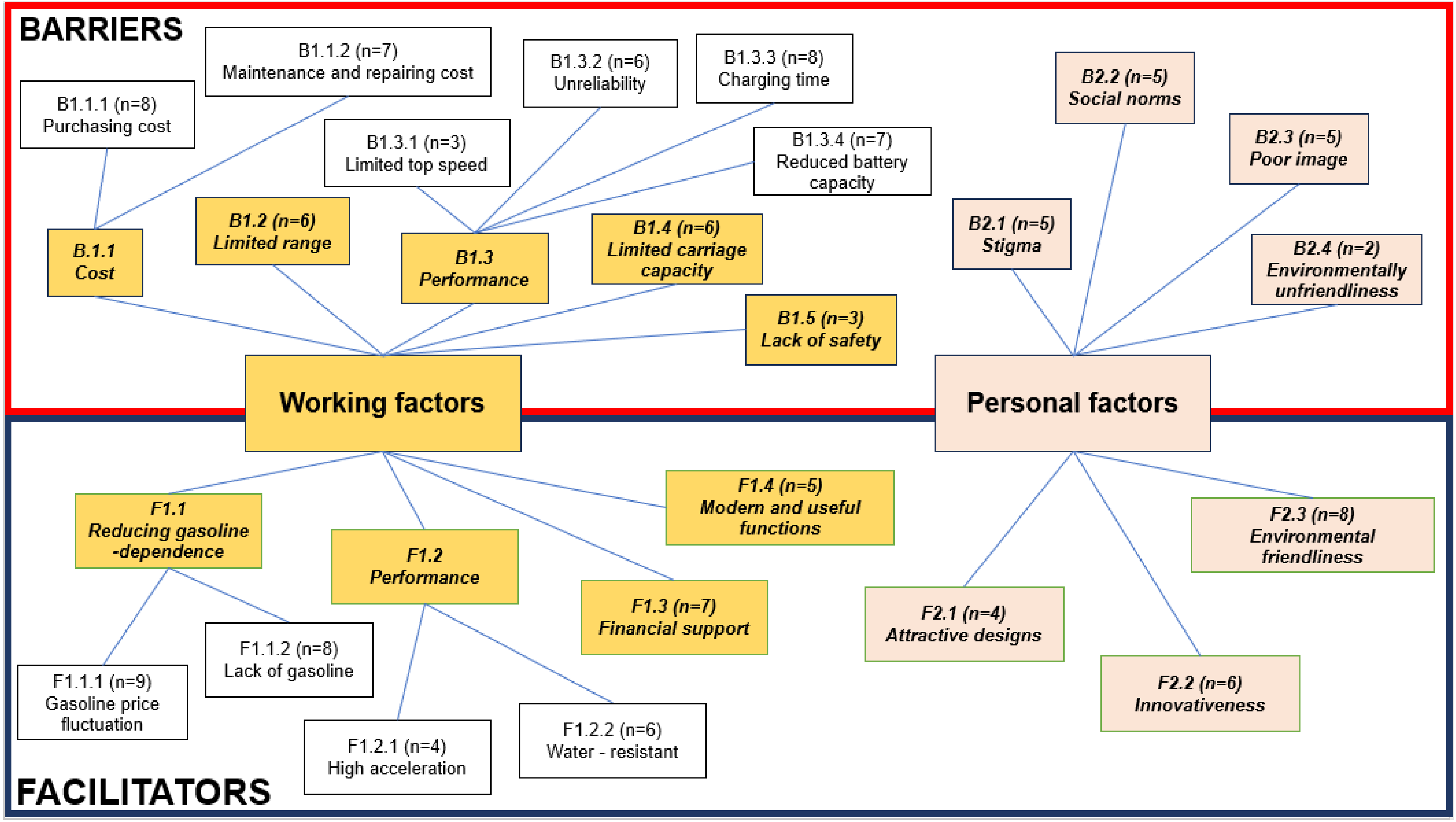

Fig. 3 Graphical results.

longer accessible to purchase. Electricity is not like that; it is available 24/7 and is present everywhere.

"Instead of toiling long hours each week for filling up, now I can charge anywhere there is a power. I also save some money because of it" – Par_5.

F1.2. Performance

F1.2.1. High acceleration

The respondents shared that the acceleration of e-motorcycles is quite high, and they like it. Not only does it help them shorten the delivery time, but it also gives them a sense of excitement when riding.

"Do you know? The acceleration of electric motorcycle helped us pass the green light in the last few seconds. I really like that feeling of being so excited" – Par_1.

F1.2.2. Water-resistant

Some comments emphasized that e-motorcycles can operate in rainy, flooded condition. According to them, this is an outstanding feature of e-motorcycles compared to conventional gasoline-powered cars. This feature helps this vehicle to be able to move in a variety of weather conditions and avoid delays in work.

… "Every time it rains heavily, I have to sit down. If I go into a deep flood, my motorcycle will stall. Whereas my colleague can still work with an e-motorcycle" – Par_7

F1.3. Financial support

From information of the media and some transport companies, FDRs know that some companies have policies to support e-motorcycles riders such as higher unit prices, priority for multiple orders, free equipment support, etc. This makes them excited about switching to electric motorcycles for work.

"Knowing that there are many policies in advance, I will choose to buy an e-motorcycle to work." – Par_4.

"Hum! It looks like there is a policy to support electric riders. I see a few colleagues who run e-motorcycles receive orders on a small range." – Par_6.

F1.4. Modern and useful functions

The respondents acknowledged that e-motorcycles have many modern features comparable to some high-end gasoline motorcycles. Some features, such as smart locks, help them shorten the time it takes to start the car. Or the electronic speed display makes it easy for them to adjust the appropriate speed. Especially, the self-checking feature helps them monitor the e-motorcycle's condition anytime, anywhere, without having to go to the check-up shop regularly. Thereby helping FDRs reduce the cost of periodic inspection.

"I think e-motorcycles have many smart and useful features" – Par_10.

<u>*F2. Personal factors*</u>

F2.1. Attractive designs

Two interviewees commented that knowing the design of some e-motorcycles is outstanding. Make them feel a little bit of attention and attract the eyes of everyone around them. Two others found that some electric motorcycles have the same design as traditional motorcycles. That is why people around them do not recognize or notice them. And they love the feeling too.

"I like the feeling of being noticed when riding an electric motorcycle." – Par_5

F2.2. Innovativeness

Some FDR desire a sense of innovativeness and being different from the people around them. They think that difference and uniqueness will get more attention from employers and customers. From there, they can easily search for more orders. And they believe that in the future, the use of e-motorcycles will become popular. So now, their use of e-motorcycles is said to be ahead of its time and leading the trend.

…. "Among so many motorcyclists, will you notice an electric motorcycle rider like me? I think anyone will notice the prominence." …- Par_8

F2.3. Environmental friendliness

Most respondents said that e-motorcycles do not emit emissions and make no noise. Therefore, riding an e–motorcycle provides a sense of environmental responsibility.

… "As you know, environmental issues are a matter of great concern now. And I think everyone should gradually switch to using electric motorbikes to contribute to

environmental protection and show their environmental responsibility" – Par_8

4. Discussions and Implications

A spike in food delivery services in urban areas, particularly after the COVID-19 pandemic, has raised the serious concerns on the environmental consequences of motorcycle-based carriage. Therefore, the acceptance of e-motorcycles for food couriers is of increasing interest.

This study highlights that riders generally pay assiduous attention to a range of factors through the working and personal views. Perhaps as the motorcycle is a tool to complete tasks to earn money, the working variable group seems to exert more effects – reflected by the number of variables found and the number of indication frequency (Figure 3).

4.1. Working and personal barriers

Consistent with the findings of earlier studies on the influential factors of usage intention of electric vehicles [4,19,20], purchasing cost and technological limitations (i.e., limited range, limited top speed, charging time, and battery capacity) are found to be obstacles to the acceptance of e-motorcycles for FDRs. However, different from conventional persons, FDRs tend to link these disadvantages to the working issues. Among the barriers, purchasing and maintenance cost is the most indicated possibly since most delivery riders are immigrated with a limited budget [21]. Ironically, while having to invest much into a new e-motorcycle, delivery riders may face significant (perceived) risks that limit their working achievements. For example, many delivery riders did not believe in the electric engine's ability to work well and reliably under a high operational pressure of delivery. Besides, the use of an e-motorcycle is in tandem with the adoption of strategies to have sufficient energy for delivering. As such, the working schedule should be steady so that riders do not confront the battery's dead. The increase in working time/distance may be impossible for this reason. The decrease in battery capacity over time can be risky for riders while the workload does not reduce, even increases. The literature shows speeding as a common risky riding behavior of delivery riders [18]; therefore, it is not surprising when some participants claimed the low(er) level of the e-motorcycle's top speed. As professional riders but several respondents show a safety concern related to e-motorcycles. It can be explained that delivery workers tend to adopt illegal riding behaviors (speeding, running in wrong lane/direction) [11]; therefore, they wish other riders to recognize and avoid them actively. Unfortunately, the operation of e-motorcycles might be so silent that others can fail to do so.

Not only working factors, but also personal ones may prevent delivery riders from adopting e-motorcycles. The social pressure is a clear barrier. Notably, delivery riders indicated the limited support from the companies. This would be due to the enterprises' worry on the reduction in productivity and interest when using e-motorcycles. Besides, possibly because of the lack/scarcity of dedicated e-motorcycles for delivery, several participants believe that this mode is currently immature.

4.2. Working and personal facilitators

The two most important motivations are not reliant on gasoline and the potential financial benefits of riding an e-motorcycle. The energy crisis with the lack of and the high price of gasoline has led delivery riders to end up the working interruption and considerably reduced income. In that case, e-motorcycle is considered as a promising solution to solve the gasoline-dependence. Meanwhile, riders also expect to get more money thanks to incentives for using e-motorcycles. Besides, the water-resistant ability together with useful functions of e-motorcycles is appreciated for working continuously (during the raining conditions) and safely.

As expectation, the environmental friendliness of e-motorcycles is mentioned at a high frequency as a facilitator. The sense of innovativeness is a reason for the choice of e-motorcycle, too. These results are in line with many earlier studies on green modes/services [22,23].

4.3. Implications

The current study has offered some novel insights into the facilitators and barriers to the intention to adopt e-motorcycles. Generally, more barriers are indicated at a higher frequency than facilitators. In this sense, the intention to adopt e-motorcycles for food delivery would not be high. The results suggest the importance of the (casual) relationships between (dis)advantages of e-motorcycles and working performances should be considered when carrying out further quantitative studies on the determinants. Perhaps, the combination between a work-specific theory (e.g., Job-Demands Resources) and a well-known behavioral model (e.g., Theory of Planned Behavior or Technology Acceptance Model) can lead to interesting findings. Additionally, the personal factors such as innovativeness or perceived risk should be taken into consideration. As suggested by a reviewer, the consumption value theory may be applied with perceived economic value (cost), perceived functional value (limited range, performance, limited carriage capacity), perceived risk (lack of safety), perceived social value (social norm, stigma, poor image), perceived environmental value (environmental unfriendly/friendly), perceived emotional value (high acceleration).

Although the findings of facilitators and barriers are qualitative, they emphasize the need to provide more financial assistance for FDRs using e-motorcycles. Equally important is the introduction of e-motorcycles that are designed for delivery. By this way, technological concerns can be relieved.

5. Conclusions

In response to the lack of understanding of the determinants of accepting or not accepting a switch from conventional motorcycles to electric ones for the commercial contexts, this study was qualitatively conducted based on the responses of FDRs in Hanoi. The findings suggest that the supporting and deterring factors can be divided into 2 groups: a working-related group and a personal group. Although the latter play a role, the former has a stronger effect because (e-)motorcycles are not only a transportation mode but also a working vehicle. This paper's findings can serve as the literature for formulating the theoretical framework to quantitatively study the determinants of adopting e-motorcycles for FDRs.

The paper is subject to two main limitations. The first is involved in the research subject. Only FDRs were considered while those carrying other goods were out of consideration. Another shortcoming is the sample size. Although the qualitative study does not require a large sample; however, with only ten interviews, we may fail to detect all underlying factors.

6. Acknowledgements

The authors would like to give many thanks to the ATRANS' members for the organization of a useful and interesting avenue for young researchers/students. Appreciation is also given to anonymous reviewer(s) for constructive comments that helped the authors to improve this paper significantly. This study presents the initial results of a research project funded by the University of Transport and Communications, Vietnam regarding the electrification in urban travel.

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Sexual Harassment in Public Transport Among Students in Developing Countries – The Case of Hanoi, Vietnam

Topic number: 2, Paper Identification number: AYRF2023-004

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Abstract

Sexual harassment in public transport is one of a typical gender-based issue that causes the fear for female passengers. In response to this matter, they can quit public transport, leading to the deterioration of gender inequalities and the reduction in ridership. Therefore, the identification of the status of sexual harassment for female users is of interest for both researchers and policy-makers. This study investigates the sexual harassment among female students using the bus services in Hanoi. The students are chosen because they are the main passenger segment and frequently as the victims of sexual harassment while Hanoi has the best bus-based public transport system with over 150 subsidized routes. The finding suggests that the prevalence of SH is high at nearly 40%. Female students have relatively sufficient knowledge on the sexual harassment problem. However, they tend to passively react to this illegal behavior instead of reporting it, even some of which cannot develop extensive avoidance behavior. They also hope there are more protection from the bus providers and the police. When the bus Hanoi is facing the decline in ridership, adopting solutions to address the sexual harassment challenge is essential, at least for retaining and attracting (more) female passengers.

Keywords: Sexual harassment, public transport, bus, Hanoi, female student**.**

1. Introduction

Sexual harassment (SH) is defined as the behavior that makes another person feels psychologically and sexually uncomfortable, that is appraised by the recipient as offensive, and that exceeds one's coping resources or threatens one's well-being [1–3]. This comprises unwanted verbal and non-verbal sexual behaviors, as well as undesirable physical behaviors [4,5]. According to [6]:

Verbal SH includes: making sexual comments, whistling, making kissing sounds, calling one 'honey' or 'sweetheart', asking to have sex, unwanted sexual teasing or remarks, asking personal question about sex life, using obscene, abusive language.

Non-verbal SH includes: unwanted sexual look or gestures, masturbating in public, showing pornographic images, indecent exposure, and stalking.

Physical SH includes: Groping (touching inappropriately), unwanted kissing to a stranger, pulling or playing with one's hair or clothing, sexual assault, and rape.

Generally speaking, SH affects every community and people of all genders, sexual orientations, and ages.

The adverse impacts of SH on both mental and somatic health are obvious and have been documented previously [5,6]. SH often occurs for women at public places particularly in public transport. A study carried out in Bolivia and Colombia reported that 37% of female public transport riders experienced unwanted SH [7]. One of the most common research subjects in the literature is female students who are young thus are most sexually attractive to harassers. A review [8] emphasizes that a substantial percentage of young women (e.g., students) are victimized sexually in most prior studies. Students have limited incomes, thus they depend mostly on public transport such as buses. If harassment is common on the bus, students will be afraid to use the bus as their main means of transportation or at least seek the way to change route selection and time of day of travel [9]. As such, students may have fewer opportunities to travel, study, and exchange knowledge. It is also one of the reasons leading to the increase in social inequality. For bus companies, the stop of using public transport for female students will cause considerable challenge. Another reason for the high frequency of SH for female students is that most of them can still be immature and lack the courage to speak up, and life experience. In reality, this subject will be easier for harassers to handle compared to wise elders [4].

SH does exist in public transport; notwithstanding, its prevalence is usually underreported. Generally, the reasons for it vary across culture and societies. For example, female students feel shamed if others know that they experience SH while some may suffer from hostility when reporting to the police or authorities [10]. A British report indicates four reasons [1].

- The first is normalization wherein victims consider SH as a 'social nuisance' to be tolerated.
- The second is internalization wherein victims desire to escape and forget the incident, or find someone who cares (e.g., friends or relatives).
- The third is the lack of awareness wherein victims are not sure about which behaviors to report, who to report to, or how.
- The fourth is system credibility wherein victims have little faith that reporting will lead to the offenders being caught or sanctioned. Even elsewhere, women have been found to see the police as a threat, fearing being blamed for being harassed. Females might also fear social stigma or scandal for themselves or their families or being at risk of reprisals.

To avoid the risk of SH, victims may make modifications to their trips when they cannot change travel modes due to financial barriers, such as getting off the bus at an earlier stop, moving to a safer position on board, changing vehicles, standing with other women [11]. Young women may choose to use the phone to text or call friends and family as an active approach to alleviate their anxiety of SH [12].

So far, the literature on SH is relatively rich but only in developed countries rather than developing ones. A study set in New York based on 1790 responses of female metro users reported the SH prevalence of 63% and 93% of the victims being female [13]. In another research based in New York City [14], 77% of 140 female students asked were the victims of SH. Also undertaken in the US, a research found that 21% of Washington DC transit riders questioned experienced SH and women were twice as likely as men to be victims. Studies set in the London transit indicated 15-19% of the female respondents are harassed [15]. Conducting a qualitative analysis, Quinones listed the ways in which women experienced SH in Bogota (Colombia) in order to propose a set of policies to tackle the SH issue [11].

This study investigates the prevalence of SH, how female passengers respond to SH and possible consequences of SH in the case of the Hanoi bus, Vietnam. Hanoi is selected because it has the second largest bus system, which is considered the best in Vietnam. SH every now and then is reported and indicated in the press; however, it has never been explored in detail. Notably, recent empirical evidence has found that the fear of SH is a significant factor that encourages female passengers to stop using the bus [16].

The rest of this paper is structured as follows. Section 2 describe the methodology while section 3 provides the results and discussions. The last part closes this paper with some conclusions and research limitations.

2. Methodology

2.1. Questionnaire

A structured questionnaire was designed to collect the data. It was designed with three sections, A, B, and C, specifically:

Section A focused on general information and was divided into two parts: surveying at bus stops and surveying on the bus. In this section, the questions mainly involved the circumstances at the survey location, such as the time, level of crowding, bus capacity, etc.

Section B consisted of questions regarding the respondents' individual information.

Section C included questions aiming to explore the awareness, opinions, experiences, and reactions of the respondents when facing SH.

The questionnaire was created based on the literature. It received some comments from three transport experts at University of Transport and Communications and was tested with five female students before being finalized to use for the official survey.

2.2. Survey

The data collection period spanned from October 18th, 2022, to November 30th, 2022 in Hanoi. Because SH is a sensitive problem for females therefore only the authors who are female undertook the face-to-face interviews at bus stops and on 33 bus routes (Figure 1). Since the likelihood of SH experience is linked to both the peak and off-peak hours, surveys were carried out during four periods: early morning (before 6:30 AM), daytime (6:30 AM to before 6:00 PM), evening/nighttime (6:00 PM to 9:00 PM), and late night (after 9:30 PM). At the end of the survey, 312 forms were completed; however, after eliminating unreliable ones, the final sample encompasses 298 responses valid for further analyses.

Fig. 1 Interviewing female passengers at bus stops and on board.

Out of 298 responses, 218 and 80 responses were collected at bus stops (73.15%) bus routes (26.85%), respectively. Of 218 responses, 88% were gathered at bus stops at urban districts (Figure 2). This is in line with the bus route distribution, which is focused more on urban areas.

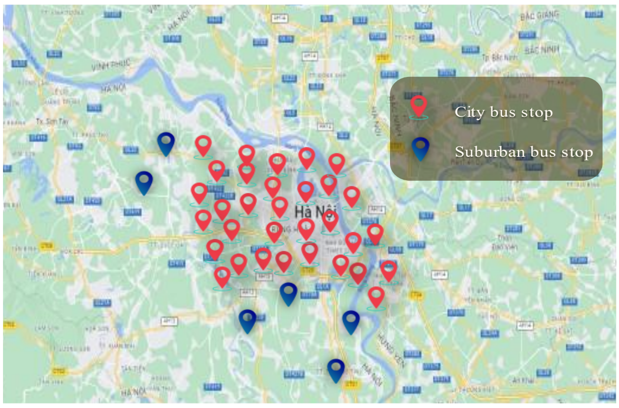

Fig. 2 Locations of surveyed stops.

2.3. Analysis Method

To analyze the data, the simple statistical methods (mainly descriptive) were utilized.

3. Results and Discussions

**** Frequency usage***

According to the data, female students' bus usage frequency was as follows: "A few times a year" accounted for 12.08%, "A few times a month" accounted for 13.76%, "A few days a week" accounted for 25.84%, and ">3 days per week (daily)" accounted for 48.32% (Figure 3). As such, most of interviewed respondents were the frequent users. This is congruent with the previous reports that most students, particularly female ones, use the bus as the frequent transportation mode [8]. In this sense, the results of this study can be representative to the young female passengers in Hanoi more or less.

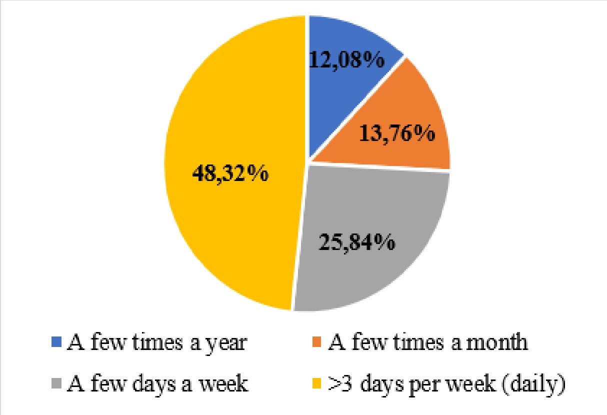

Fig. 3 Frequency of bus use among the respondents.

**** SH awareness***

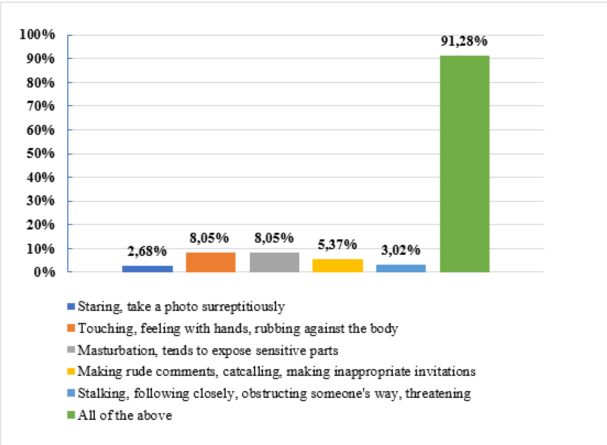

Fig. 4 Perspectives of female students and behaviors that are considered sexual harassment.

In terms of awareness, overall, the female students participating in the research survey demonstrated good knowledge about this issue with a relatively comprehensive understanding of SH and its related behaviors (Figure 3). This was reflected that the vast majority of the respondents selected the option "all of the above," accounting for 91.28%. Specifically, actions such as staring, taking covert photos, or making catcalls were also considered forms of sexual harassment, not necessarily requiring explicit and overt actions like touching, physical contact, or body rubbing. This is a positive point, as previous studies in developing countries like Nepal often overlook these behaviors or do not consider them SH [10].

**** Witnessing SH***

To figure out whether female students witnessed SH when using the bus services within the last 12 months from the time of the survey, the research team designed a specific questionnaire on this issue in relation to three stages: (1) walking to bus stops or from bus stops to the destinations, (2) waiting at bus stops, and (3) on board.

(1) Walking to bus stops or from bus stops to the destinations

The most common SH behaviors, which were seen, were rudely catcalling, whistling, requesting pesonal information with 13.42% witnessing them. Besides, about 10% of the participants caught other female passengers being stared at or secretly photographed. Whereas, there were very few survey participants (1%) catching the act of "Masturbation, exhibitionism" (Figure 5).

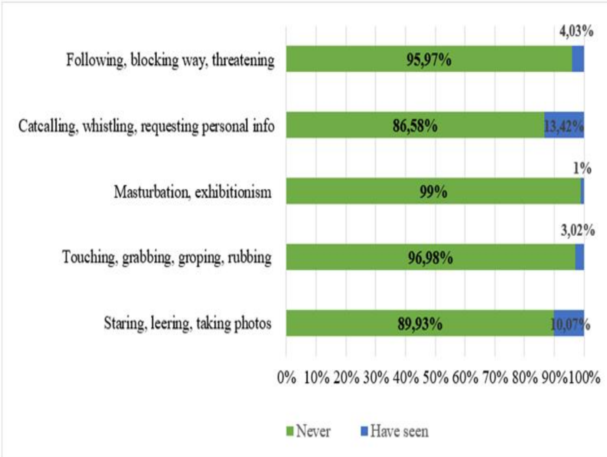

Fig. 5 Percentagse of participants witnessing acts of SH while walking to bus stops or from bus stops to the destinations.

(2) Waiting at bus stops

Similar to the case of walking from/to stops, when it comes to waiting at bus stops, the two most common forms of SH were 'Staring, leering, taking photos' (20.81%) and 'Catcalling, whistling, requesting personal info' (13.42%). However, the percentage of witnessing was higher for almost all behaviors (compared to walking situations). As such, waiting phases would be more risky for female students (Figure 6).

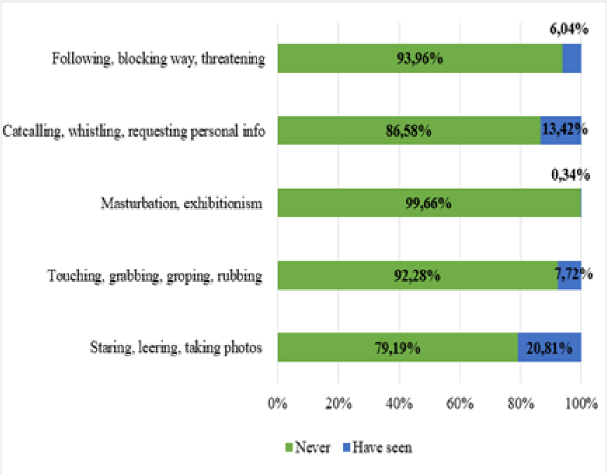

Fig. 6 Percentagse of participants witnessing acts of SH while waiting at bus stops.

(3) On board

The results showed that the rates of seeing SH behaviors on board were higher than those in waiting and walking stages. Notably, nearly 16% of the respondents reported to witness 'touching, grabbing, groping, rubbing' while the figures for the waiting and walking phases were only 7.7% and 3%, respectively (Figure 7).

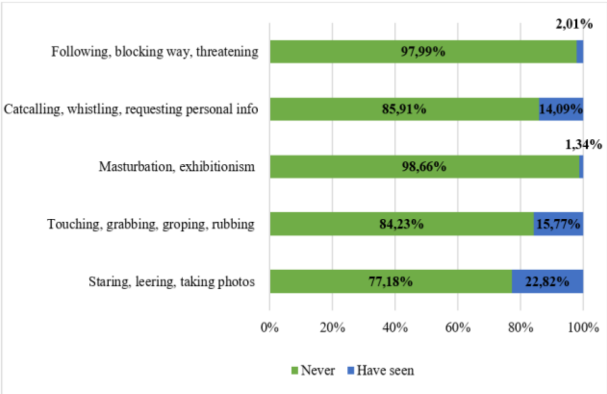

Fig. 7 Percentagse of participants witnessing acts of SH while being on board.

The prevalence of forms of SH highlighted that SH occurred in all phase of bus use, including walking, waiting, and riding. In agreement with previous studies [8], this study found that verbal harassment and non-verbal harassment were the most prominent behaviors while physical harassment was rarer. SH became more prevent with more serious behaviors when the crowd of passengers gathers, particularly in a closed space (i.e., in vehicle). The rate of physical harassment (touching, grabbing, groping, rubbing) was relatively high at 15.77% compared to cities in developed countries [13].

**** Experiencing SH***

The research team continued to delve into the issue of female students being sexually harassed when using bus services within the last 12 months based on three stages : (1) Walking to bus stops or from bus stops to the destinations ; (2) Waiting at bus stops ; (3) On board. Generally, the minor number of respondents reported to experience SH. While this was good news, this result may be under-reported since those who had experienced SH may left the bus. As well as this, female students may hide the experience in SH. As expected, verbal and non-verbal SH were more common and the bus was the most sexual risky for female passengers (Figures 8, 9, 10).

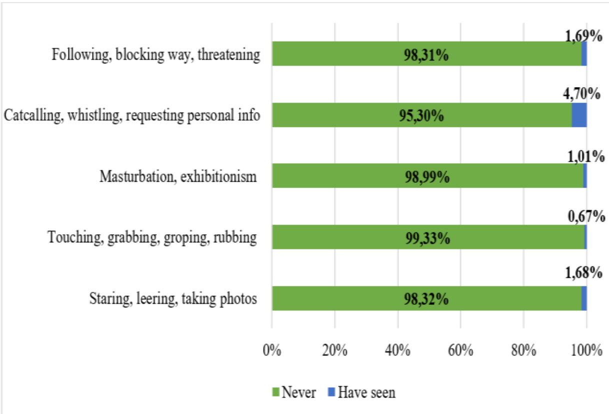

Fig. 8 Percentage of survey respondents experiencing sexual harassment while walking from/to a bus stop.

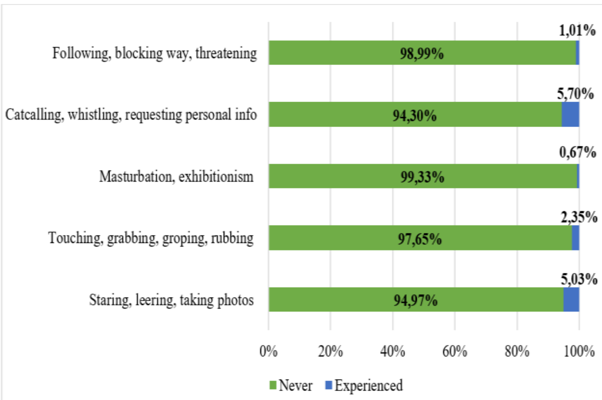

Fig. 9 Percentage of survey respondents experiencing sexual harassment while waiting at bus stop.

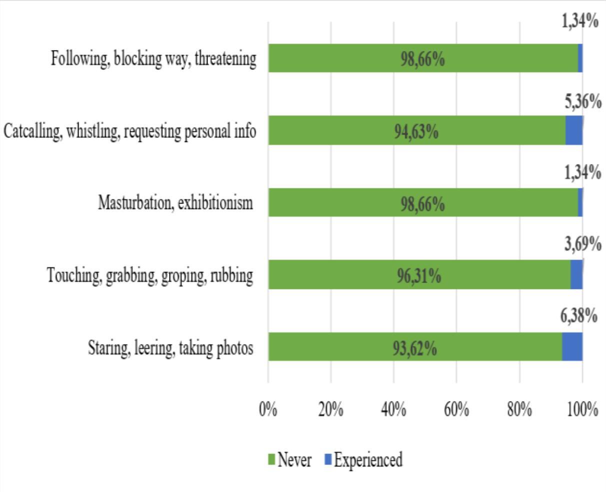

Fig. 10 Percentage of survey respondents experiencing sexual harassment on a bus.

**** Perpetrators***

The research team continued to look at who are perpetrators through asking those who experienced SH during the last 12 months.

A total of 57 people responded that they had had bad experiences at the bus stop and 44 respondents had had unpleasant experiences on the bus, resulting in the prevalence of SH of 33.9%.

Regarding 57 victims of sexual harassment at bus stops, the proportion of people who were harassed by other male passengers and taxi motorcyclists were 38.60% and 35.08% respectively. Additionally, the remaining victims (26.32%) answered that they were harassed by other objects like pedestrians, customers in some street stalls nearby.

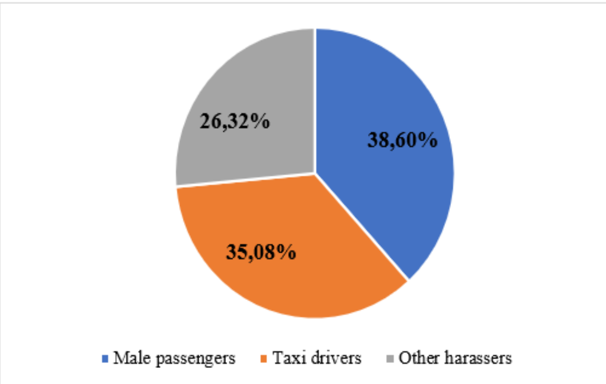

Fig. 11 Harassers at the bus stop

As for 44 people who were harassed on the bus, a vast majority (93.18%) answered that they had bad experiences due to harassing actions of male passengers. Whereas, 6.82% of victims surveyed were harassed by bus staff.

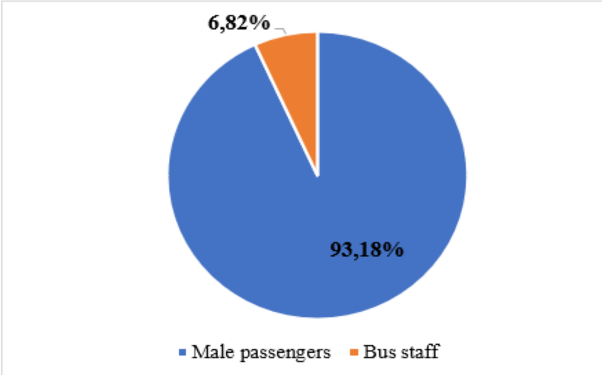

Fig. 12 Harassers on bus

**** Reactions to SH when facing SH***

The research group further inquired about the respondents' responses when facing harassment on public transportation, and the results were as follows (Figure 10). Similar to [11], this study found that changing locations is the most common reaction. This activity may lead to the leave of the bus if a respondent cannot find a safe place. Some participants (13.64%) reported verbal reactions. This way is expected to work well if other passengers and/or bus staff also have an effect, such as forcing the perpetrator out of the vehicle [4]. However, observers may choose to be silent, leading the victim to be in a more dangerous situation. The participants choosing physically confronting the harasser made up only 4.5%. Meanwhile, nearly 20% of the respondents opted to do nothing, perhaps because of the normalization of SH behavior or the fear. No one try to report the incident to the police while about 18% thought the support from the bus staff.

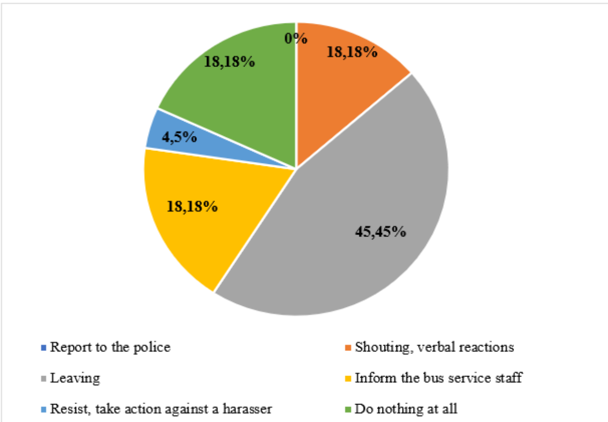

Fig. 13 Victim's reactions to harassment.

(Perceived) Reasons for SH

The research team also explored the opinions of the participants regarding the reasons for SH in public transportation. The majority of survey participants believed that the reasons victims encountered sexual harassment while using bus services were primarily due to "Traveling alone" (23.15% of respondents "Strongly agreed", and 50.34% "Agreed") (Figure 11). Following that, "Not knowing how to recognize and avoid harassers or not knowing how to protect oneself" was considered a clearly contributing factor too (22.82% "Strongly agreed," and 35.57% "Agreed"). Similar percentages were seen for "Wearing provocative clothing" (20.81% "Strongly agreeing" and 36.24% "Agreeing") and "Using phone, texting, reading books" (15.44% "Strongly agreeing" and 34.25% "Agreeing"). Finally, a very small number of respondents believed that "Wearing excessive or heavy makeup" was one of the causes for victims being sexually harassed (5.37% "Strongly agreeing" and 9.06% "Agreeing").

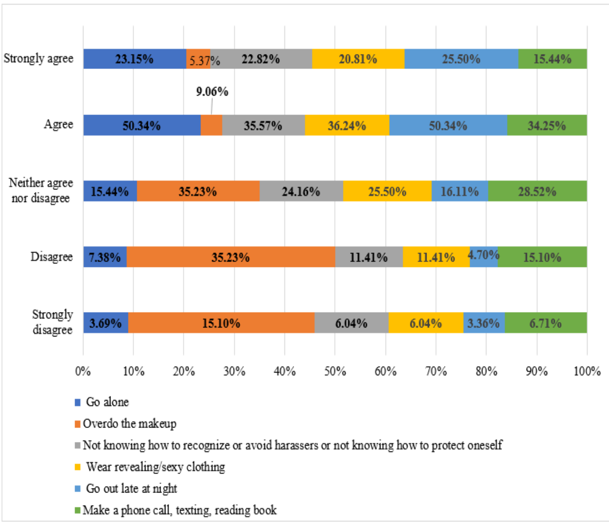

Fig. 14 Opinions of survey participants on the causes of victims of sexual harassment when using public bus services.

While the reasons mentioned above would right in terms of offering opportunities or attracting the attention from bad persons, it is critical to state that the responsibility of being harassed is blamed for female passengers – either potential or actual victims. As such, the gender inequality becomes more serious. Moreover, due to these opinions on the reasons for SH, women may have to formulate solutions to SH, which reduce the comfort and convenience when using the bus. As a consequence, female passengers are likely to leave public transport services.

(Perceived) Efforts of addressing SH

The research group further presented statements to explore the (dis)agreement among female students with the efforts of preventing SH. The results revealed that only less than 30% of participants thought the bus providers have sufficient approaches to protect female passengers from SH (Figure 12). The belief in the support of others would also be limited with around 40% agreeing that the police and other riders may help when SH occurred. While these results were only the perception of female riders, they can serve as an empirical evidence of the poor support and protection from the public and authorities for female passengers. This would be the shared phenomena in developing countries. Unsurprisingly, the family was considered the most reliable place and persons when female passengers were at risk of SH.

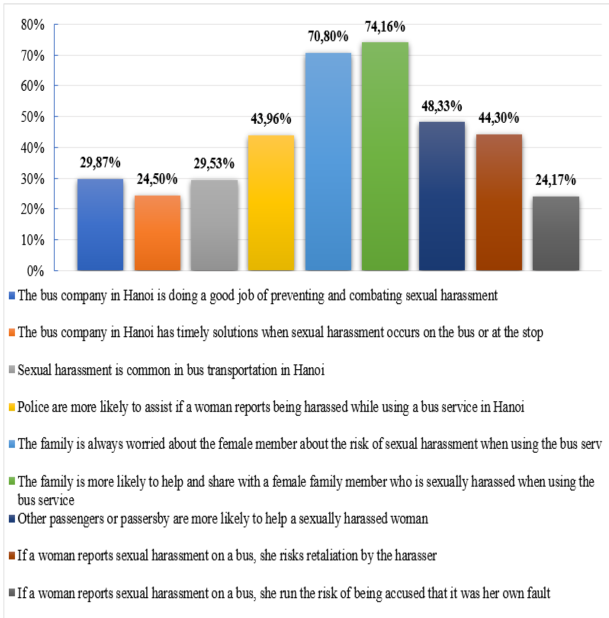

Fig. 15 Perceived current efforts to limit SH.

4. Conclusions

SH is an increasing problem for the sustainable development of public transport in Hanoi because it is a significant factor that encourages female students leave the bus [16]. Unfortunately, the understandings of the status of SH is rather limited. In response to this gap, the current paper investigates and reports SH in the bus system based on the data from nearly 300 female users. The main finding is SH does exist with the prevalence of over

33.9% (based on the respondents' experience in different SH forms). While most of SH behaviors were verbal and non-verbal, physical SH was recorded, particularly at a high level on board. Female students have good knowledge on SH; however, a significant proportion of those asked did not have effective solutions when facing SH. This would be attributable to the limited belief in the support of the police, other riders, and the police. As such, transport authorities and the bus providers should adopt more protections for female users.

The study is carefully designed and implemented; notwithstanding, limitations are unavoidable. The first shortcoming is the focus only on female students, leading to a question on the SH practice for other female passengers. The second weakness is the lack of measuring the details of SH incident (e.g., place, time, status of environment when SH occurs), resulting in the impossibility of conduct in-depth statistical analysis. All of findings of the present paper are only descriptive. Thirdly, the present study only consider SH during the last 12 months while some previous studies focused on the SH during 36 months. Hence, the comparison of SH prevalence should be conducted carefully. Finally, this is a study of Hanoi alone; therefore, it is relatively subjective to conclude the status of SH there. It would be interesting to do a comparative research between Hanoi and other cities (in different countries). All the afore-said limitations are the suggestions for future authors when thinking about the topic of SH in public transport.

5. Acknowledgment

The ATRANS conference is a fantastic opportunity for young researchers; hence, the authors would like to show their sincere gratitude to the organizers. The paper presents the results of a student-level research project conducted by the students from University of Transport and Communications.

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External Human Machine Interfaces between Autonomous Shuttle Bus and Pedestrians in Road Crossing Scenario

Topic number: 4, Paper Identification number: AYRF2023-015
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Abstract

During the encounter of pedestrians and autonomous vehicles (AVs) in the road crossing scenario, communication between pedestrians and AVs has become one of many very important challenges for AV developers. The traditional communication methods, such as hand signals and eye contact, may not be effective with AVs as they do not need drivers. Therefore, researchers are developing eHMI (External human-machine interfaces) to facilitate communication between pedestrians and AVs. However, the eHMI has not been standardized. This research aims to develop an eHMI concept focusing on the eHMI for autonomous shuttle buses to help pedestrians to understand the intentions of the AVs. The eHMI features include text messages ("WALK" and "CROSS"), symbols (people symbol and arrows symbol), and colors (white and green). The scenario involves a pedestrian at the road crossing with an autonomous shuttle bus displaying eHMI approaching. The scenario was simulated in the CARLA simulator then the understanding time of pedestrians was collected and then analyzed. The results show that green, "WALK", and pedestrian symbol were faster understood by the pedestrian. And, the combination of the pedestrian symbol and "WALK" gave the fastest understood time among all scenarios.

Keywords: Autonomous vehicles, External human-machine interfaces, Pedestrian-vehicle interaction, vulnerable road users

1. Introduction

During rush hours, people commonly commute by the mass transit system, but the mass transit system could not transport passengers on a door-to-door basis. Therefore, the passengers need to use other methods of commuting to reach their destination, walking is one of them. Hence, with the widely developing of autonomous vehicles, the developers need to develop the feature to ensure the safety of the autonomous vehicle and vulnerable road users. Regarding pedestrian safety, conventional communication is between the pedestrian and the driver of the vehicle, however, the communication between the high-level autonomous vehicle and pedestrian would not be present because of lacking a driver.

In that regard, this research would like to propose the external human-machine interface, which is a tool to help the vehicle to communicate with the pedestrian. The eHMI concept was developed for the pedestrian at the road crossing to help the pedestrian to understand the intention of the autonomous vehicle by comparing many features of the eHMI and comparing with the combined feature.

2. Literature Review

Regarding the wide development of autonomous vehicles, one of the key purposes of using autonomous vehicles is to address human error while driving and wish to decrease road casualty caused by human error. The high-level autonomous vehicles do not need the driver, therefore, causing a lack of communication between the driver and pedestrian. The understanding of the vehicle intention will reduce the risk of the pedestrian, which is 23% of the casualty of the road accident reported by the world health organization. The study shows that pedestrians could make a decision faster and feel safer if the vehicle communicates with them [1]. The conventional communication method is unofficial communication such as waving hands, facial expressions, and eye contact [2]. The high-level autonomous vehicles could not communicate with the conventional method. Therefore, the communication method for the high-level autonomous vehicle is needed to be developed.

In the past years, eHMI development has become one of the focus research topics. There were many features of eHMI have been proposed such as audio [3], frontal green light strip [4], artificial facial expression [5], and colors strip [6]. In addition, the research found that the different sizes of the objects approaching human cause the different anxious levels in the human. The bigger objects cause more anxiety levels than the smaller objects. Hence, the mass transit system usually uses bigger vehicle types such as buses. If there is an autonomous bus, the eHMI should be implemented to reduce anxiety levels and the risk to the pedestrian.

3. Research Methodology

3.1 Sample Group

In the context of evaluating various eHMI designs in terms of time requirements, the sample group is carefully chosen to stand for the typical road users, ensuring an unbiased outcome of the experiments. The sample group consisted of 100 people who carried out the experiments. It was separated by age and the driving license (Table 1.) because there are studies concluded that the age of a sample and the knowledge of traffic laws affect the understanding of eHMI [8, 9]. Participants must pass the survey to ensure their comprehension of the eHMI text message, confirm absence of colorblindness, and verify lack of knowledge about autonomous vehicles.

Table 1 The sample group details.

Type	Detail	Participants
Gender	Male	50
	Female	50
Age	18 – 30	25
	31 – 45	25
	46 – 60	25
	> 60	25
Driving license	Own	52
	Not own	48

3.2 Experimental Scenario

The participant took the experiments one at a time by watching the series of videos that the autonomous shuttle bus approaching the road crossing. The series of videos includes, 16 scenarios with the autonomous shuttle approaching the road crossing with a different eHMI and then stopping at the road crossing, 1 scenario with the autonomous shuttle approaching the road crossing without eHMI and then stopping at the road at, and 3 scenarios with the autonomous shuttle approaching the road crossing without eHMI and does not stop at the road crossing.

The videos were created using CARLA simulator. The simulation simulates an urban road with 2 lanes road and a road crossing. The autonomous vehicle was simulated using a bus drive automatically via CARLA api. The vehicle starts with constant velocity at 30 km/hr. traveling along the road for 1.8 seconds, then the vehicle shows eHMI and decelerates for 4.2 seconds until stop at the road crossing, with deceleration not more than 2 m/s2 which is within the normal driving zone [11], finally, the vehicle stops for 3 seconds (Fig. 1). The participant was simulated to have a vision of 1 meter from the road curb and a height of 1.65 meters looking at the approaching vehicle. The simulations were recorded from the simulated participant view with 1920 x 1080 @ 60 fps video format (Fig.2).

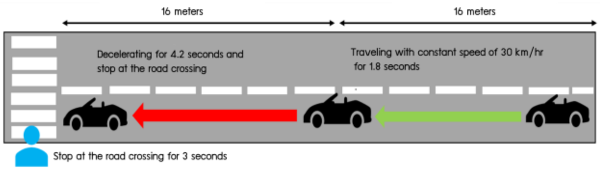

Fig.1 Simulation Scenario

Fig.2 Simulation Scenario Video

The experiments were carried out at the Smart Mobility Research Center, Chulalongkorn University, with 24 inches 1920 x 1080 resolution monitor. The participants were seated 70 centimeters away from the monitor and looked perpendicular to the monitor [10]. The experiments were carried out without any disturbance (Fig.3). After starting the experiment, the participants were asked to press the button when understanding the intention of the autonomous vehicle.

Fig.3 A participant during the experiment

3.3 eHMI Design

The design uses green and white colors, which are the 2 most occurrent colors in eHMI design [12], "WALK" and "CROSS" text messages [13, 14], and pedestrian and arrow symbols [15,16]. The eHMI designs that were used in the experiments are green and white text message, green and white symbol, and green and white combined text and symbol (Fig.4)

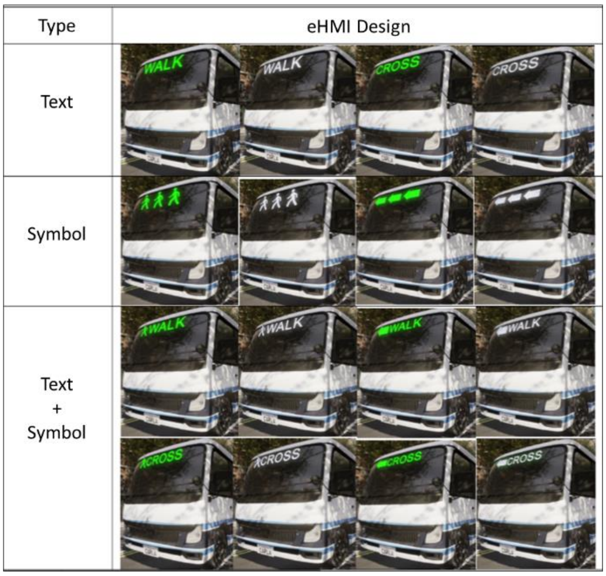

Fig.4 eHMI designs that were used in the experiments.

3.3 Data Collecting

The collected data were a time when the participants first understood the intention of the autonomous vehicle. The mean and standard deviation were calculated to determine the design that the participants understood the fastest. The T-test was used to find the significant differentiation of the design. The p values were used to compare the difference between of the similar design.

4. Experimental Results

The overall results of the experiments show that the eHMI improves the time of understanding of the pedestrian, as shown in Fig.5. Table 2 shows the mean and standard deviation of the response time of the experiment. The results show that the eHMI significantly improve the understanding time of the pedestrian comparing with the vehicle without eHMI.

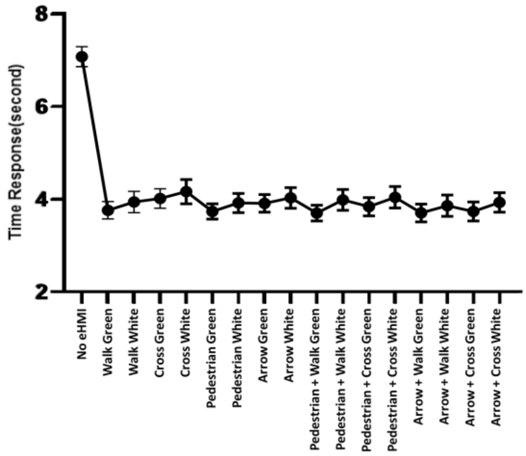

Fig.5 Box plot of the experimental results.

Table 2 Mean and standard deviation of the experiment

eHMI Design			Mean	S.D.
Color	Text	Symbol		
-	-	-	7.07	1.08
Green	Walk	-	3.76	0.94
White	Walk	-	3.94	1.15
Green	Cross	-	4.01	1.06
White	Cross	-	4.16	1.31
Green	-	Pedestrian	3.73	0.84
White	-	Pedestrian	3.92	1.04
Green	-	Arrow	3.91	0.96
White	-	Arrow	4.03	1.22
Green	Walk	Pedestrian	3.61	0.72
White	Walk	Pedestrian	3.89	1.06
Green	Cross	Pedestrian	3.84	0.98
White	Cross	Pedestrian	4.04	1.17
Green	Walk	Arrow	3.71	0.97
White	Walk	Arrow	3.86	1.16
Green	Cross	Arrow	3.73	1.04
White	Cross	Arrow	3.93	1.07

4.1 Colors Comparison

This section compares the result of the eHMI with different colors (i.e., green and white). The result shows that every eHMI designs with green color show a lower understanding time than the eHMI design with white color, as shown in Fig. 6 and Table 3.

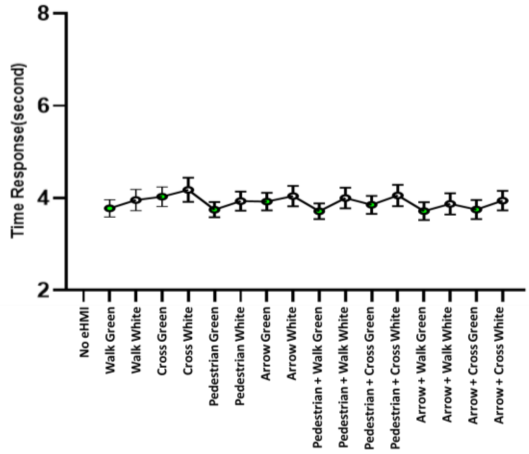

Fig.6 Box plot of the color comparison.

Table 3 Mean and standard deviation the color comparison.

eHMI Design			Mean	S.D.
Color	Text	Symbol		
Green	Walk	-	3.76	0.94
White	Walk	-	4.01	1.15
Green	Cross	-	3.94	1.06
White	Cross	-	4.16	1.31
Green	-	Pedestrian	3.73	0.84
White	-	Pedestrian	3.92	0.96
Green	-	Arrow	3.91	0.96
White	-	Arrow	4.03	1.22
Green	Walk	Pedestrian	3.61	0.72
White	Walk	Pedestrian	3.89	1.06
Green	Cross	Pedestrian	3.84	0.98
White	Cross	Pedestrian	4.04	1.17
Green	Walk	Arrow	3.71	0.97
White	Walk	Arrow	3.86	1.16
Green	Cross	Arrow	3.73	1.04
White	Cross	Arrow	3.93	1.07

4.2 Texts Comparison

This section compares the result of the eHMI with different texts (i.e., WALK and CROSS), however not include the combined designs. The result shows that eHMI designs with WALK show a lower understanding time than the eHMI design with CROSS, as shown in Fig. 7 and Table 4.

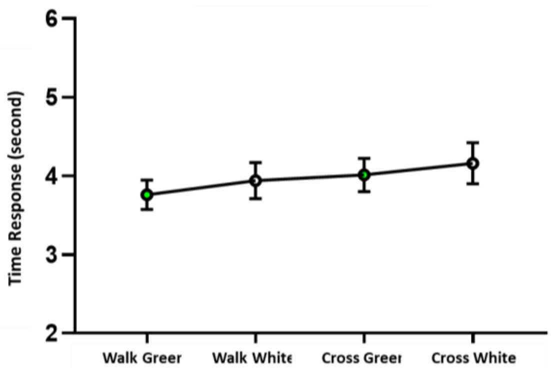

Fig.7 Box plot of the texts' comparison

Table 4 Mean and standard deviation the texts comparison.

eHMI Design		Mean	S.D.	T	P*
Color	Text				
Green	Walk	3.76	0.94	1.78	0.0768
Green	Cross	4.01	1.06		
White	Walk	3.94	0.84	12.6	0.1679
White	Cross	4.16	0.96		

* If P < 0.05 the designs are significant difference

4.3 Symbols Comparison

This section compares the result of the eHMI with different symbols (i.e., Pedestrian and Arrow), however not include the combined designs. The result shows that eHMI designs with pedestrian symbol show a lower understanding time than the eHMI design with arrow symbol, as shown in Fig. 8 and Table 5.

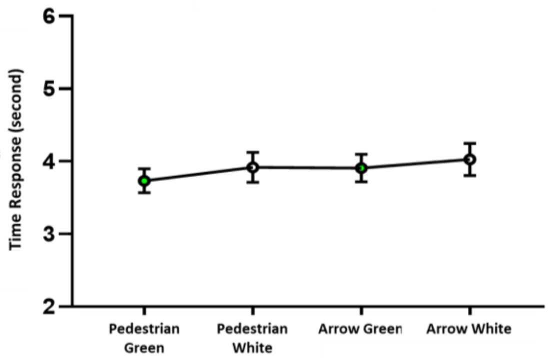

Fig.8 Box plot of the symbols' comparison

Table 5 Mean and standard deviation the symbols comparison.

eHMI Design		Mean	S.D.	T	P*
Color	Symbol				
Green	Pedestrian	3.73	0.84	1.38	0.1678
Green	Arrow	3.91	0.96		
White	Pedestrian	3.92	1.04	0.71	0.4788
White	Arrow	4.03	1.11		

* If P < 0.05 the designs are significant difference

4.4 Combined Design Comparison

This section compares the result of the eHMI with different combined design (i.e., Green Pedestrian WALK, Green Pedestrian CROSS, Green Arrow WALK, Green Arrow CROSS, White Pedestrian WALK, White Pedestrian CROSS, White Arrow WALK, and White Arrow CROSS), The result shows that eHMI designs with Green Pedestrian WALK show the lowest understanding time, as shown in Fig. 9 and Table 6.

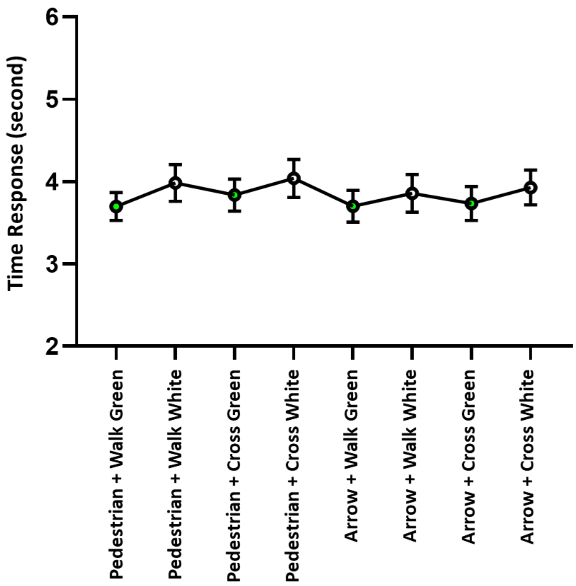

Fig.9 Box plot of the combined design comparison

If we compare the understanding time of all designs, we found that the eHMI design with Green Pedestrian WALK have the lowest understanding time.

5. Conclusion and Recommendations

5.1 Conclusions

This study has the objective of studying the pedestrian's understanding time to the eHMI that tell the pedestrian to cross the road by considering different features of eHMI such as colors, texts, symbols, and combined design. The result shows that the difference of the feature does not show a significant improvement. However, the existence of eHMI significantly improves the pedestrian understanding time.

In terms of color, the green color provides lower understanding time because the green represents the allowance. On the other hand, the white color represents neutrality. However, there are not significantly different. Both green and white color could be used to show the allowance to the pedestrian. Nevertheless, green color would perform better.

Table 7 The order of eHMI design from the lowest to the highest.

eHMI Design			Mean	S.D.
Color	Text	Symbol		
Green	Walk	Pedestrian	3.61	0.72
Green	Walk	Arrow	3.71	0.97
Green	-	Pedestrian	3.73	0.84
Green	Cross	Arrow	3.73	1.04
Green	Walk	-	3.76	0.94
Green	Cross	Pedestrian	3.84	0.98
White	Walk	Arrow	3.86	1.16
White	Walk	Pedestrian	3.89	1.06
Green	-	Arrow	3.91	0.96
White	-	Pedestrian	3.92	1.04
White	Cross	Arrow	3.93	1.07
White	Walk	-	3.94	1.15
Green	Cross	-	4.01	1.06
White	-	Arrow	4.03	1.22
White	Cross	Pedestrian	4.04	1.17
White	Cross	-	4.16	1.31
-	-	-	7.07	1.08

There is not a significant difference in term of text. However, the text WALK performs slightly better than the text CROSS.

Table 6 Mean and standard deviation the combined design comparison.

eHMI Design			Mean	S.D.	T	P*
Color	Text	Symbol				
Green	Walk	Pedestrian	3.61	0.72	1.41	0.1617
Green	Cross	Pedestrian	3.84	0.98		
Green	Walk	Arrow	3.71	0.97	0.22	0.824
Green	Cross	Arrow	3.73	1.04		
Green	Walk	Pedestrian	3.61	0.72	0.79	0.4334
Green	Walk	Arrow	3.71	0.97		
Green	Cross	Pedestrian	3.84	0.98	0.71	0.4761
Green	Cross	Arrow	3.73	1.04		
White	Walk	Pedestrian	3.89	1.06	0.72	0.4709
White	Cross	Pedestrian	4.04	1.17		
White	Walk	Arrow	3.86	1.16	0.44	0.6569
White	Cross	Arrow	3.93	1.07		
White	Walk	Pedestrian	3.89	1.06	0.23	0.8187
White	Walk	Arrow	3.86	1.16		
White	Cross	Pedestrian	4.04	1.17	0.7	0.4842
White	Cross	Arrow	3.93	1.07		

* If $P < 0.05$ the designs are significant difference

In terms of the symbols, the pedestrian symbol performs better because the symbol has a similarity to the traffic sign. On the other hand, the arrow might confuse the pedestrian between the vehicle allowing the pedestrian to cross and the vehicle would like to turn in the arrow direction

The best perform combined design has the combination of the best performance of the previous feature, therefore, the green pedestrian WALK design has the best performance of all designs.

5.2 Recommendations

This research could be used as a guideline for eHMI design for heavy vehicles. However, there were com recommendations to be concerned.

- The text feature WALK and CROSS could be used. However, the design should survey for the understanding of the work in the area where the vehicles would be operated.\
- If the designer chooses the symbols as an eHMI feature, the symbols that are similar to the traffic sign will perform better because of the familiarity of the pedestrian with the traffic sign.
- This study recommends using a combined design. The combined design help to ensure the intention of the vehicles.
- If the designer wants to use the results for the widely conventional of widely operated vehicle, the designer should carry out the experiment with a sample group that could represent the whole population.

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Development of Decision-Making and Local Planning for Autonomous Vehicle to Mitigate Pedestrian Crash

Topic number: 4, Paper Identification number: AYRF2023-016

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Abstract

Nowadays, accidents that occur in Thailand include vehicle to vehicle, vehicle to motorcycle and pedestrian to vehicle. And accidents between pedestrians and vehicle can be life-threatening violence, most of such accidents occur on Jaywalk. Autonomous vehicle (AV) has come to reduce the accidents that occur. Many developers and researchers are interested to develop Autonomous vehicle in decision-making, perception or path planning too. In this paper we are interested to develop decision-making system of autonomous vehicle in scenario of crossing on jaywalk of pedestrian while there was an obstacle vehicle on the shoulder of the road, by using Time-To-Collision (TTC) and Time-To-Brake (TTB) are criteria of decision. If TTB is less than TTC, autonomous vehicle decides to brake, but TTB is more than TTC, autonomous vehicle decides to avoidance. In the results section, we show the simulation results that our algorithm can actually reduce the collision and the risk of such scenario. In the last section is the experiments section, part to confirm the results from simulation.

Keywords: Autonomous vehicle, Pedestrian, Decision-making, Obstacle vehicle

1. Introduction

With pedestrian accidents ranking as one of the most common types of road incidents, it has become crucial to enhance safety measures. As technology advances and third-level autonomous vehicles become a reality, the decision-making process becomes a critical aspect. Unlike humans, autonomous vehicles lack the ability to make instant decisions based on past experiences. Therefore, developing sophisticated decision-making capabilities within autonomous vehicles is essential to reduce accidents involving pedestrians.

This research focuses on creating a Level-3 Low-speed Autonomous Shuttle, designed for low-speed shuttles. Its main goal is to assist in decision-making when the autonomous vehicle encounters a pedestrian crossing the road in front of a parked vehicle. Instead of developing the perception part of the vehicle, the research utilizes data from the perception system to inform the decision-making process.

Throughout this paper, we will explore relevant literature, explain the methodology used, present the results obtained, and engage in a comprehensive discussion. By addressing the challenges of pedestrian accidents and empowering autonomous vehicles with improved decision-making abilities, we can create a safer and more efficient transportation environment.

2. Literature Review

The fundamental components of the autonomous vehicle system, as summarized by Shinpei Kato and colleagues, consist of three parts: 1. Sensing, which involves perceiving the external environment. 2. Computing, which encompasses various calculations and processing tasks. 3. Actuation, which involves executing actions based on the computed information. As shown in Fig. 1

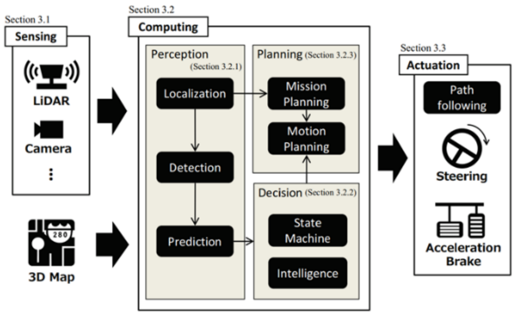


Fig. 1 The basic working diagram of an autonomous vehicle.

Decision-making an important system as it plays the role when encountering various situations, or it can be said to be the "brain" of the autonomous vehicle. The decision-making methods are divided into 2 approaches: 1. Machine Learning-based decision-making and 2. Rule-Based decision-making In this research, we have employed a rule-based approach which involves defining rules or conditions that govern the system and specifying the actions associated with each rule.

The research by Mohamed Abdel-Aty and colleagues [2] introduces the use of AEB control by incorporating a TTC threshold to determine when to activate Automated Emergency Braking (AEB) in order to reduce accidents between vehicles and pedestrians. The experimental results of the study [2] revealed that employing AEB control can effectively reduce collision incidents, and the TTC threshold has an impact on the performance of the AEB system. TTC (Time-To-Collision) refers to the remaining time before a collision occurs or before impact. A higher TTC value indicates a safer situation with more time available before potential impact.

The research by F. Jimenez and colleagues [1] presents a method for determining the Time-To-Collision (TTC) between two vehicles moving at an angle of less than 90 degrees, as shown in Fig. 2. Another important value is Time-To-Brake (TTB) which is the time it takes for a vehicle to come to a stop or reduce its speed before colliding with obstacles while driving autonomously.

The research [1] introduced the approach to calculate the TTC and TTB by using the time that the walker and the Autonomous take to enter and exit the conflict area.

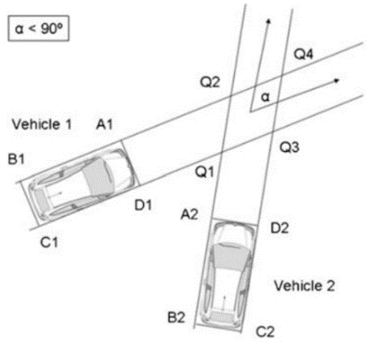


Fig. 2 Two vehicles are moving in a straight direction at an intersection with an angle of less than 90 degrees

It was found that if we use TTC and TTB values for decision-making, it can be stated that if TTB < TTC, the vehicle can brake safely (considering feasible deceleration rates) before collision. However, if TTB > TTC, the vehicle does not apply the brakes, and a collision occurs.

Currently, the development of Automated Emergency Braking System is mainly focused on the head-on TTC, which is the function of time headway. However, if the obstacle is moving across the vehicle trajectory the conventional method might not be sufficient to migrate the collision, hence, the obstacle will visible for the vehicle of a short period of time before the collision. This research implemented the TTC and TTC calculations from the time that the obstacle (pedestrian) and the ego vehicle entering the conflict area as a new method for calculate TTC for Automated Emergency Braking System.

3. Methodology

3.1 Decision-making System Design

In this research, the main variables considered for decision-making are Time-To-Collision (TTC) and Time-To-Brake (TTB). The scenarios involve four actors: the autonomous vehicle, the parked vehicle, the pedestrian, and the vehicle behind the autonomous vehicle. We focus on the decision-making process of the autonomous vehicle when it detects a pedestrian after a vehicle parked alongside the road while also considering the presence of a vehicle behind it, as shown in Fig. *3*.

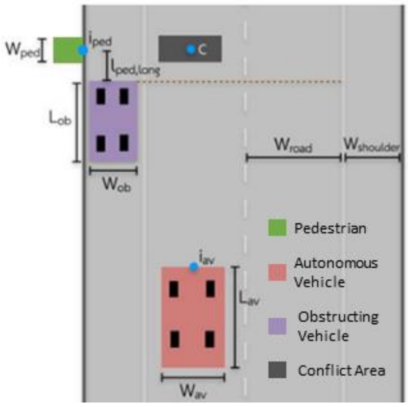


Fig. 3 The scenarios and various parameters used in this research.

3.1.1 Design Parameters

As the scenario mentioned above, the starting point of the autonomous vehicle referred to as i_{av}, is defined as the first position where the AV detects the parked vehicle. Similarly, the starting point of the pedestrian, denoted as i_{ped}, is defined as the initial position from which the pedestrian begins crossing the road. These starting points are located at the front center of the boundary, as depicted in Fig. 3. While point C is situated at the center of the conflict area, precisely defined as the intersection between the path of the pedestrian and the path of the autonomous vehicle.

The distance from i_{av} to point C, denoted as $i_{av}C$, is calculated based on the sensor-detected distance to the parked vehicle (r_{sensor}), the length of the vehicle parked alongside the road (L_{OB}), and the longitudinal distance between the pedestrian and the parked vehicle ($l_{ped,long}$), as depicted in equation 1. Other variables are defined as shown in Table1

$$i_{av} = \sqrt{r_{sensor}^2 - \left(\frac{W_{road}}{2} - \frac{W_{sholder} - W_{OB}}{2}\right)^2} + L_{OB} + l_{ped,long} \qquad [1]$$

The distance between i_{ped} and point C, denoted as $i_{ped}(t)C$, is calculated using equation 2. The calculation is based on the distance from the starting point of the autonomous vehicle to point C ($i_{av}(t)C$), which represents the distance from the autonomous vehicle's starting point to the middle of the conflict area. By knowing the length and width of the parked vehicle, we can determine β and use it to calculate ($i_{ped}(t)C$), using equation 2, as illustrated in Fig.4

$$i_{ped}C = \tan(\beta) \times i_{av}(t)C \qquad [2]$$

Table 1 Variables used in this research.

Variables	Meaning	(m)
W_{av}	Width of Autonomous Vehicle Boundary	2.07
L_{av}	Length of Autonomous Vehicle Boundary	4.48
W_{ped}	Width of Pedestrian Boundary	0.38
L_{ped}	Length of Pedestrian Boundary	0.38
W_{ob}	Width of Obstructing Vehicle Boundary	1.93
L_{ob}	Length of Obstructing Vehicle Boundary	4.72
W_{hv}	Width of Following Vehicle Boundary	1.93
L_{hv}	Length of Following Vehicle Boundary	4.72
$L_{ped,long}$	Longitudinal Distance Pedestrian to Parked Vehicle	2
W_{road}	Width of a Single Lane on the Road	3
$W_{shoulder}$	Width of Road Shoulder	2

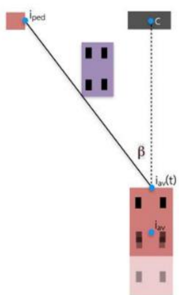


Fig.4 The geometry used to calculate the initial position of the pedestrian.

3.1.2 Vehicle Brake Model

In this study, two vehicle brake models are considered: Relaxation Length Tire Model and the Wheel Model.

3.1.2.1 *The Relaxation Length Tire Model*

The Relaxation Length Tire Model simulates the deceleration caused by the deformation of the tire's contact patch with the road surface during braking, as depicted in equation #3.

$$F_{longitudinal} = C_s \left(\frac{V_w}{s+V_w}\right) \lambda \qquad [3]$$

In the context of the tire model, Cs represents the longitudinal stiffness of the tire. V_w represents the longitudinal velocity of the wheel, and λ represents the slip ratio of the wheel.

3.1.2.2 The Wheel Model

The Wheel Model is used to simulate the wheel behavior during braking and the interaction between the tire and the road surface, which affects the rolling behavior. It takes into account the differences between the rolling speed and the longitudinal velocity of the wheel. The rolling speed and slip ratio can be calculated using equations 4 and 5

$$I_w \alpha = F_{longitudinal} R_w - \tau_{brake} \quad [4]$$

$$\lambda = \frac{(V_w - \omega R_W)}{V_W} \quad [5]$$

In these equations:

- $I_w w$ represents the moment of inertia
- α represents the angular acceleration
- ω represents the angular velocity
- R_w is the radius of the wheel
- τ_{brake} represents the wheel braking torque [2]

3.1.3 Time-To-Collision (TTC)

Time-To-Collision (TTC) and Time-To-Brake (TTB) are key variables in the decision-making process. TTC refers to the estimated time it will take for a collision to occur. It is used in two ways: Time-To-Collision of Autonomous vehicle (TTC_{av}) and Time-To-Collision of the Human Vehicle (TTC_{hv})

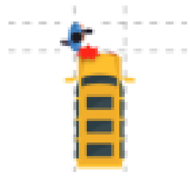
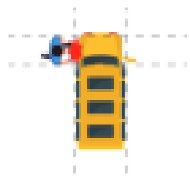
3.1.3.1. Time-To-Collision of the Autonomous Vehicle (TTC_{av})

Time-To-Collision of the Autonomous Vehicle (TTC_{av}) determines how long it will take for the autonomous vehicle to reach the conflict area.

In this study, we adopted Felipe Jimenez's research [1], which introduced the concept of Time to Collision (TTC) calculation. TTC is determined by calculating the intersection between the entry and exit times of two objects within the conflict area.

As setting a scenario where a walker and an autonomous vehicle are set on a perpendicular path. Within this setup, we anticipate two possible outcomes: either the AV collides with the walker or the walker collides with the AV. These events are determined based on the conditions outlined in Table 2.

Table 2 Condition for each scenario.

Case	Scenario	Condition
1		$T_{B3,out} > T_{A1,in} > T_{B4,in}$
2		$T_{A2,out} > T_{B4,in} > T_{A1,in}$

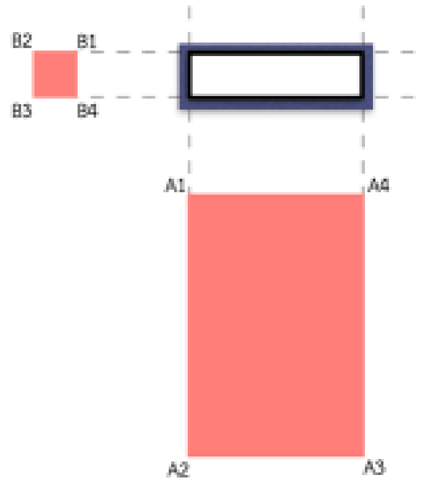


Fig. 5 The names of the boundary angles.

$T_{B4,in}$ is the time a pedestrian takes to enter the conflict area. $T_{B3,out}$ is the time it takes for a pedestrian to exit the conflict area. $T_{A1,in}$ is the time it takes for the autonomous vehicle to enter the conflict area. $T_{A2,out}$ is the time that the autonomous vehicle's boundary takes to get out of the conflict area.

Considering the first case, the autonomous vehicle will collide with the pedestrian if the time it takes for the autonomous vehicle to enter the conflict area ($T_{A1,in}$) falls within the range of $T_{B4,in}$ and $T_{B3,out}$. To analyze the relationship between these variables, we have plotted a graph in Fig. 6 where the variable "D" represents the distance within which a collision could occur. Within this graph, we get an intersection point, denoted as $T_{A1,in}$, which represents the Time-To-Collision (TTC) for this specific scenario.

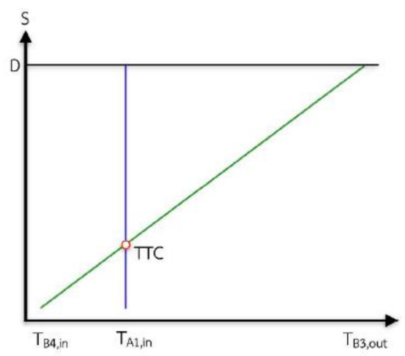


Fig. 6 The graph between the time when the vehicle and pedestrain enter and exit the conflict area, resulting in a collision in Case I

Another case is that the pedestrian will collide with the autonomous vehicle if the time it takes for the pedestrian to enter the conflict area ($T_{B4,in}$) falls within the range of $T_{A1,in}$ and $T_{A2,out}$. With the relationship in the graph in Fig. 7, the TTC is denoted as $T_{B4,in}$

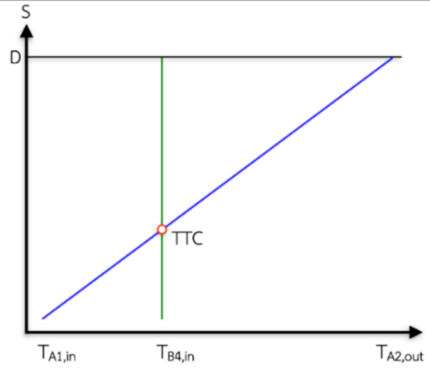


Fig. 7 The graph between the time when the vehicle and pedestrain enter and exit the conflict area, resulting in a collision in Case II

3.1.3.2. Time-To-Collision of the Human Vehicle (TTC_{hv})

Time-To-Collision of the Human Vehicle (TTC_{hv}) determines the time it takes for the vehicle behind the autonomous car to collide. It is calculated using the Headway distance (H), the speed of the autonomous vehicle (V_{av}), the speed of the following vehicle (V_{hv}), and the length of the autonomous vehicle (L_{av}). The calculation for TTC_{hv} is done using Equation 7.

$$TTC_{hv} = \frac{H-L_{av}}{V_{hv}-V_{av}} \quad [7]$$

The suggested value of Time Headway (H_t) is 2 seconds [4] Therefore, the Headway distance (H) can be calculated with equation 8.

$$H = H_t \times V_{hv} \quad [8]$$

In this research, the Time-to-Collision (TTC) is calculated to confirm that the deceleration of the autonomous vehicle remains within a safe range when the following vehicle travels at a speed not exceeding 90 km/h and maintains the recommended Headway distance (H). This ensures that there will be no collision with the autonomous vehicle.

3.1.4 Time- To-Brake (TTB)

Time-To-Brake refers to the time required to apply the brakes in order to meet the specified requirements. In this research study, the autonomous vehicle is instructed to apply maximum deceleration when approaching a parked vehicle, as depicted by the brown line in Fig. 3. The maximum deceleration rate is used in the calculation, as defined in Equation 9.

$$TTB = \frac{-V_{av}(t)}{a_{av,max}} + T_{delay} \; [9]$$

By $V_{av}(t)$, we mean the velocity of the autonomous vehicle at a given time. $a_{av,max}$ represents the maximum deceleration rate that the autonomous vehicle can achieve, which is set to -7.06 m/s^2. This value corresponds to the highest deceleration rate within the range of emergency braking in the longitudinal direction. Additionally, a Time delay (T_{delay}) of 0.5 seconds is accounted for in the perception system.

3.1.5 Decision-making

When an autonomous vehicle encounters a pedestrian crossing the road, it refers to Fig.8 to make decisions. If the autonomous vehicle detects a parked vehicle alongside the road, it decides to temporarily reduce its speed using a deceleration rate of -0.9 m/s^2. In such situations, it calculates both the Time to Brake (TTB) and the Time to Collision with the Average Vehicle (TTC_{av}), and compares the two values. If the TTB is smaller than the TTC_{av}, it determines the maximum deceleration rate to apply, bringing itself to a complete stop at the position indicated by the brown dashed line in Fig. 3. However, if the TTB is greater than the TTC_{av}, it initiates emergency braking with a maximum deceleration rate of -7.06 m/s^2, which represents the highest limit for Longitudinal deceleration during emergency situations.

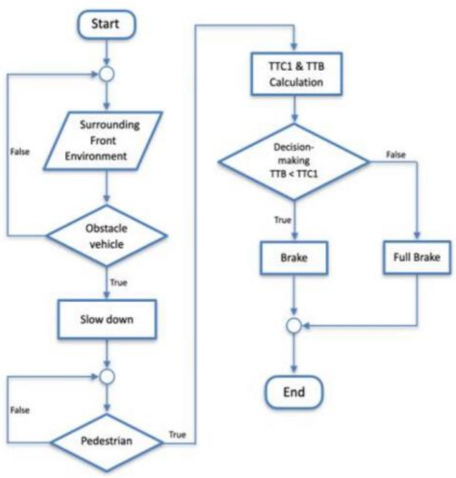


Fig.8 Decision-making diagram

3.2 Simulation

In this research, the situations considered, as discussed in the introduction, are divided into three scenarios depicted in Fig. 9:

Scenario I (Fig.9a): Simultaneous movement of a pedestrian and an autonomous vehicle from their respective initial positions.

Scenario II (Fig. 9b): Pedestrian starts moving from the initial position before the autonomous vehicle, with time intervals of 1, 2, and 3 seconds.

Scenario III (Fig. 9c): Autonomous vehicle starts moving from the initial position before the pedestrian, with time intervals of 1, 2, and 3 seconds.

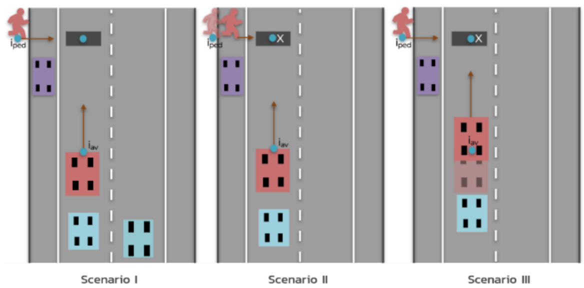


Fig. 9 Considered scenarios

In all three scenarios, there are variations in the departure from the initial positions of the pedestrian and the autonomous vehicle. In Scenario II, if the pedestrian starts moving before the autonomous vehicle from the initial position, the autonomous vehicle can effectively detect and identify this situation.

In Scenario I, the pedestrian is at a greater distance, enabling quicker decision-making compared to Scenario II. However, in Scenario III, where the autonomous vehicle moves first, it needs to detect pedestrians who are closer, posing a higher risk. Hence, all three scenarios must be considered to develop the autonomous vehicle's decision-making system effectively.

In this research, the speed of the autonomous vehicle was considered in all scenarios, ranging from 10 to 30 km/h with increments of 2 km/h. Additionally, the pedestrian speed ranged from 1 to 2 meters per second with increments of 0.2 meters per second, resulting in a total of 11 speeds for the autonomous vehicle and 6 speeds for the pedestrian. Overall, there were 66 combinations of speeds, resulting in a total of 462 events as shown in Fig. *3*. It is important to note that This research experiment was conducted by varying the size of the conflict area. Specifically, two variations were implemented:

1. Non-buffered Conflict area: Size based on the dimensions of the pedestrian and the autonomous vehicle.

2. Buffered Conflict area: Size based on the dimensions of the pedestrian and the autonomous vehicle, with an additional buffer.

The "Buffer" refers to an additional margin added to increase the width and length of the conflict area, as shown in the shaded region in Fig. *5*.The buffer area does not result in collisions, but it may lead to close encounters or be the area with the highest risk of collision. Therefore, it is necessary to consider this buffer area. In this research, two buffer sizes were set at 0.5 and 0.7 meters, corresponding to the width and length of the conflict area, respectively. This resulted in a total of 914 experimental scenarios.

Table 3

Scenario		Number of events	Number of collisions (Non-buffered)	Number of collisions (Buffered)
I		66	23	27
II	1 second	66	11	14
	2 seconds	66	4	7
	3 seconds	66	0	2
III	1 second	66	34	37
	2 seconds	66	29	34
	3 seconds	66	23	27

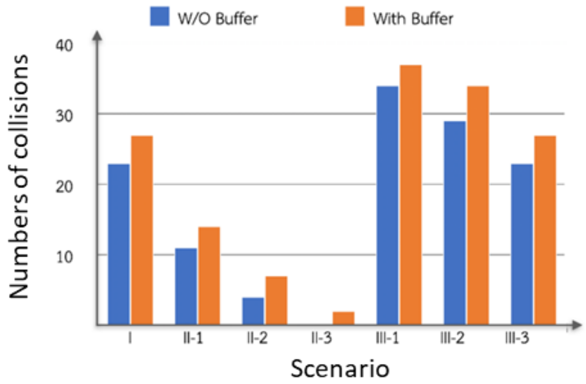


Fig. 10 Bar graph showing the number of collisions.

4. Results

Due to the high risk of accidents, simulation was selected as the exclusive method for conducting this research.

4.1 Simulation Results Without Decision-Making System

Table 3 presents the total number of events considered for each scenario and indicates the number of collision events that occurred in each scenario. The additional bar graph in Fig. 10 Bar *graph showing the number of collisions.* further illustrates this information. It can be observed that Scenario II has a lower number of collision events compared to Scenarios I and III. This is because the pedestrian moves from the initial position, meaning the pedestrian exits the conflict area before the autonomous vehicle enters. Scenario II had 11, 4, and 0 collision events for 1, 2, and 3-second intervals, respectively. On the other hand, Scenario III had the highest number of collision events, with 34, 29, and 23 collision events for 1, 2, and 3-second intervals, respectively. In all scenarios, the number of collision events was calculated considering the buffer value added to the conflict area. This means that in every scenario, the number of collision events was higher than if the buffer value was not taken into account and only the conflict area was considered.

4.2 Simulation Results with Decision-Making System

The simulation results revealed that in Scenario I, braking within the Aggressive zone could completely avoid collisions. This applies to scenarios where both buffer and non-buffered conflict areas were considered. The distance from the initial position of the vehicle to point C, calculated using Equation 1, was found to be 26.66 meters. Similarly, the distance from the initial position of the pedestrian to point C, calculated using Equation 2, was determined to be 4.69 meters.

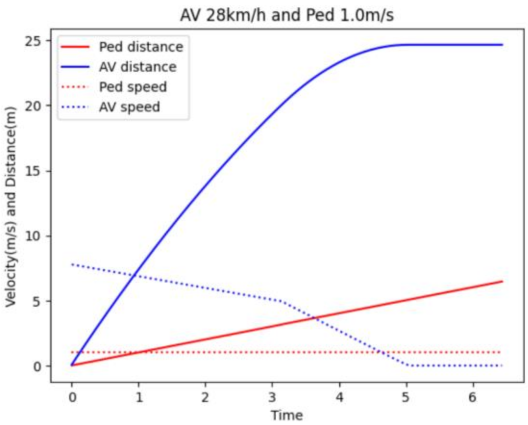


Fig. 11a A graph depicting the speed and distance of an autonomous vehicle event. The initial speed is 28 km/h, and the walker speed is 1 meter/second in scenario I.

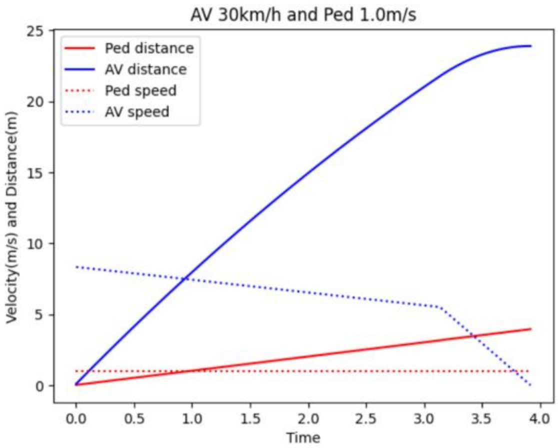


Fig. 11b A graph depicting the speed and distance of an autonomous vehicle event. The initial speed is 30 km/h, and the walker speed is 1 meter/second in scenario I.

Scenario I is illustrated in Fig. 11a, which depicts the speed and distance of both the autonomous vehicle and the pedestrian. It can be observed that the autonomous vehicle reduces its speed when encountering a parked vehicle alongside the road and when encountering a pedestrian crossing the road. The decision to brake is made prior to entering the conflict area, utilizing a deceleration rate not exceeding -5.08 m/s^2. This allows sufficient time for the pedestrian to exit the conflict area before the autonomous vehicle reaches it. In almost all cases, the speed profiles of both the autonomous vehicle and the pedestrian follow a similar pattern. As an example, let's consider a scenario where the autonomous vehicle has a speed of 28 km/h and the pedestrian has a speed of 1 meter per second, as shown in Fig. ***11***a.

However, there is one particular event in this scenario where the autonomous vehicle decides to perform emergency braking with a maximum deceleration rate of -7.06 m/s^2. This represents the highest deceleration rate during emergency braking. This event occurs when the speed of the autonomous vehicle is 30 km/h and the pedestrian's speed is 1 meter per second, as shown in Fig 11b. In this situation, the autonomous vehicle is capable of performing a sudden and full stop before entering the conflict area. However, this may startle the passengers on board the vehicle. Ultimately, the outcome is that no collision occurs.

Scenario II is described in Fig. ***12***, which illustrates the speed and distance of both the autonomous vehicle and the pedestrian. As the pedestrian starts moving before the autonomous vehicle, it is similar to Scenario I. In Scenario II, the autonomous vehicle decides to brake in every event, resulting in no collisions occurring in any of the scenarios.

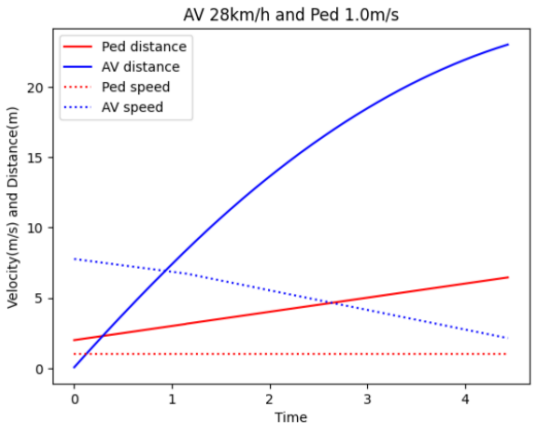


Fig. 12 A graph depicting the speed and distance of an autonomous vehicle event. The initial speed is 28 km/h, and the walker speed is 1 meter/second in scenario II.

Scenario III is depicted in Fig. 13a, illustrating the speed and distance of both the autonomous vehicle and the pedestrian. As the autonomous vehicle starts moving before the pedestrian, the speed profiles of both entities generally follow a similar pattern. For instance, consider the scenario where the autonomous vehicle has a speed of 22 km/h and the pedestrian has a speed of 1.8 meters per second, as shown in Fig 13a. Moreover, at a speed of 26 km/h, the autonomous vehicle decides to perform emergency braking with the maximum deceleration rate, as shown in Fig 13b. Unfortunately, a collision occurs within the shaded area.

In summary, based on the 462 events observed in all three scenarios, the decision-making system designed in this research successfully eliminated accidents in Scenarios I and II by 100%. However, collisions still occurred in Scenario III. This is due to the close proximity between the pedestrian and the autonomous vehicle, making it difficult to brake in time.

According to the decision-making system implemented in this research, the number of ongoing collisions can be summarized from the bar graph in Fig. 15.

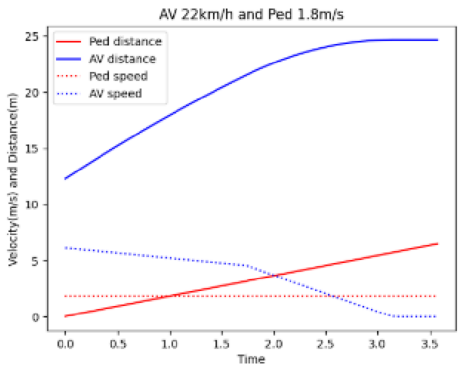


Fig. 13a A graph depicting the speed and distance of an autonomous vehicle event. The initial speed is 22 km/h, and the walker speed is 1.8 meter/second in scenario III.

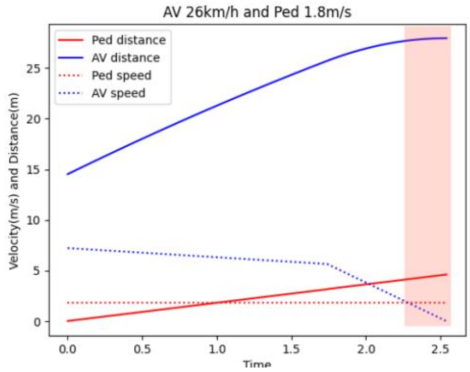


Fig. 13b A graph depicting the speed and distance of an autonomous vehicle event. The initial speed is 26 km/h, and the walker speed is 1.8 meter/second in scenario III.

Fig. 14 illustrates the speed and distance of the vehicle following behind when the autonomous vehicle reduces its speed with a deceleration rate of -0.9 m/s^2 from an initial speed of 10 km/h. If the vehicle behind the autonomous vehicle maintains a Time Headway (H_t) value of 2 seconds, as recommended by [1], it can be observed that the rear vehicle applies a deceleration rate of -3 m/s^2 to maintain the desired H_t value. This deceleration rate falls within an acceptable range as it falls within the early range of the Aggressive Driving Zone. Therefore, if the initial speed of the autonomous vehicle is greater than 10 km/h, the rear vehicle can brake with a deceleration rate not exceeding -3 m/s^2 when the autonomous vehicle reduces its speed.

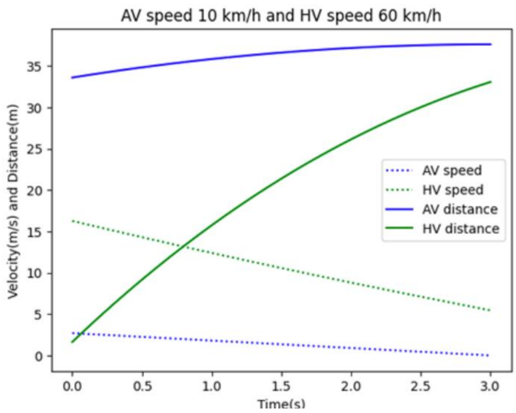


Fig. 14 A graph depicting the speed and distance of an autonomous vehicle event. The initial speed is 10 km/h, which is currently decelerating, and there is a following vehicle with an initial speed of 60 km/h.

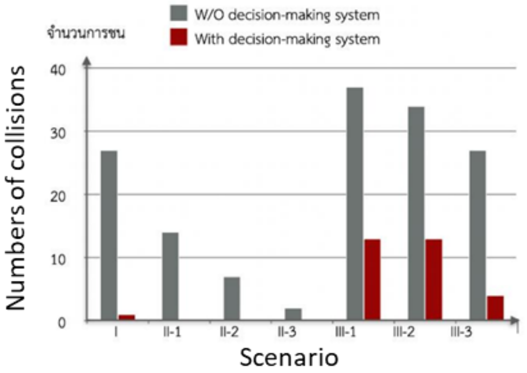


Fig. 15 Bar graph showing the number of collision events with and without a system

The results from the experiments demonstrate that the design concept of the autonomous vehicle's decision-making system when encountering pedestrians crossing the road near a parked vehicle has proven effective in reducing accidents. However, despite the system's effectiveness, there are still situations where collisions occur. These collisions typically arise from the fact that the autonomous vehicle detects pedestrians who are crossing the road at extremely close distances, leaving insufficient time to avoid a collision.

5. Conclusion

The autonomous vehicle's decision-making system aims to reduce accidents when encountering parked vehicles and pedestrians. It uses Time-to-Collision (TTC) and Time-to-Brake (TTB) as criteria. TTC refers to the remaining time before the autonomous vehicle collides with a pedestrian. TTB indicates the time it takes for the autonomous vehicle to apply the brakes with a deceleration rate of -5.08 m/s^2. If TTB is greater than TTC, it's a high-risk situation, and the vehicle will brake at -7.06 m/s^2. If TTB is smaller, the vehicle will brake with calculated rates. The system effectively reduces accidents, though not all, improving road safety significantly.

From the above summary, it can be seen that collisions still occur even when using the maximum deceleration rate of -7.06 m/s^2 in emergency braking. This rate is considered dangerous for passengers on the autonomous vehicle. Therefore, relying solely on braking may not be sufficient, and collision avoidance methods such as steering should be implemented to prevent accidents. Avoiding collisions remains a crucial research topic for the research team to pursue further.

6. Acknowledgement

This research was supported by the Smart Mobility Research Center at Chulalongkorn University as a part of the research efforts to develop autonomous shuttle of the Smart Mobility Research Center to enhance the mobility services of Thai society.

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SESSION 3.1B: AYRF 2022 RESEARCH PAPER PRESENTATION
From Paper ID: 2023-008, 2023-009, 2023-020, 2023-029

Paper ID	Paper Entitled	Presented by
AYRF 2023-008 Page 94-104	"Attitude, Motivation, and Engagement of High School Students toward Traffic Safety Education in Ho Chi Minh City, Vietnam"	**Mr. Hoai Nguyen PHAM** Institute of Smart City and Management, University of Economics Ho Chi Minh City, Vietnam
AYRF 2023-009 Page 105-112	"Survey on Bicycle Overtaking Maneuvers of Cars and Motorcycles in Bangkok"	**Mr. Jun SAKURAI** Faculty of Information and Communications, Bunkyo University, Japan
AYRF 2023-020 Page 113-123	"A Comparison of Driver Behavior at Intersections During Peak Hours: Paranaque City vs Subic City"	**Mr. Christian Edward Rapatan Viado** De La Salle University, The Philippines
AYRF 2023-029 Page 124-131	"Degradation of the Retroreflectivity of Thermoplastic Pavement Markings in Bangkok Highways"	**Assoc.Prof.Dr. Viroat SRISURAPANON** Department of Civil Engineering, KMUTT, Thailand

Attitude, Motivation, and Engagement of High School Students toward Traffic Safety Education in Ho Chi Minh City, Vietnam

Topic number: 3, Paper Identification number: AYRF2023-008
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Abstract

This research was conducted to explore students' perspectives of motivation, attitude, and engagement on their dimensions toward traffic safety education in Vietnam and how dimensions of motivation and attitude, independently and simultaneously, affect dimensions of engagement, taking socio-demographic characteristics into account. The research was based on a questionnaire. A total of 302 respondents from a high school in Ho Chi Minh City participated in this research. The results showed that illegally riding motorcycles had a negative impact on traffic safety among high school students. While a high level of extrinsic motivation existed among students, moderate levels of engagement and low levels of attitude dimensions were found among them. Since all dimensions of motivation, attitude, and engagement significantly affect students' perceptions of traffic safety education, innovative learning methods such as game-based learning need to take these dimensions into account in their implementation.

Keywords: Traffic Safety Education, Attitude, Motivation, Engagement, High School Student

1. General Introduction

Traffic crashes are the leading cause of death for children and young adults aged from five (5) to twenty-nine (29) around the world [1]. Compared to developed countries, developing countries experienced higher rates of road traffic injuries (90%) [2]. Although recent annual numbers of traffic crashes in Vietnam have been statistically observed to be decreasing, crashes involving students have been reported to increase considerably, with a number of 2000 children per year [3]. Among these children, Vietnamese high school students aged from 15 to 18 years old tended to experience traffic crashes with a mortality rate around five times higher than the average mortality rate of all ages for the whole country and eight to nine times higher than the mortality rate of the same group in developed countries due mainly to risky behaviours such as wrong lane running, dangerous changes of direction, speeding, dangerous overtaking, and dangerous road crossing; most traffic crashes have been found among male students [3].

Recognizing that human error is the main cause of traffic crashes (90-95%) [4, 5], traffic safety education has been implemented in many countries [4, 6] to enhance learners' knowledge, skills, positive attitude, and motivation towards road safety and correct their behaviour on roads [7]. When effective learning practices were adopted, traffic safety education showed its significant role in increasing knowledge about traffic signs and skills of situation awareness [8], changing attitudes, and correcting unsafe behaviours [9]. Lack of road safety knowledge was significantly related to an increase in risky behaviour, resulting in a higher rate of traffic injuries among students [10-13]. Especially for teenagers, if they did not complete their traffic safety programs, the likelihood of crash involvement was 1.22 times higher than that of those who underwent these programs [14].

In Vietnam, traffic safety education has been implemented at high schools since the 1990s through school curricular and extracurricular activities; however, very little is known about their effectiveness. Regarding school-based settings, traffic safety education was non-mandatory and integrated into ethics classes, with five (5) modules concerning traffic culture, traffic accidents and prevention, traffic signal systems, safe behaviours in transport mode options, and traffic safety for (e)-cyclists. When it comes to extracurricular activities, educational campaigns are conducted every year; however, the effectiveness of these campaigns has not been clearly mentioned, except for the fact that these campaigns have been spread nationwide since the academic year 2016-2017 and gained students' participation from all high schools in the country. Having in mind magnitude of traffic safety education, the National Road Safety Strategy by 2020 and a vision to 2030 (Prime Minister's Decision No: 1586/QĐ-TTg, 2012) have been distributed to "renovate the contents, forms, and methods of teaching traffic law in schools" and "develop criteria, traffic cultural behaviours for traffic participants and promote propaganda, dissemination of these criteria, traffic cultural behaviours.".

Over the last decades, student engagement, attitude, and motivation have been recognized as significant factors fostering the effectiveness of learning activities [15-17]. Although the notion of student engagement, motivation, and attitude towards their learning has been extensively examined internationally, relatively few studies on the topic have been identified in the context of traffic safety education in Vietnam. Furthermore, there is no study exploring relationships between dimensions of engagement, attitude, and motivation in traffic safety education.

Considering the above, the present research was conducted to determine the relationships between dimensions of engagement, attitude, and motivation towards road safety education, with the expectation that promising solutions concerning learning methods for traffic safety education among Vietnamese high school students would be proposed.

The other sections of this paper are organized as follows. A literature review and conceptual framework are provided in Section 2. Section 3 presents the research method. Findings and discussions of this research are provided in Sections 4 and 5, respectively. Finally, Section 6 presents the conclusions.

2. Literature Review and Conceptual Framework

Student engagement, defined as "participation in educationally effective practices, both inside and outside the classroom, which leads to a range of measurable outcomes", should be more than just participation since it requires feelings, sensemaking, and activity [18]. For high school students, engagement was formed by dimensions of energy (the emotional dimension), dedication (the cognitive dimension), and absorption (the behavioural dimension) [19]. Energy refers to high levels of vigor and mental resilience in the learning process; dedication is associated with the sense of being strongly committed to the learning process; and absorption is characterized by high concentration on learning, whereby time passes quickly [20, 21].

Regarding attitude, it refers to the degree to which a person has favourable or unfavourable behaviour, including affective attitude and instrumental attitude [22]. While affective attitude corresponds to whether an individual is interested or uninterested in the behaviour, instrumental attitude refers to whether an individual believes behaviour is beneficial for them [23, 24]. Attitude has played a significant role in transferring drivers' knowledge into action and establishing their proper behaviour on the roads [25].

In terms of motivation, motivated students tend to concentrate on what they are doing, use their own effort and energy to achieve their tasks, direct their behaviours toward particular goals, gain satisfaction [17], and increase their academic performance [26]. Deci and Ryan [27] divided motivation into intrinsic motivation and extrinsic motivation. While students are intrinsically motivated to participate in an activity in order to satisfy their internal values and demands, extrinsically motivated students participate in an activity because of rewards, certificates, and verbal praise [28].

It was well established in the literature that attitude and motivation were important drivers of engagement [29], especially in the lifelong learning process [30]. When it came to the relationship between attitude and engagement, Erdoğdu [31] found that students with a positive attitude towards learning participated more in activities in the school, listened to the teacher in the class more carefully, and were thereby more successful in learning. Learners who possessed positive attitudes towards learning performed more successfully in academic terms [32, 33] and gained higher levels of knowledge [34, 35]. Negative attitudes are positively associated with poor engagement with a course [36]. Abun, Magallanes and Incarnacion [29] stated that both affective and instrumental attitudes significantly affected school engagement in higher education. Emotions and thoughts about learning influence student behaviours in real life [37].

Regarding the relationship between motivation and engagement, it was widely recognized that motivation was one of the most important factors influencing engagement [38-40]. When students were more motivated to learn, they were more likely to be engaged [41]; as a result, they achieved learning objectives [41] and showed better academic performance and learning outcomes [42, 43]. Especially for students aged sixteen and over, lack of motivation was considered a personal barrier preventing them from engaging in learning activities [38]. Students who had intrinsic motivation not only tended to enjoy their learning, but they also had a better understanding of learning content, were more persistent in their goals [44-47], and gained satisfaction from curiosity, self-expression, and personal challenge [48]. As a result, they achieved a higher level of engagement in their learning compared to students who were extrinsically motivated [49, 50].

Traffic safety education has been proposed as a lifelong learning process in which students should be actively engaged in their own learning activities [4, 51, 52]. However, students preferred "cool" to "safe" [53]; as a result, they found traffic safety education unuseful due to non-innovative teaching methods such as textbooks [53-55]. Besides that, an overestimation of grades and course passing resulted in the fact that learners tended to only focus on obtaining a driving license by getting enough grades to pass tests; they did not learn for the sake of gaining knowledge and skills to prevent them from being killed or injured on roads [55]. In other words, dimensions of engagement, motivation, and attitude may significantly correlate with student perceptions of traffic safety education.

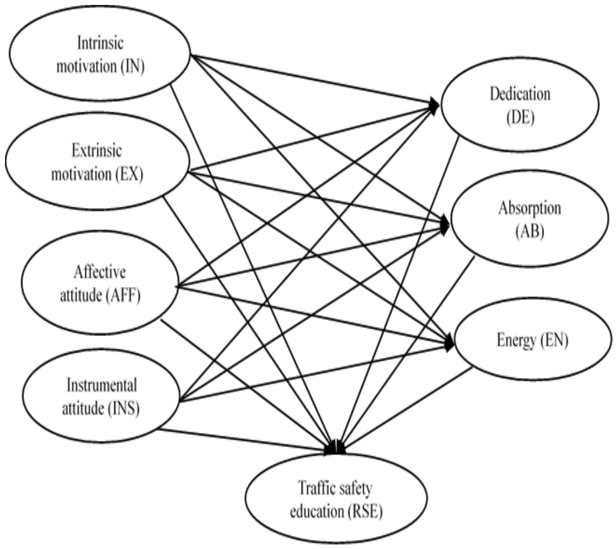

Fig. 1 The conceptual framework

Fig. 1 shows the conceptual model of the present research.

3. Research Method

3.1 Research Instrument and Design of Questionnaire

An online questionnaire was developed to explore high school students' motivation, engagement, attitude dimensions, and perceptions towards traffic safety education. The questionnaire consisted of four sections: (1) questions about social-demographic characteristics including genders, ages, transport modes, motorcycle driving license, involvement of traffic crashes, and traffic fines; (2) a 8-item motivation scale, including intrinsic and extrinsic motivation (4 items per dimension), is adapted from the Academic Motivation Scale [56]; (3) a 6-item attitude, including affective and instrumental dimensions (3 items per dimension), is developed by [57]; (4) a 15-item engagement scale, including subscales of Energy, Dedication, and Absorption (5 items per dimension), is adapted from the Measurement Scale of Engagement [58]; and a 9 item student perception on their learning about traffic safety education. Items in each scale were anchored by a 7-point Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree) to allow for a wider range of response options, and then translated into Vietnamese.

3.2 Data Collection and Analysis

After the development of the online questionnaire, a total of 302 students were gathered from a high school in Ho Chi Minh City, Vietnam. For a better understanding of the participants, the research's objective was explained to them before they answered the online questionnaire in the school's computer rooms under the supervision of the researcher and the other two teachers of the school. All students gave valid responses, which were used for data analysis.

Descriptive statistics were conducted to explore the socio-demographic characteristics of respondents and the motivation, engagement, and attitude dimensions of students in traffic safety education. Spearman's correlation was used to investigate correlations among dimensions. The reliability test examined the internal consistency of constructs. Exploratory factor analysis (EFA) was carried out to evaluate the constructs and discriminant validity of the research instrument. Furthermore, the relationships between the variables were examined using the structural equation modeling (SEM) technique through the AMOS (analysis of moment structures) 21 software.

4. Findings

4.1. Respondents' Socio-demographic Characteristics

Table 1 Socio-demographic characteristics of respondents

Variable	Level	Frequency	Percent (%)
Gender	Male	134	44.40
	Female	168	55.60
Driving license	Yes	0	0.00
	No	302	100.00
Crash involvement	Yes	144	47.68
	No	158	52.32
Traffic fines	Yes	31	10.26
	No	271	89.74
Transport mode	Motorcycle (illegally)	124	41.10
	Bicycle	40	13.30
	Moped	37	12.30
	E-bicycle	17	5.60
	Pedestrian	11	3.64

Table 1 shows the socio-demographic characteristics of the respondents. Among 302 students, 44.4% of respondents are male (mean age = 16, SD = 0.53). With respect to transport modes, 76% of respondents went to school by themselves. Given that none of them had motorcycle driving licenses, 41.1% of respondents went to school (illegally) by motorcycle (>50cc) by themselves, followed by 13.3% of bicyclists, 12.3% of moped drivers (<50cc), 5.6% of electric bicyclists, and 3.6% of pedestrians.

Regarding traffic crash involvement, around 48% of respondents were involved in traffic crashes. The highest number of crashes was caused by motorcyclists (17.55%), followed by moped drivers (6.95%), cyclists (6.29%), e-cyclists (3.31%), and pedestrians (1.99%). While around 20% of boys were involved in traffic accidents, more than 28% of girls experienced these situations. However, the number of girls who were involved in accidents as pillion passengers was around three times higher than that of boys. Boys were involved in most modes of transport, including cyclists (5.63%), moped drivers (3.64%), and motorcyclists (5.96%).

When it came to traffic fines, 10.26% of students admitted that they got fined due to traffic fines. Again, the highest proportion was recorded in the group of motorcyclists (6.95%), and boys got fines more than girls due to no helmet, speeding, red light running, wrong lane changing, and no signal of turning direction. No one got fined for their illegal use of motorcycles.

4.2. Descriptive Statistical Analysis

Fig. 2 shows descriptive statistics among dimensions of engagement (energy, dedication, and absorption), motivation (intrinsic motivation and extrinsic motivation), and attitude (affective attitude and instrumental attitude). The highest mean was found in extrinsic motivation (5.77), followed by energy (4.06), intrinsic motivation (3.44), absorption (3.83), dedication (3.38), affective attitude (2.80), and instrumental attitude (2.47).

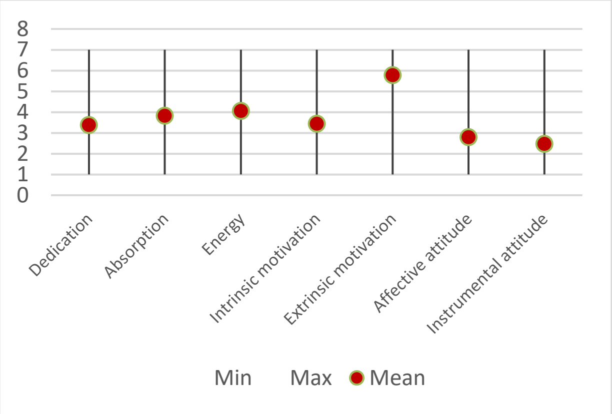

Fig. 2 Mean, min, and max values of dimensions of engagement, motivation, and attitude

4.3. Validity and Reliability of the Questionnaire

Table 2 Result of exploratory factor analysis (EFA)

	Factor							
	1	2	3	4	5	6	7	8
AB2	.946							
AB5	.887							
AB4	.884							
AB3	.875							
AB1	.863							
DE2		.859						
DE3		.839						
DE1		.801						
DE5		.744						
DE4		.708						
EX2			.975					
EX3			.973					
EX4			.958					
EX1			.954					
EN2				.913				
EN3				.861				
EN1				.814				
EN5				.764				
EN4				.737				
IN2					.893			
IN1					.859			
IN4					.831			
IN3					.786			
INS3						.924		
INS2						.902		
INS1						.859		
AF1							.873	
AF2							.815	
RSE 1								.767
RSE 2								.735
RSE 3								.810
RSE 4								.822
RSE 5								.745
RSE 6								.786
RSE 7								.734
RSE 8								.722
RSE 9								.823

Dimension: AB (AB1-5), DE (DE1-5), EX (EX1-5), EN (EN1-5), IN (IN1-4), INS (INS1-3), AF(AF1-2), RSE(RSE1-9)

The questionnaire's validity was tested using Exploratory Factor Analysis (EFA). The primary EFA was run on 28 items. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.833(>0.5), indicating the adequacy of the data for EFA. Bartlett's Test of Sphericity was revealed to be statistically significant (p=0.000), indicating a satisfactory correlation between the items [59]. The maximum likelihood factor analysis with a cut-off point of 0.40 and the Kaiser's criterion of eigenvalues>1 [60] yielded a seven-factor solution as the best fit for the data, accounting for 79.04% of the variance. The rotated component matrix exhibited seven valid components. The component of intrinsic motivation was represented by the four items. The component of extrinsic motivation was represented by the four items showing loadings. The component of affective attitude was represented by the three items, but one item has a low factor loading. Therefore, this item was removed. The component of instrumental attitude was presented by the three items. The components of energy, dedication, and absorption, respectively, were presented by the five items. Table 2 presents the results of the exploratory factor analysis (EFA).

Reliability analysis with regard to internal consistency yielded Cronbach alpha coefficients of 0.88 for intrinsic motivation, 0.97 for extrinsic motivation, 0.77 for affective attitude, 0.87 for instrumental attitude, 0.88 for energy, 0.92 for dedication, and 0.92 for absorption. The further examination of item-total correlations revealed that all items in each subscale contributed to the consistency of scores, with an item total correlation higher than 0.40.

Following the EFA using model fit indices, the structural equation modelling (SEM) through AMOS-21 was applied to investigate relationships between the variables in the research. Table 3 presents findings through SEM analysis.

The results confirm that there is a positive and significant impact of intrinsic motivation on dedication. This effect is observed through a path coefficient of 0.457 and a standard error of 0.052, indicating that a higher level of intrinsic motivation leads to higher level of students' dedication.

Besides intrinsic motivation, the results also confirm a positive and significant relationship between extrinsic motivation and dedication. This effect is observed to have positive significance with a coefficient of 0.118 and a standard error of 0.042. This indicates that higher extrinsic motivation leads to a higher level of dedication. Furthermore, extrinsic motivation also has a positive and significant effect on students' absorption, with a coefficient of 0.457 and a standard error of 0.052. The impact of extrinsic motivation on the energy is also observed as positively significant with a coefficient of 0.429 and a standard error of 0.055. These mean that there are more levels of students' absorption and energy, with a higher level of extrinsic motivation.

The results also show that a higher affective attitude tends to lead to higher level of dedication because there is a positive and significant impact of affective attitude on dedication, with a coefficient of 0.258 and a standard error of 0.048.

In addition, instrumental attitude has a positive and significant effect on energy, with the coefficient and the standard error are 0.289 and 0.052, respectively. Similarly, instrumental attitude also has a positive and significant effect on absorption, with the coefficient and the standard error being 0.140 and 0.047, respectively.

The results found that intrinsic motivation, extrinsic motivation, dedication, energy, absorption, affective attitude, and instrumental attitude have positive and significant effects on students' perceptions of traffic safety education.

Table 3 Result of SEM analysis

Relationship	Estimates	S.E	C.R	P
IN → DE	.457	.052	8.756	***
IN → EN	.127	.055	2.298	.022
IN → AB	.111	.051	2.171	.030
EX → DE	.118	.042	2.785	.005
EX → EN	.429	.055	7.862	***
EX → AB	.457	.052	8.786	***
AF → DE	.258	.048	5.381	***
AF → EN	.099	.056	1.766	.077
AF → AB	.092	.052	1.759	.079
INS →DE	.109	.041	2.628	.009
INS → EN	.289	.052	5.559	***
INS → AB	.140	.047	3.002	.003
IN → RSE	.187	.084	2.219	.002
EX → RSE	.297	.086	3.438	***
DE → RSE	.287	.108	2.668	***
EN → RSE	.278	.089	3.137	.002
AB → RSE	.061	.094	.650	.003
AF → RSE	.256	.073	3.486	***
INS → RSE	.222	.069	3.227	.001

Note: IN: intrinsic motivation, EX: extrinsic motivation, DE: dedication, EN: energy, AB: absorption, AF: affective attitude, INS: instrumental attitude, RSE: student perception on traffic safety education

4.4. Structural Equation Modeling (SEM)

The structural model of this research is shown in Fig. 3. A good model fit is measured by the set of fit statistics including the root mean square error of approximation (RMSEA), the goodness of fit index (GFI), the Tucker Lews index (TLI), and the confirmatory fit index (CFI). Generally, GFI, TLI, and CFI values in the 0.90s are accepted as the standard for the appropriate fit [59]. A good fit for RMSEA should have a value below 0.5. In the model estimation output, chi-square value of 2. 028 is significant at the p<0.001 level. The GFI of 0.838, the TLI of 0.942, the CFI of 0.947, and RMSEA of 0.68 suggest a approriate fit.

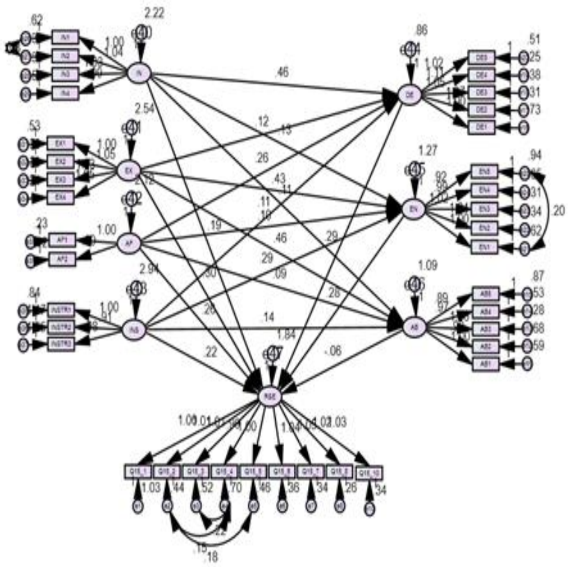

Fig. 3 The result of the SEM model

5. Discussions

Participants were high school students who were not allowed to use motorcycles before the age of 18 (without taking a driving test). However, a majority of them used this transport mode. While a minority of them were fined due to risky behaviours such as no helmet, speeding, red light running, wrong lane changing, and no signal of turning direction, no one got fined due to their illegal use of motorcycles [3].

The objective of the present research is to determine the relationship of dimensions between engagement, attitude, and motivation towards road safety education, with the expectation that promising solutions for traffic safety education among Vietnamese high school students were proposed. Students were asked to indicate how they experienced their traffic safety education in terms of motivation (intrinsic and extrinsic motivations), attitude (affective and instrumental attitudes), engagement (energy, dedication, and absorption), and their perception on traffic safety education.

The results of the descriptive analysis highlighted that students had a higher level of extrinsic motivation compared to other variables. Based on the questionnaire, respondents admitted that they were extrinsically motivated toward traffic safety education because they would like to demonstrate themselves to be intelligent people and succeed in their learning. However, there was no pleasure or satisfaction when they discovered new things or broadened their knowledge in traffic safety education [55]. Regarding attitude dimensions, the results showed that both negative affective attitude and instrumental attitude existed among students, indicating that they are not only uninterested in traffic safety education [53, 54, 60], but they also find this topic unbeneficial for them [55]. With respect to engagement, the results implied that students were neutral to somewhat agreed about the presence of energy, dedication, and absorption in traffic safety education. The questionnaire revealed that students were not very energetic and enthusiastic towards traffic safety education; they could not find traffic safety education meaningful, and it was easy for them to detach themselves from their learning. In this sense, engagement, in general, is low levels among students in the middle of their school years [16, 61]. Students who have a lower level of engagement gain a lower amount of knowledge [62]. Paying sufficient attention to engagement helps educators and policymakers design effective teaching and learning methods in order to advance the curriculum [63].

The results underscored that intrinsic motivation significantly positively affected only dedication. This indicates the fact that students tend to commit and devote their time when they learn traffic safety education for the sake of knowledge, skills, and pure satisfaction. Meanwhile, the results showed that extrinsic motivation had an effect on not only dedication but also absorption and energy. This means that students commit, concentrate, and have energy towards traffic safety education when they receive external motivation such as rewards and points for their learning. Scholars have found that intrinsic motivation has played a higher role in engaging students compared to extrinsic motivation [49, 50]. However, extrinsic motivation is still a good start for students who are not excited about their learning activities [47, 64]. In the long run, intrinsic motivation should be given much attention by suggesting self-selected learning activities [65], and innovating teaching contents [47].

The results found that affective attitude had a positive influence on dedication, while instrumental attitude positively affected absorption and energy. This implies that students who have the most positive emotions toward traffic safety education have the highest level of commitment to traffic safety education. Besides that, students who think traffic safety education is beneficial for them tend to have more concentration and energy for their learning. Teenagers who are sensation seekers [66] need to find the benefits of traffic safety education through their learning [53-55].

6. Recommendations

In recent years, game-based learning (GBL), considered a form of student-centered learning that places problem-solving scenarios in a game context [67], has become a promising approach to enhancing students' motivation, engagement, and problem-solving competences [68]. GBL can be presented in the form of gaming and gamification. A game is originally developed just for entertainment goals [69], and serious game, considered one type of (digital) games, gain their popularity in combination of both serious aspects such as teaching, learning, communication, and game-related aspects [70]. However, serious games are created in a typical game structure, while gamification infuses only game design elements into a non-game context [71], e.g., a traditional e-learning program [72]. Therefore, gamification is not a whole game. With the rapid development of computer three-dimensional processing capacity and the emergence of low-cost sensors, advanced digital technologies such as Virtual Reality (VR) and Augmented Reality (AR) have been applied in gamification and (serious) games to increase the levels of learners' immersion and presence in simulated environments during their learning process [73]. In general, both gamification and gaming come with some disadvantages and advantages. When it comes to disadvantages, amusement features of games may distract learners from the academic content of the game and reduce their efforts to process the material more deeply [74]. Because of this, it is necessary to ensure that the introduction of competition does not encourage carelessness among students [75]. Besides, some students express their strong negative feelings about the use of game elements such as points when a learning course is presented in the form of gamication [75]. Therefore, the optimal combination of game elements to produce the best result may be chalenging for the developers [76]. In spite of some disadvantages, both techniques express their advantages in creating conductive environments for increasing learners' engagement, motivation, and retention of knowledge and skills [77, 78]. For this reason, both techniques have already been applied to traffic safety internationally. Related to gamification, the gamified e-learning application "Route2School" was developed by the Transportation Research

Institute (IMOB, Hasselt University) to make traffic safety education for primary school pupils more interesting and challenging by including gamified elements such as virtual rewards, points, and levels, among others. Game elements are also applied in the platform "Arility" for primary pupils, but AR technology shows its benefits in providing safety education lessons and capturing pupils' learning. Related to gaming, the game "Take The Lead" from the road safety campaign "THINK!" is a game for child pedestrians, where they learn how to perform safe behaviour (e.g., crossing roads) to go to school safely; or "Beat The Street" is a VR game for children (13-14 years old) to learn playfully how to be safe participants in traffic.

The application of such methods in the field of transportation is very novel in Vietnam. For this reason, GBL could be considered an innovative learning approach to improve attitude, motivation, and engagement dimensions of high school students in Vietnam in future research. However, GBL methods are very diverse, and each technique also comes with its own merits and limitations. The selection of the appropriate GBL method needs to be considered carefully. Moreover, traffic safety education always occurs in a local context, with its specific roadway environments and traffic safety culture. Therefore, the applied GBL method must be sensitive to both the cultural norms of learners and the specific learning environment. It is essential that the GBL method for use in Vietnam be sufficiently researched, developed, and tested in future research.

7. Conclusions

Traffic crashes are an urgent issue for Vietnamese high school students due to their risky behaviours and illegal motorcycle use. To tackle this problem, stricter regulations on motorcycle use need to be enforced. Besides that, traffic safety education could not be underestimated to equip students with knowledge and skills, and help them correct behaviours on roads. To this end, psychological factors such as motivation, engagement, and attitude need to be taken into consideration. Traffic safety education does not only focus on external motivation such as rewards and points, but it also concentrates on how to enhance intrinsic motivation because it is the better aspect that has attached students to this topic for a long time. Besides creating students' perceptions of the important role of traffic safety education, establishing their interest in learning could lead to better learning experiences. The improvement of students' motivation, engagement, and positive attitude towards traffic safety education could be implemented through innovative learning methods. Game-based learning, including internal and external motivators, has been applied internationally in traffic safety education. The transfer of western educational materials into schools in developing countries is not a direct solution, but they can be adapted to form the basis of a local solution. It is important that these methods and materials for use in a developing country such as Vietnam have been researched, developed, and tested in future research.

8. Acknowledgement

The authors received no financial support for the research and authorship of this article.

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Surveyal Study on Bicycle Overtaking Maneuvers of Cars and Motorcycles in Bangkok

Topic number: 3, Paper Identification number: AYRF2023-09

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Abstract

Thailand has recently faced a critical situation concerning traffic accident damages. While motorcycles dominate the transportation landscape in Thailand, the usage rate of bicycles is also high among developing countries. Hence, it is imperative to conduct investigations aimed at enhancing safety measures for vulnerable road users, including bicycles. Although extensive studies have been conducted in developed countries to evaluate overtaking maneuvers of cars towards bicycles, research specific to Thailand has been lacking in terms of experimental verification using an engineering approach. Consequently, this study aims to fill this research gap by conducting bicycle riding experiments on roads in Bangkok, employing instrumented bicycles to explore the potential impact of bicycle lanes and helmet usage on passing distances.

Keywords: Instrumented Bicycle, Passing Distance, Traffic Safety, Overtaking Maneuvers, Bangkok

1. Introduction

In Thailand, the seriousness of traffic accident damages can be observed from the fact that the country ranked 9th globally in terms of traffic accident mortality rate in 2018[1], and the number of fatalities due to traffic accidents increased from 2011 to 2016[2]. Examining the proportion of traffic fatalities by type, we came to conclusion, that while bicycles accounted for 12.8% in Japan in 2018[3], motorcycles constituted 70.7% and bicycles only 1.5% in Thailand in 2019[4], highlighting motorcycles as the predominant mode of transportation in Thailand.

On the other hand, regarding the usage of bicycles in Thailand, a research paper investigating bicycle ownership rates in various countries reported that Thailand has a rate of approximately 60%, which is relatively high among developing countries[5]. Additionally, according to a survey conducted among 198 individuals residing in areas with established bicycle lanes in Bangkok, 47.6% of men and 55.3% of women responded that they currently use bicycles[6]. Furthermore, another study surveyed 754 residents of areas in Bangkok with established bicycle lanes to assess the frequency of bicycle usage[7]. The results showed that approximately 54% of respondents answered "Everyday", "Almost everyday" or "Often" in terms of their bicycle usage frequency. However, these study cases are the results of a survey of areas with established bicycle lanes, and it is possible that the bicycle ownership rate is not so high in Thailand as a whole.

Furthermore, concerning the development status of bicycle lanes, the Bangkok Metropolitan Administration (BMA) has made efforts to install dedicated bicycle lanes with a total length of approximately 8 kilometers in the vicinity of Koh Rattanakosin in Bangkok between 2008 and 2013 (though they were removed in 2019) [8]. Additionally, in 2008, there were infrastructure projects to convert 23 sidewalks with a total distance of 184.56 kilometers into bicycle paths[9]. These developments show the possibility of the further increase in the number of bicycle users in Bangkok. Therefore, conducting investigations aimed at enhancing safety measures for vulnerable road users such as bicycles becomes crucial.

Existing studies on bicycle traffic safety have predominantly focused on overtaking maneuvers by cars, as contact accidents during overtaking maneuvers are common. Such studies have been widely conducted, particularly in developed countries. For instance, Walker et al.

utilized instrumented bicycles equipped with ultrasonic sensors to measure the passing distances between cars and bicycles[10]. They compared factors such as helmet usage by cyclists, gender differences, and cycling positions, revealing that car drivers are sensitive to the appearance of cyclists. Additionally, Parkin and Meyers examined the presence of bicycle lanes and found that on roads with speed limits of 40 and 50 miles per hour, the absence of bicycle lanes resulted in significantly greater passing distances. However, on roads with a speed limit of 30 miles per hour, no significant difference was observed[11]. Furthermore, the authors conducted comparative experiments on car-overtaking bicycles in Japan, focusing on younger and older age groups, suggesting that the sense of danger among older individuals may not depend on passing distances or the speed of overtaking vehicles[12].

On the other hand, when focusing on research cases in Thailand, studies addressing traffic safety with a focus on motorcycles and cars exist[13], but there have been insufficient experiments conducted using an engineering approach to verify the traffic safety of bicycles.

Therefore, in this study, we aim to investigate the usage patterns of bicycles in Bangkok as of 2022, and subsequently conduct bicycle riding experiments using instrumented bicycles on roads in Bangkok. The objective is to examine the overtaking maneuvers of cars and motorcycles towards bicycles in Bangkok from an engineering perspective.

2. Survey on Bicycle Usage in Bangkok

2.1 Bicycle Usage Environment

A survey was conducted on the bicycle usage environment in Bangkok from August 15th to August 29th, 2022. First, photographs depicting the PUN-PUN rental bicycle service installations are shown in **Fig. 1**.

Fig. 1 Rental bicycle service

This service was initiated in 2012, and there are currently 50 stations located throughout Bangkok. Each station is equipped with approximately 10 bicycles, which enabled us to observe local residents actually using these bicycles.

Next, **Fig. 2** illustrates roads with bicycle lanes that are located in the vicinity of these rental bicycle stations.

Fig. 2 Bicycle lanes

These are bicycle lanes installed on Sathorn Road. Here, a significant number of bicycle riders, presumed to be using bicycles for daily commuting and transportation, were observed. Finally, **Fig. 3** shows bicycle parking areas installed on the sidewalks of major roads in Bangkok.

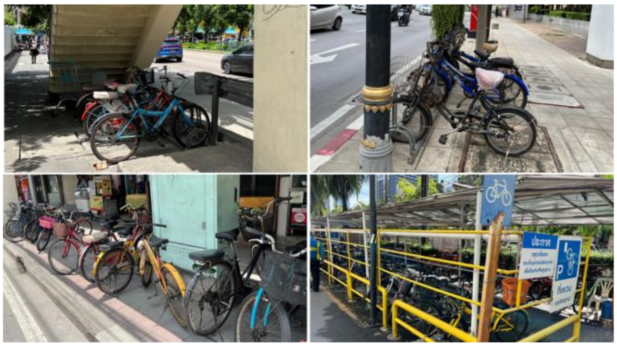

Fig. 3 Parking of bicycles

As depicted, various locations were observed where bicycle parking spaces were freely available, such as underneath pedestrian bridges or adjacent to large facilities like shopping malls. From these observations, it can be inferred that the bicycle usage environment in Bangkok has been improving with the development of such infrastructure.

2.2 Traffic Conditions of Bicycles

To investigate the actual traffic conditions of bicycles on major roads in Bangkok, fixed-point observations of bicycles on the roads were conducted using video cameras installed on pedestrian bridges. It should be noted that bicycles riding on sidewalks were not included in this survey.

The survey locations were South Sathorn Road, a four-lane road with bicycle lanes, and Ratchadaphisek Road, a four-lane road without bicycle lanes. Both the uphill and downhill directions of each road were observed for one day each, totaling four days of observations. The observation period was from 10:00 AM to 4:00 PM, six hours per day.

Fig. 4 below illustrates examples of bicycle observations on each road. Additionally, **Table 1** presents a summary of the observed bicycle types categorized by samples.

Fig. 4 Example of bicycle observation

Table 1 Bicycle observation result

Field		Number	Percentage
Bicycle lanes	Included	35	83%
	Not included	7	17%
Gender	Male	38	90%
	Female	4	10%
Bicycle helmet	Wearing	13	31%
	Not wearing	29	69%
All		42	-

Based on the results mentioned above, a total of 42 cyclists were observed over the course of four days. These cyclists had a high proportion of riding on roads with bicycle lanes, and the majority of them were male. Additionally, approximately 30% of the cyclists were observed wearing helmets. Furthermore, in the observations conducted on roads with bicycle lanes, instances that were deemed potentially dangerous are shown in **Fig. 5**.

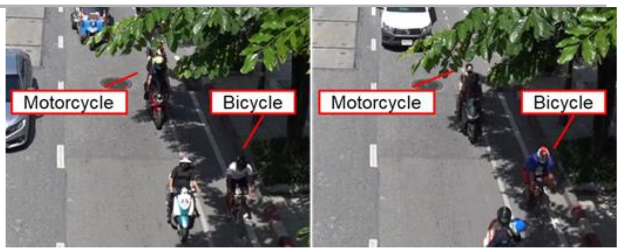

Fig. 5 Example of bicycle overtaking

This shows a situation where motorcycles are overtaking bicycles from behind while both are traveling on the bicycle lane. As it becomes obvious from the photo, the bicycle lane is also being used by motorcycles, and it can be observed that they approach the bicycles closely during the overtaking maneuver.

Based on these results, it can be inferred that multiple bicycles are present during the daytime, and some overtaking maneuvers suggest a potential high level of danger.

3. Bicycle Overtaking Experiment

3.1 Overview

In this experiment, we aimed to examine the impact of factors such as the presence of bicycle lanes and the use of helmets by cyclists on overtaking maneuvers. The experimental equipment used was an instrumented bicycle developed by the authors, as shown in **Fig. 6**.

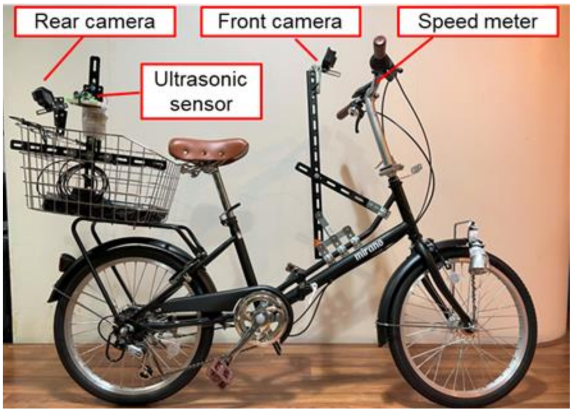

Fig. 6 Probe bicycle

The bicycle used in the experiment was the folding bicycle (MO-TZ-206HDTC-BK) manufactured by TOBU Co., Ltd. The equipment included the following sensors: an ultrasonic sensor (HC-SR04) for measuring the passing distance, front and rear action cameras (GoPro) for measuring the speed of cars and motorcycles, and a speedometer (iGPSPORT iGS130) for measuring the bicycle's speed.

The experiment was conducted at six locations as shown in **Fig. 7** and **Table 2**.

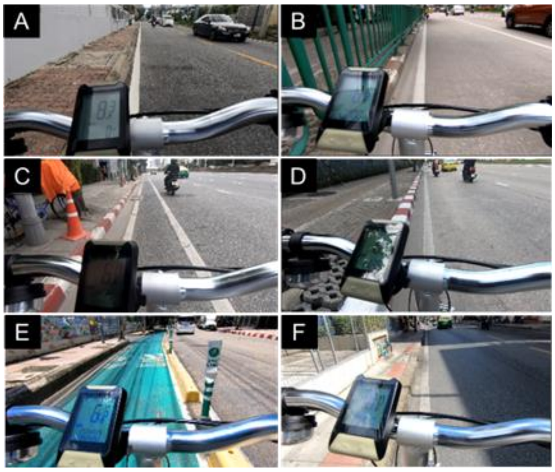

Fig. 7 Experiment location

Table 2 Details of experimental location

Location		Bicycle Lanes	Lane Width	No. of lanes
A	91 Duang Phithak Rd	Not	3.15m	1
B	Ratchada phisekRoad	Not	3.05m	4
C	South Sathorn Road	Included	2.90m	4
D	Kamphaeng Phet 2 Rd	Not	3.85m	4
E	Kamphaeng Phet 3 Rd	Included	2.70m	1
F	Soi pracha suk	Not	3.25m	1

Each road was characterized by different conditions such as the presence of bicycle lanes, lane width, and the number of lanes on each side. The author acted as the subject and performed the instrumented bicycle rides during daylight hours from August 17th to August 24th, 2022. The rides were conducted in two separate time periods: one wearing a white helmet and the other without wearing a helmet.

3.2 Measurement Method

The measurement procedure for overtaking maneuvers is shown in **Fig. 8**.

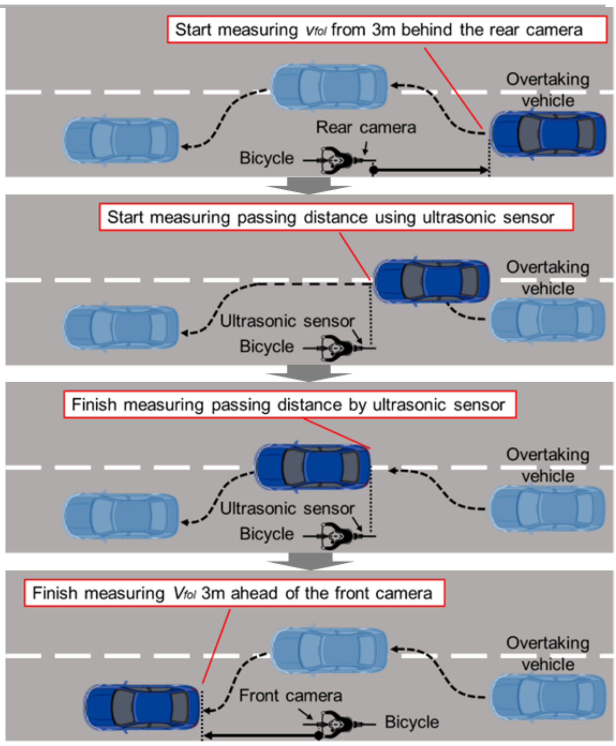

Fig. 8 Measuring procedure

For overtaking maneuvers, the speeds of cars or motorcycles and the distance between them and the bicycle were measured. Regarding the speed measurement, an action camera mounted on the bicycle was used. Measurement started from a distance of 3m behind the rear camera, passed a distance of 0.96m between the front and rear cameras, and ended at a point 3m in front of the front camera. The reason for the 3-meter setting was that the position of the vehicle's tires needed to be visible in the image. The time taken to cover this distance (6.96m) was measured, and the time difference was used to calculate the speed using Equation (1).

$$v_{fol} = \frac{6.96}{t_{front} - t_{rear}} \times 3.6 + v_{cyc} \quad (1)$$

In Equation (1), v_{fol} represents the speed of the car or motorcycle, v_{cyc} represents the speed of the bicycle, t_{front} represents the time at the front camera measurement, and t_{rear} represents the time at the rear camera measurement.

Regarding the distance measurement, an ultrasonic sensor installed sideways on the rear basket of the bicycle continuously recorded the distance between the bicycle and the target object at a frequency of approximately 7Hz. Among the multiple values measured during the overtaking process, the shortest value was considered as the passing distance.

4. Experiment result

4.1 Measurement Results of All Samples

The collected data on overtaking maneuvers in this experiment consisted of a total of 903 samples. The breakdown of the data is as follows:

1. Six types of roads
2. Presence or absence of oncoming vehicles

Table 3 Measurement results by category (Red color: $P < 0.01$)

Category	Condition	Samples	Passing Distance (cm)		Car/Motorbike Speed(km/h)	
			Mean	SD	Mean	SD
1) Road	A	226	111.5	28.8	48.5	13.5
	B	178	113.4	34.8	40.0	11.0
	C	89	93.7	32.5	29.4	8.0
	D	195	127.1	25.6	48.2	8.9
	E	147	123.1	31.5	47.7	14.6
	F	68	103.1	33.4	30.8	7.6
2) Oncoming vehicles	0. Absence	781	117.1	32.8	43.9	13.2
	1. Presence	122	99.6	23.3	40.2	14.1
3) Vehicles in adjacent lanes	0. Absence	796	118.0	31.3	44.4	13.3
	1. Presence	107	90.2	28.2	35.8	12.2
4) Vehicle type	0. Car	534	119.5	28.3	43.9	13.0
	1. Motorcycle	369	107.8	36.2	42.8	13.9
5) Number of riders on motorcycle	0. one person	316	107.1	36.6	43.3	14.1
	1. two persons	53	111.7	32.9	40.0	12.5
6) Helmet of motorcycle riders	0. Not wearing	33	112.9	33.2	43.1	16.8
	1. Wearing	336	107.3	36.4	42.8	13.6
7) Leading vehicles	0. Absence	646	116.6	31.9	45.6	13.7
	1. Presence	257	110.1	32.6	38.0	10.9
8) Following vehicles	0. Absence	603	115.8	33.2	45.5	14.1
	1. Presence	300	112.6	30.1	39.2	10.8
9) Parked cars ahead	0. Absence	876	114.9	32.3	43.7	13.2
	1. Presence	27	110.0	31.7	34.8	18.0
10) Parked motorcycles ahead	0. Absence	865	115.3	32.3	43.7	13.5
	1. Presence	38	100.5	27.2	37.1	10.2
11) Bicycle lanes	0. Absence	667	115.7	31.2	44.3	12.5
	1. Presence	236	112.0	34.9	40.8	15.3
12) Helmet of cyclist	0. Not wearing	205	115.0	29.2	49.7	13.0
	1. Wearing	698	114.6	33.1	41.6	13.0
13) Number of lanes on one side	0. 1 lane	441	114.0	31.3	45.5	14.6
	1. 4 lanes	462	115.3	33.1	41.4	11.8
14) Lane width	Less than 3m	236	112.0	34.9	40.8	15.3
	3m or more	667	115.7	31.2	44.3	12.5
15) Taxi	0. Non-taxi	422	118.7	28.3	43.9	13.1
	1. Taxi	112	122.7	27.8	43.7	12.7
16) Large car	0. Non-large car	521	119.7	28.3	44.0	13.1
	1. Large car	13	111.4	26.9	37.7	11.0
ALL		903	114.7	32.2	43.4	13.5

3. Presence or absence of vehicles in adjacent lanes
4. Vehicle type (car or motorcycle)
5. Number of riders on motorcycles (1 person or 2 people)
6. Helmet usage by motorcycle riders
7. Presence or absence of leading vehicles
8. Presence or absence of following vehicles
9. Presence or absence of parked vehicles ahead
10. Presence or absence of parked motorcycles ahead
11. Presence or absence of bicycle lanes
12. Helmet usage by cyclists
13. Number of lanes on one side (1 lane or 4 lanes)
14. Lane width (less than 3m or 3m or more)
15. Whether it is a taxi (non-taxi or taxi)
16. Whether it is a large vehicle (non-large vehicle or large vehicle)

Among these factors (2-16), significant differences at the 1% level were identified using the t-test, and these results are indicated in red font in **Table 3**. From these results, the following trends were observed:

- Cars tend to have larger passing distances compared to motorcycles.
- The presence of oncoming vehicles, vehicles in adjacent lanes, leading vehicles, and motorcycles parked on the road result in smaller passing distances and lower vehicle speeds.
- The presence or absence of bicycle lanes and the use of helmets by cyclists did not show significant differences in passing distances.

However, it is important to note that the samples included in each item come from the six types of roads, so they may be influenced by other factors such as road structures, road environments, and individual attributes. Therefore, in the next section, we will describe the results of multivariate analysis to further analyze the factors affecting passing distances in detail.

4.2 Analysis of Factors Contributing to Dangerous Overtaking Maneuvers

To analyze the factors contributing to dangerous overtaking maneuvers, a stepwise multiple regression analysis was conducted for both the car and motorcycle models, with passing distance as the dependent variable.

First, as explanatory variables for the car model, 13 items were set including Category 2, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 from **Table 3**, along with car speed. The actual numerical values were used for car speed and lane width, while dummy variables (0, 1) indicated by Condition in **Table 3** were set for other variables. The multiple regression analysis results for passing distance of cars are presented in **Table 4**.

Table 4 Multiple regression analysis of car

Element	SPRC	t	P
Car Speed	0.13	3.07	0.00
2) Oncoming vehicles	-0.29	-7.34	P<0.01**
3) Vehicles in adjacent lanes	-0.28	-7.22	P<0.01**
10) Parked motorcycles ahead	-0.07	-1.73	0.08
11) Bicycle lanes	0.20	3.89	P<0.01**
12) Helmet of cyclist	0.15	3.49	P<0.01**
14) Lane width	0.20	3.58	P<0.01**
16) Large car	-0.06	-1.57	0.12
(Constant)	-	4.61	P<0.01**
Adjusted R^2			0.23
Number of samples			534

From these results, it was found that the presence of oncoming vehicles or vehicles in adjacent lanes, the existence of bicycle lanes, the use of helmets by cyclists, and wider lane widths have a significant impact on increasing the passing distances.

Next, as explanatory variables for motorcycle models, 13 items were set including Category 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 from **Table 3**, and the motorcycle speed. The values were determined in a similar manner to cars. The multiple regression analysis results for passing distance of motorcycles are presented in **Table 5**.

Table 5 Multiple regression analysis of motorcycle

Element	SPRC	t	P
Motorcycle Speed	0.32	6.28	P<0.01**
2) Oncoming vehicles	-0.08	-1.71	0.09
3) Vehicles in adjacent lanes	-0.21	-4.11	P<0.01**
5) Number of riders on motorcycle	0.07	1.41	0.16
11) Bicycle lanes	-0.16	-2.59	0.01*
14) Lane width	-0.19	-3.11	P<0.01**
(Constant)	-	6.14	P<0.01**
Adjusted R^2			0.20
Number of samples			369

Basing on these results, we came to conclusion, that higher motorcycle speeds, the absence of vehicles in adjacent lanes, the absence of bicycle lanes, and single-lane roads have a strong influence on increasing the passing distances. In particular, regarding bicycle lanes and lane width, it showed an opposite trend to the results for cars. This suggests that, as mentioned in Chapter 2, the fact that bicycle lanes serve as motorcycle routes has a significant impact. In other words, the lane width is shortened and a bicycle lane is provided, but the passing distance between bicycles and motorcycles is close due to the fact that the lane is also used by motorcycles in addition to bicycles. Therefore, in order to save cyclists from this situation, it is considered important to clearly separate the riding areas for bicycles and motorcycles by placing fences or poles.

5. Conclusion

In this study, we investigated the usage patterns of bicycles in Bangkok and conducted bicycle riding experiments on roads using instrumented bicycles. As a result, the following insights were obtained:

- Bicycle lanes also serve as motorcycle routes, leading to reduced passing distances and increased potential dangers for cyclists.
- The wearing of helmets by cyclists tends to result in larger passing distances during overtaking maneuvers by cars.

We hope that these findings can contribute to the discussions on the development of safe and comfortable cycling environments in Bangkok. However, it is important to note that the results of this experiment were obtained under limited conditions on six types of roads. Therefore, it is necessary to be aware that increasing the sample size may reveal different trends.

Moving forward, we aim to further develop research that contributes to traffic safety measures through subjective evaluations, such as the perceived sense of danger by bicycle riders, and international comparisons, particularly with advanced countries like Japan.

6. Acknowledgment

This research was conducted under the IATSS research project (No. 2330). In addition, part of this research was supported by a research grant program of MLIT, which is headed by Dr. Yoshida of Osaka Metropolitan University.

Thank for the great cooperation of Dr. Nattapong of Chulalongkorn University, Ms. Hishida and all staff of the Bangkok office of Nippon Koei Co., Ltd., and Mr. Iwase of JICA.

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A Comparison of Driver Behavior at Intersections During Peak Hours: Paranaque City Versus Subic City

Topic number:3, Paper Identification number: AYRF2023-020

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Abstract

This study compares driver behavior between Metro Manila and Subic Bay Freeport Zone (SBFZ) in the Philippines, aiming to identify the factors that contribute to variations in driving patterns. Metro Manila is known for aggressive driving, poor infrastructure, dense population, and severe congestion, while SBFZ is known for its stricter traffic rule enforcement and adherence to regulations. The research focuses on similar intersections in both areas to evaluate driver behavior and examine the influence of the environment on driving patterns. Limited research exists on driver behavior in different locations, especially outside Metro Manila. By studying Paranaque City in Metro Manila and SBFZ, this research expands our understanding of diverse driving cultures. The findings will provide insights for policymakers, such as the Metropolitan Manila Development Authority (MMDA), and Land Transportation Office (LTO), to improve driver training, monitoring, and enforcement strategies. Two intersections were selected for analysis: Argonaut Highway and Rizal Highway in SBFZ, and Diosdado Macapagal Boulevard and Belle Avenue in Paranaque. The study minimizes variables by focusing on intersections with similar characteristics, traffic control systems, signaling devices, and traffic enforcement presence. Data collected will be presented as percentages to accommodate for varying population sizes. This research contributes to road safety improvement by investigating the underlying causes of driver behavior differences. It also serves as a starting point for future research in cities beyond Metro Manila. The outcomes will help authorities design safer and more driver-friendly roads.

Keywords: Traffic, Driver, Behavior, Subic, Manila

1. Introduction

Metro Manila is notorious for its challenging driving conditions, attributed to aggressive driving culture, inadequate infrastructure, dense population, and traffic congestion. In a report by Japan International Cooperation Agency last 2014, the daily cost of congestion currently amounts to PHP 3.5 billion and is projected to rise to PHP 6 billion by 2030. In contrast, the Subic Bay Freeport Zone (SBFZ) serves as an economic zone with one of Luzon's busiest port areas and boasts strictly implemented traffic rules enforced by the Subic Bay Metropolitan Authority (SBMA).

The study aims to explore the disparities in driver behavior between the two cities—both belonging to the same country but exhibit different driving habits. The specific areas selected for comparison are the SBFZ in Subic City and Paranaque City in Metro Manila. Despite the pressing transportation issues in Metro Manila, limited research focuses on driver behavior outside this area, leaving a gap in understanding and addressing road safety concerns.

To address this gap, the study compares driver behavior at similar major intersections in each location, seeking to identify what environmental factors could contribute to the differences. The goal is to determine whether the observed variation stems from objective driving conditions or subjective perceptions of the locations.

By shedding light on these differences, this research can aid in improving road safety, design considerations, and policy making in the Philippines. Authorities such as the MMDA, SBMA, LTO, and other privately owned management agencies, could utilize the findings to enhance training and education among drivers, monitoring surveillance footage, and enforcements.

The study will focus on two intersections: Argonaut Highway and Rizal Highway in Subic, and Diosdado Macapagal Boulevard and Belle Avenue in Paranaque. To minimize these variables, the intersections selected had similar properties. Since population size varies for both areas, data will be simplified into percentages to make it easier to interpret. It is worth noting that Subic's data is less compared to Metro Manila, but the researchers will utilize all accessible data for this study.

2. Literature Review

2.1 Policies Concerning Road Safety

Aggressive behavior is widely recognized as a highly significant concern in terms of traffic safety, as it has been consistently linked to increased risks of road traffic crashes. The occurrence of road traffic crashes is closely associated with driving behavior, and numerous factors have been identified as influencing this behavior, including driver fatigue, socio-demographic background, and behavioral characteristics. Moreover, both attitude and practice have been found to play significant roles in shaping road traffic crashes (Mirzaei et al., 2014).

2.2 Relation of Distractions to Driver Behavior

The increase in the trend of distractions lead to a higher crash rate. Distraction may be but is not limited to visual and cognitive tasks such as phone calls, listening to any information, and glancing at advertisements along the road (Zhang et al., 2019).

Stress plays a crucial role in various forms of risky driving behaviors, including aggressive driving, negative cognitive/emotional driving, and drunk driving. This is attributed to stress overwhelming the working memory processing capacity of drivers. The connection between stress and traffic congestion further strengthens the link between traffic congestion and risky or aggressive driving behavior (Ge et al., 2014).

2.3 Effects of Behavior on Road Environment

Numerous studies have investigated the relationship between traffic congestion and driver aggression, shedding light on this complex issue. Some studies have found a positive correlation between driving during rush-hour and the occurrence of ordinary violations, indicating that individuals are more likely to engage in risky driving behaviors when faced with traffic congestion. However, there is insufficient evidence to support a significant direct link between traffic congestion itself and aggressive driving (Kerwin & Bushman, 2020). Nonetheless, it is important to consider the impact of individual factors, such as higher levels of trait anger and aggressive driving attitudes, on the road environment. Furthermore, even when maintaining the same following distance as under normal traffic conditions, higher speeds can amplify the likelihood of being perceived as aggressive by other drivers.

2.4 Population Size

In contrast, population size does not exert a significant influence on the frequency of traffic collisions, and it can be extrapolated that the same applies to aggressive driving. This enables a meaningful comparison of selected locations without the need to account for population differences as a variable contributing to aggressive driving (Cabrera-Arnau & Bishop, 2021).

3. Framework and Methodology

3.1 Conceptual Framework

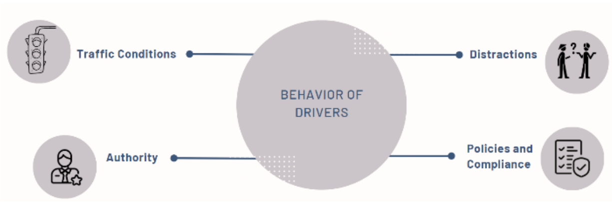

Fig. 1 General Conceptual Framework

Traffic safety culture varies from place to place, as this is the case for Paranaque City and Subic City. *Fig. 1* shows the general conceptual framework for this study. The diagram visually presents how the researchers believe the behavior of drivers branch out to these different factors.

Traffic conditions are often the root cause of various issues faced by road users, particularly during peak hours. These conditions intertwine with the factor of time, as drivers experience time pressure when they are running late, leading to impatience. This impatience, in turn, gives rise to a sense of competition among drivers. Consequently, drivers may resort to taking shortcuts, such as running red lights or making illegal U-turns, in their quest to save time. Additionally, drivers often resist attempts by other road users to merge or change lanes, further disrupting the flow of traffic. This resistance reflects a decreased compliance with traffic rules as drivers prioritize reaching their destinations quickly. Furthermore, distractions and cognitive factors, such as being easily distracted by phones or engaging in multitasking, contribute to unsafe behaviors. While the presence of law enforcement officers' acts as a deterrent to reckless driving, a lack of enforcement can result in a less safe driving experience. Policies and compliance play a vital role in improving road safety. However, poorly thought-out policies can lead to increased traffic congestion, frustration among motorists, and economic losses due to wasted time. Well-designed laws provide clear guidelines, educate drivers, and facilitate the creation of efficient road infrastructure.

3.2 Theoretical Framework

The study focuses on how the driver's behavior differs depending on their city or environment. The study will investigate the frequency of aggressive driving in two different intersections in two different study areas and discover the factors that affect these behaviors.

3.2.1 Anonymity Theory

Anonymity theory focuses on how area size plays an important role in an individual's identity. The size of a city may contribute to elevated crime rates due to anonymity. When participants are anonymous, they are more readily involved in aggressive behavior. In the study area chosen, it is evident that Paranaque, being known to have more drivers prone to risky practice on the road, are less likely to be acknowledged. In comparison, Subic is of a smaller scale which may also be a reason why drivers in the area tend to abide by the rules more.

3.3 Research Methodology

3.3.1 Observation Study

The study will conduct traffic observation studies at both intersections by capturing video footage of the intersection and the corresponding road segments during specific hours. To ensure that the data is aligned with the peak traffic hours in each city, the researchers will seek permission from relevant authorities and utilize the data that is available to them and CCTV footage for analysis; these will be considered as secondary data.

Primary data will be collected by the researchers themselves through manual traffic volume counts. Additionally, specific driver behaviors that meet the criteria for aggressive driving will be observed through the video footage and recorded as quantitative data. A total of 4 recordings will come from each city, with one-hour long recording during peak traffic hours and another during lean traffic hours, both for the intersection and two leading road segments. This approach aims to analyze vehicle behavior before entering the intersection and during traffic light cycles. For reference, *Fig. 2* and *Fig. 3* provide an overview of the areas covered in the video footage.

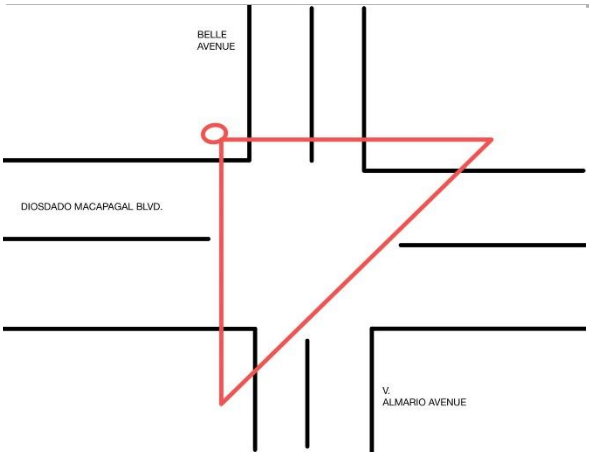

Fig. 2 Position of CCTV Used for Observation in Paranaque City

The method of obtaining recordings differs between Paranaque and Subic. In Paranaque, CCTV cameras were available and are in place, enabling easy retrieval of recordings and manual observation from an office setting. For Subic's chosen intersection, the researchers were unable to access CCTV recordings as no cameras were installed in that area. Nonetheless, permission was obtained to manually record in the Subic intersection.

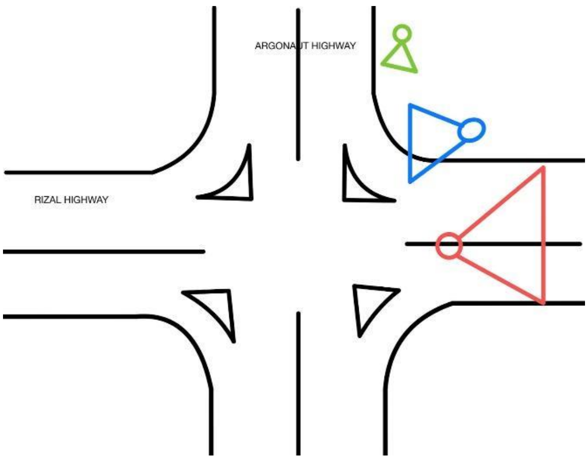

Fig. 3 Position of CCTV Used for Observation in Subic City

Considering that both cities have distinct population densities, using percentages becomes advantageous for standardizing the comparison. Since the context of the data remains similar, employing percentages allows for easier interpretation and comprehension of the magnitude of differences between variables in this study.

3.3.2 Defining Specific Driver Behaviors

When gathering the selected data, the researchers established specific parameters for each behavior to be considered as aggressive driving on the road. It is important to note that the listed behaviors are not necessarily road violations but are classified as aggression on the road. While there are numerous other behaviors that could be observed, the researchers decided to focus on the following ones: stoplight violations, blocking of pedestrian lanes, driving in the wrong lane, unnecessary and prohibited lane changes, failure to yield, not giving way to emergency vehicles, and overtaking in an unsafe manner. Although there might be other considerations for these behaviors, they were not included in the analysis if they were not observed at the intersections. The chosen behaviors are instrumental in gauging the driving environment of both cities.

3.3.3 Officer Interviews

Obtaining insights from chief officers responsible for traffic management can be highly valuable in this study, as they play pivotal roles in problem identification, decision-making, policy development, and enforcement. Additionally, these officers are important in the infrastructure planning process and collaborating with various stakeholders to address the issues at hand. Their access to critical information about the road environment—traffic flow patterns, accident statistics, and volume count data—provides them with the means to regularly analyze driver behavior patterns. For law enforcement agencies, this data could be helpful when they make data-driven decisions, ultimately leading to enhanced traffic safety and management.

3.3.4 Metro Manila Authority Work Management versus Subic Authority Work Management

Both government agencies are responsible for managing their respective regions. They have similar goals of improving and developing the system for a better experience in the area. However, they are not entirely the same in their approach to management. Geographically, Metro Manila is composed of 16 urbanized cities and is within the National Capital Region. Subic is in Zambales and SBMA only covers the Subic Bay Freeport Zone—the area open for locals and tourists. Other differences include governance structure, management focus, and role in economic development. The differences between these government agencies will be expounded more on in the latter part of the paper. This will be used as supporting data to explain why even if both managements are alike, there are differences to explore to see if improvement can be found.

3.4 Research Design

Data from Paranaque will be gathered through manual counting through CCTV footage provided by ASEANA One to the researchers. These kinds of requests are subject to approval by the security officer in-charge. Data from Subic will be gathered from the video recording the intersection and road segments; the capturing of videos is also subject to approval by the officer in-charge of SBMA. The recordings last for one hour each and show the behavior of vehicles during its peak hours and off-peak hours. After which, this will be analyzed by the researchers to assess the behavior of drivers at that certain hour.

Analyzing it will include formulas, models, methods, and observations to help interpret data. The researchers will use the level of urbanization diagram, triangulation analysis, and participant observation. The results of this study will be portrayed in the form of charts and graphs to be able to present them in a way that shows how critical the factors are; some charts to mention are rose plots, bar graphs, and line graphs. From the results, the researchers can recommend ways to help solve the issues affecting driver behavior.

4. Data Analysis

This chapter presents the results gathered from the process done. Moreover, the process of how it was analyzed and the findings in the study will be discussed. The study included vehicles passing through intersections. Observations of whether they showed aggressive driving behavior or not will be shown in the following tables and graphs.

4.1 Comparison of Violation Counts (%)

To better understand and compare the data collected, it is necessary to present the data in percentages. This is because Subic and Paranaque have different volume counts, which could affect the number of violations.

Paranaque showed a higher count percentage in all violations except for driving in the wrong lane. As seen in *Fig. 4*, Paranaque dominated four violations: stop light violations, unnecessary lane change, failure to yield, and overtaking. Stoplight violations may occur more in Paranaque, especially during peak hours, because drivers tend to rush to their destinations, sometimes beating the red light to lessen their time on the road. "It was determined that countdown timers create a sense of urgency for drivers in the last 5 seconds —as do blinking lights during the blinking phase — increasing the tendency to speed up in both types of lights' warning phases." (Felicio et al., 2015). With that being said, when vehicles speed up during the yellow light, there is a big possibility that they will most likely be caught beating the red light while they are still in the intersection. Yellow lights must be a warning light for drivers to slow down, not speed up.

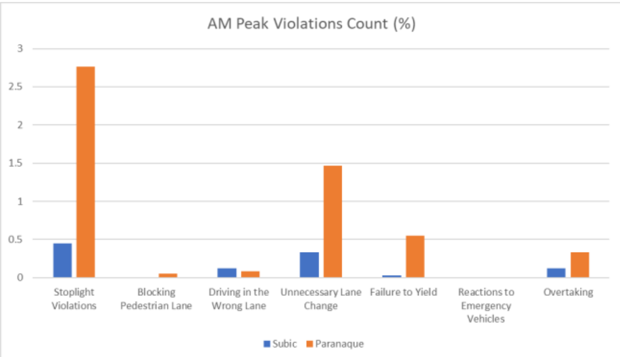

Fig. 4 Subic vs. Paranaque AM Peak Violation Count (%)

As seen in *Fig. 5*, the violation count percentage of Paranaque significantly dropped to less than half of the AM peak violations count percentage. While, the violation count percentage of Subic only slightly decreased. The decrease in both violation counts can be attributed to lesser congestion during the off-peak hour. "The correlation found in the present study between rush-hour driving and ordinary violations might indicate that violating behavior actually pays off in rush-hour traffic." (Lajunen et al., 1999). Unlike the AM peak, stoplight violations flipped, with Subic tallying higher numbers than Paranaque.

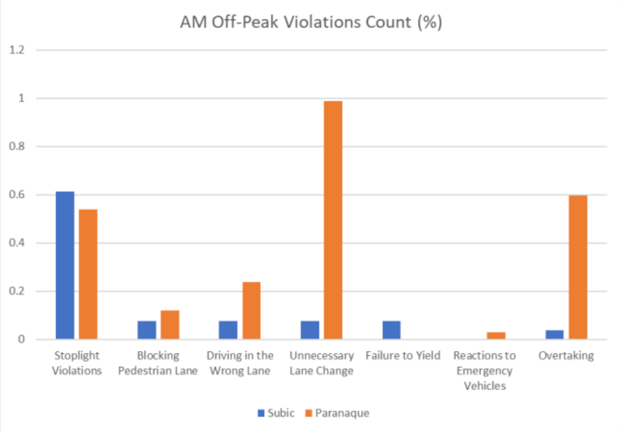

Fig. 5 Subic vs. Paranaque AM Off-Peak Violation Count (%)

Fig. 6 reveals a slightly higher number of violation counts in Subic than in Paranaque. Notably, this particular hour stands out from the other three observed hours, as it is the only hour where Subic recorded a higher total percentage, nearly double that of the preceding hour. Compared to the previous two hours, Subic experienced an increase in violation counts for various infractions, including blocking pedestrian lanes, driving in the wrong lane, failure to yield, unnecessary lane changes, and overtaking.

The emergence of Subic with a higher violation count percentage than Paranaque may be attributed to factors beyond the scope of this research, such as psychological influences on drivers or external elements impacting intersection behavior. However, it is essential to note that the difference in violation count percentage is not substantial enough to indicate a complete shift in results.

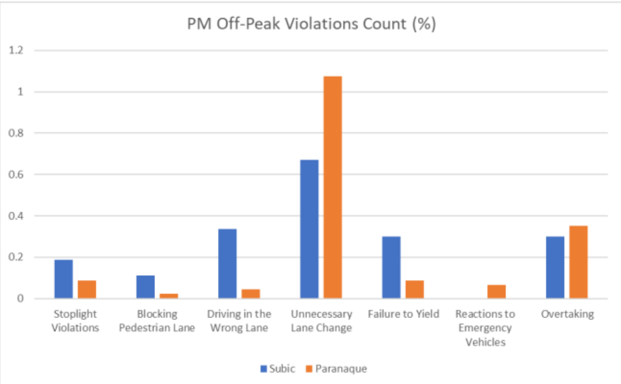

Fig. 6 Subic vs. Paranaque PM Off-Peak Violation Count (%)

Fig. 7 presents the violation count percentages for Paranaque and Subic. Notably, the value for Subic decreased to just over half of the previously observed hour. In contrast, Paranaque experienced a slight increase in violation count percentage. Among all violations, unnecessary lane change contributed the most to the total value for Paranaque.

However, when comparing the PM peak hour to the AM peak hour, both cities exhibited improvement in violation count percentage. This improvement could be attributed to drivers having a greater sense of urgency in the morning as they rush to reach their workplaces than when they return home.

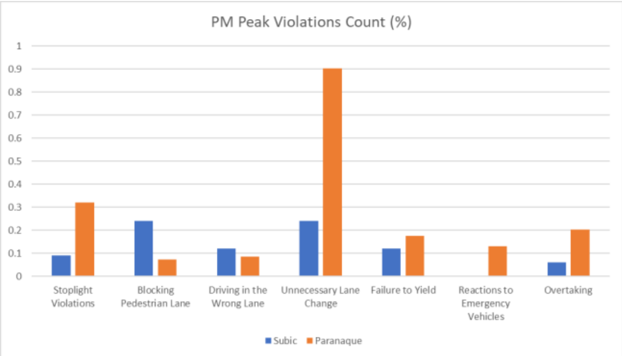

Fig. 7 Subic vs. Paranaque PM Peak Violation Count (%)

Fig. 8 presents the violation count percentages for both Paranaque and Subic, revealing an overall higher violation count percentage for Paranaque. Specifically, Paranaque recorded the highest number of violations during the AM period compared to the PM period, with the AM peak hour having the highest count. In contrast, Subic had a higher violation count during the PM period, with the PM off-peak hour registering the highest count. Consequently, it can be inferred that a greater number of drivers in Paranaque engage in violations compared to those in Subic, given the significantly higher violation count in Paranaque.

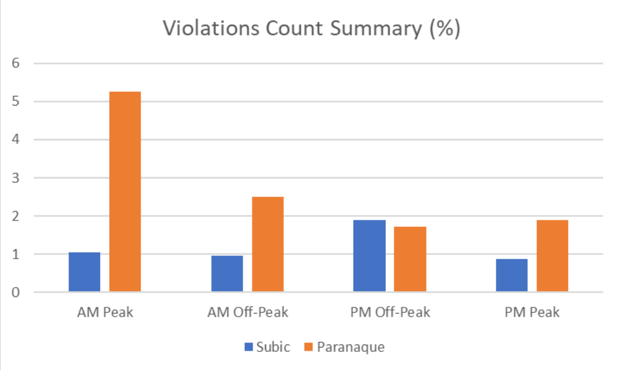

Fig. 8 Subic vs. Paranaque Violation Count Summary (%)

4.2 Comparison of Peak and Off-Peak

The study revolves around the counting of vehicles at a certain time to see how many vehicles travel at a certain time. For this study, volume counts were compared during the peak hour and off-peak hour to see what effect it may have on the driver's behavior. More importantly, volume counts are important to determine which area will need improvement for overall effectiveness. The summary of the volume count in the chosen intersection of Subic City is shown in *Table 1*. The results show that cars and motors have the highest volume in terms of occupancy on the road. For peak and off-peak hours, the highest vehicle count also varies. In addition, not all types of vehicles were present in Subic. The number of taxis was also very minimal. More shuttles and buses were passing by this intersection during the peak hours shown. The volume of motorcycles in the area proved to be much higher in the peak hours. Most cars and trucks made their trips during the off-peak hours. There are less modes of transport for commuting in the area since taxis and jeeps seldom pass through the area.

Paranaque City, on the other hand, has a higher volume count for cars than motorcycles. The volume of vehicles passing through the intersection is highest at PM peak. Paranaque City is known for having various accessible intersections for vehicles to pass through and maneuver through traffic. *Table 2* shows that PM peak is greater than AM off-peak, AM peak, and PM off-peak. Cars and motorcycles were highest during this period. Trucks also followed the peak hours of Paranaque as this showed the highest volume count for that specific category.

Table 1 Subic City Road Segment Volume Count Per Hour

	Volume Count							
	AM Peak		**AM Off-Peak**		**PM Off-Peak**		**PM Peak**	
	Rizal Hwy.	**Argonaut Hwy.**	**Rizal Hwy.**	**Argonaut Hwy.**	**Rizal Hwy.**	**Argonaut Hwy.**	**Rizal Hwy.**	**Argonaut Hwy.**
Car	692	383	867	529	856	541	861	500
UV	0	0	0	0	0	0	0	0
Bus	59	63	13	0	50	16	14	59
Taxi	0	0	0	0	1	0	8	0
Jeep	3	4	1	4	1	4	1	8
Motor	185	588	84	114	137	185	130	683
Truck	30	10	63	47	46	49	52	21
Bike	10	21	6	10	0	6	5	21
	979	1069	1034	704	1091	801	1071	1292

Table 2 Paranaque City Road Segment Volume Count Per Hour

	Volume Count							
	AM Off-Peak		**AM Peak**		**PM Off-Peak**		**PM Peak**	
	Macapagal Blvd.	**Belle Ave.**	**Macapagal Blvd.**	**Belle Ave.**	**Macapagal Blvd.**	**Belle Ave.**	**Macapagal Blvd.**	**Belle Ave.**
Car	1792	97	1965	185	2,326	187	3581	239
UV	0	2	0	0	0	0	0	1
Bus	223	0	249	1	325	5	474	6
Taxi	15	15	55	6	180	13	178	31
Jeep	26	3	41	1	60	0	45	0
Motor	576	74	502	20	717	72	1197	66
Truck	16	1	38	2	54	3	74	1
Bike	124	18	18	7	17	3	42	1
	2772	210	2868	222	3,679	283	5591	345

4.3 Officer Interview

Question	Answer
Interviewer: Can you state your name?	Paranaque: Mr. Chan Braganza, Security Operations Head of Aseana One
	Subic: Officer Roland Lomboy, Officer-in-charge of the traffic branch
What is your opinion on the current situation of traffic and road environment in Paranaque/Subic?	MMDA has done significant improvements to help improve the road in terms of main thoroughfare. One of the challenges we have in the Philippines is that if you see the ranking in terms of hierarchy it is always pedestrians, bikes, then cars, but here it is every man for himself - who gets their first and the hierarchy is hardly followed in the Philippines as a whole.
	-
How do you collaborate with other relevant departments or agencies to address road-related issues effectively?	Regular meetings with concerned stakeholders, whether it be MMDA for road safety.
	The SBMA have not been given the authority to confiscate licenses by the LTO.
What technologies or tools are utilized to enhance road safety monitoring, enforcement, and incident response?	We have an integrated operations center which helps ensure safety and security and ensure traffic rules and regulations are followed within the estate, and it is real time. For example, personal KPI, which I set here is for our Delta and Shield units, these are our emergency first responder teams, is 5-minute KPI.
	When there are emergency vehicle coming from different directions, those are the vehicles we prioritize (Referring to the manual adjustment of traffic light signals)
What improvements in facilities could be improved on for MMDA/SBMA?	They have always been supportive of us. However, I think consistency and performance of services can be improved.
	We are hoping that the LTO accepts our request to be given the authority to confiscate licenses. Besides this, we are also hoping that they allow us to link our database with theirs.
Are you very strict in issuing tickets or is there a degree of leniency?	There is a degree of leniency. If we are able to give a lesson and if it more impactful then I prefer to give a feedback than giving a ticket. The thing is it is abused or can be taken advantage of. It also depends on the judgement of the officer.
	Enforcing traffic rules is a strict job although we are still open to considerations. It's possible that we simply give verbal warnings instead of outright giving a ticket although this always depends on the enforcer's discretion.

From the answers given in the interview, both the intersections in Subic and Paranaque have similarities in the way that they are managed. For example, both areas have cameras and enforcers watching intersections so that they can manage traffic in real-time by communicating with their operations center. Besides this, they are also willing to be lenient with motorists and warn first-time violators to educate them over simply ticketing them although this is still dependent on the judgment of their enforcers. Some of the areas that they contrast in are that the SBMA has no authority to take licenses or access to the database of drivers that the LTO has, making it difficult for them to follow through with the tickets they serve. Comparing it to the management in Paranaque, where the enforcement includes ASEANA traffic enforcers and is supported by MMDA since this is still located within Metro Manila. This gives them a greater ability to follow through with violations and, in some cases, confiscate licenses if necessary.

Additionally, both officers in charge have provided some of their insights on the traffic situation in both the area they manage and the other area, as well as the behavior of drivers in the Philippines. One of the stated challenges was how drivers would drive "every man for himself," where drivers prioritize getting to their destination first over caring for pedestrians and bikes.

4.1 Two-Tailed t-test with Unequal Variance

To prove that the differences between the risky behavior that was observed between the two locations is significantly different, a two tailed t-test with unequal variance was performed in Microsoft Excel using the percentage values that were calculated for a fair comparison. An alpha of .05 was used with the H_0 stating that there is no significant statistical difference between the mean values of the violations between Subic and Paranaque while the alternate hypothesis states that there is a statistically significant difference between the data obtained.

Table 3. Subic City Road Segment Volume Count Per Hour

Behavior	t-Statistic	P(T<=t) two tail	t-Critical two tail
Stoplight Violation	-0.20641	0.84330	2.44691
Blocking Pedestrian Lane	0.45459	0.66539	3.18245
Driving in the wrong lane	0.68808	0.51710	2.44691
Unnecessary Lane Change	4.40317	0.00455	2.44691
Failure to Yield	0.53481	0.61201	2.77645
Reaction to Emergency Vehicles	2.00987	0.09117	3.18245
Overtaking	2.38583	0.05433	2.57058
Total	2.98471	0.02449	2.44691

Table 3 shows the collated results of the t tests performed for each of the behaviors that the researchers observed. Out of the obtained t-statistics, the values that are not within the critical values are the unnecessary lane changes and total violations per area. Besides this, overtaking notably goes past the critical values for a one tail t-test but not for the two-tail t-test.

The results of the t-test show that overall, there is a significant difference between the number of risky behaviors that motorists engage in between the two areas. However, if individual observed behaviors are to be compared, only unnecessary lane changes were found to be significantly different while all other violations were found to have no significant differences between the means when performing a two-tailed t test.

5. Conclusion

Improving road safety, reducing traffic congestion, and promoting responsible driving habits are major objectives in creating a safer road environment. Addressing the negative impacts of aggressive driving and its danger to other road users necessitates implementing the following measures: creating policies for continuous service improvements, providing consistent training for enforcers, instilling discipline among authorities and road users, promoting safer roads and public transport usage, and educating road users.

Data analysis reveals that stop light violations, blocking of pedestrian lanes, unnecessary lane changes, and driving in the wrong lane were more likely to occur as aggressive driving behaviors. These actions hinder safe driving, particularly during peak hours. Although not all driving behaviors significantly disrupt traffic flow, numerous behaviors are relevant to this study. Even with traffic congestion, road users tend to force their way into traffic lanes without yielding to others, affecting road safety. Relating this to the answers given in the interviews, there are multiple similarities that can be seen in the approach that both of the management authorities take in handling offenders and in how they oversee their respective areas. This is not to say that management is exactly the same in both areas as a thorough study of their organizations was not done in this study and may be done by future researchers in order to develop a more detailed comparison.

Drivers exhibit differences in behavior when placed in different environments due to the unpredictable psychological aspect. The role of the environment is crucial in shaping a driver's perception and actual behavior. External factors in the environment may be due to road designs, traffic conditions, and the enforcement of laws. Road users have their own way of reacting to these differences; some would be more cautious and abide, while some could become confused and frustrated, affecting driver behavior. In addition, human behavior is very complex and varies from person to person. One's perception, cognitive load, and emotional state are external factors that are not within the reach of the researchers or authorities. The combination of external factors and the psychological aspect make it challenging to predict precisely how drivers would behave in different driving environments. This, together with the diversity of human personalities and experiences, make the topic more complex. Understanding these complexities is crucial for formulating strategies to promote road safety and responsible driving habits.

The increasing prevalence of cyclists, E-bikes, E-tricycles, and motorcycles on the road calls for management to emphasize the risks involved for them to implement policies to safeguard all road users. Addressing issues like abusing lane splitting should be a priority since cars and truck drivers may not always be aware of motorcyclists splitting lanes. A recommendation for this is to make clear the guidelines and regulations on promoting road safety awareness and wearing appropriate protective gear.

Future researchers may explore other behaviors and methods to conduct a more comprehensive study. Comparing driver behavior across different areas and applying the same methodology can yield valuable insights to improve road safety further.

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Degradation of the Retroreflectivity of Thermoplastic Pavement Markings in Bangkok Highways

Topic number: 3, Paper Identification number: AYRF2023-029
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Abstract

Road traffic markings serve as signals that govern the position and direction of vehicle operation, providing drivers with information to steer their vehicles within traffic lanes and apply proper acceleration and deceleration for safe movement on the road. Therefore, visibility of road markings is crucial, especially during nighttime or in conditions with low illumination. Driving at night becomes less dangerous when there are clearly visible road markings. The visibility of road markings at night can be measured by the retroreflectivity [1]. This study aims to investigate the deterioration of road traffic markings in Bangkok. It involved selecting four-lane roads with different ages of traffic markings within the range of 0-24 months. Random positions were chosen to measure the retroreflectivity of road traffic markings at every 500-meter interval. The analysis, conducted using linear regression, revealed that the retroreflectivity value of road traffic markings varies with their age, traffic exposure and percent of trucks and is influenced by the thickness of the markings. Additionally, the study found statistically significant differences in retroreflectivity values based on the positions of the road traffic markings.

Keywords: Pavement marking, Retroreflectivity, Linear regression model, Bangkok Highways

1. Introduction

Traffic markings on roads provide crucial information for drivers to control their vehicles within traffic lanes and choose appropriate speeds corresponding to the road alignment. Unclear road markings can lead to uncertainties for drivers in determining their vehicle position and selecting suitable speeds for straight or curved movements, thereby jeopardizing driving safety and increasing the risk of accidents.

The measurement of the clarity of traffic markings can be achieved through retroreflectivity values. Retroreflectivity (R_L) of road traffic markings is essential and should be regularly inspected and maintained during their service life. A vital component of traffic markings is the glass beads applied during the marking process, which significantly enhances retroreflectivity. In field tests, R_L values can be used to assess the aging condition of traffic markings. It has been proven that R_L measurement is the most efficient method for ensuring road safety. Previous research has indicated that expenditures on high-quality materials for the creation and maintenance of traffic markings are far less than the costs incurred due to road accidents, up to 60 times less [2]. Furthermore, studies have found that every 100 mcd/m^2/lx increase in RL value can reduce accidents at intersections by up to 23%, independent of weather conditions [3]. Despite this, there has been limited research on factors affecting the deterioration of road traffic markings in Bangkok. This study aims to identify the underlying factors contributing to the deterioration of road traffic markings in Bangkok and proposes ways to enhance and develop future traffic markings.

2. Literature Review

The retroreflectivity value is measured in milli-candela per square meter per lux (mcd/m^2/lx). According to the standards set by the Bangkok Metropolitan Administration (BMA), for freshly painted thermoplastic pavement markings, white lines should have a retroreflectivity value of no less than 300 mcd/m²/lx, and yellow lines should have a value of no less than 200 mcd/m²/lx, with a minimum thickness of 3 mm. Within 150-180 days of installation, the minimum retroreflectivity values for white and yellow lines are 75 mcd/m²/lx and 50 mcd/m²/lx, respectively [4]. The Manual on Uniform Traffic Control Devices (MUTCD) recommends minimum retroreflectivity thresholds of 50 mcd/m²/lx and 100 mcd/m²/lx for posted speed limits of 35 mi/h (56.4 km/h) or greater and 70 mi/h (112.7 km/h) or greater, respectively [5].

Factors influencing the retroreflectivity of road traffic markings include the choice of materials, particularly the use of glass beads applied to the markings, the technique used for applying the markings, the location of the markings, their age, thickness, traffic volume, and the quantity of trucks passing over the road [6,7]. Cleaning and environmental conditions, such as areas prone to flooding or parking, also play a role. Previous research has attempted to estimate the retroreflectivity of road traffic markings by surveying field data related to these various factors. Some studies focused only on the independent variable of the age of the markings, while others considered a combination of age, traffic volume, and other influencing factors [8].

The objective of this study is to investigate the degradation of road traffic markings due to various factors, including the age, traffic exposure, thickness of the markings, cleaning activities, and their specific location on the road.

3. Methodology

The roads used for this study are four-lane roads, with two lanes in each direction. The selected roads include Phuttha Bucha 36 Alley, Pracha Uthit Road, Rat Burana Road, Sakae Ngam Road, and Bang bon 5 Road as shown in Fig. 1. These five roads have different ages of traffic markings within the range of 0 to 24 months. For each road, random positions were chosen at every 500-meter interval, with at least 10 sections. At each section, measurements were taken at six points, which include lane edge lines adjacent to the sidewalk, lane dividing lines, and lane edge lines adjacent to the median, for both inbound and outbound directions, as shown in Fig. 2.

Fig.1 The observed roads

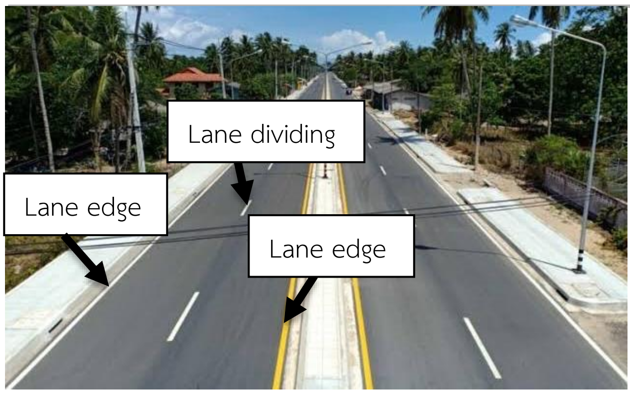

Fig. 2 Position of pavement markings

The retroreflectivity and thickness of the road traffic markings at these six points were measured, as depicted in Fig. 3.

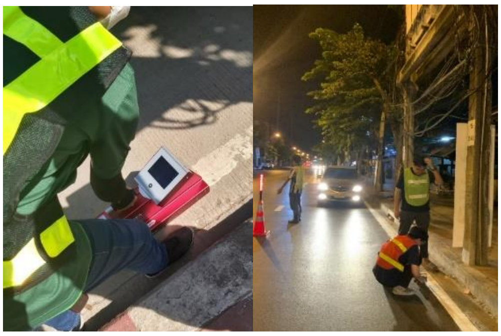

Fig. 3 Retroreflectivity and thickness measuring

To analyze the research data, the linear regression method was employed, with retroreflectivity as the dependent variable and the following independent variables: age of the traffic markings, traffic exposure, thickness of the markings, cleaning activities, and the position of the road traffic markings as shown in Table 1.

4. Results

The surveyed road traffic markings are divided into three positions as follows:

1. Lane edge line adjacent to the sidewalk: A continuous white line.
2. Lane dividing line: A dashed white line.
3. Lane edge line adjacent to the median: A continuous yellow line.

The surveyed road traffic markings have a width of 15 centimeters and vary in age within the range of 0 to 24 months. The mean values of retroreflectivity, categorized by the age of the traffic markings, are presented in Table 2 and Fig. 4.

Table 1 Descriptive statistics of variables used in this study

Variable name	Minimum	Maximum	Mean	S.D.
Continuous variables				
Retroreflectivity (mcd/m^2/lx)	9	674	174.34	149.26
Age (month)	0	24	9.66	8.09
ADT (veh/day)	1832	33190	1.450×10^4	6.928×10^3
Traffic Exposure (veh)	0	1.290×10^7	4.371×10^6	3.771×10^6
Percent of trucks	0.76	11.06	3.90	3.55
Thickness (mm)	0	4.69	2.23	1.06
Binary variables				
Line washing	0	1	0.17	0.37
Indicator for pavement marking type (1:white lane edge line; 0:otherwise)	0	1	0.36	-
Indicator for pavement marking type (1:white lane dividing line; 0:otherwise)	0	1	0.32	-
Indicator for pavement marking type (1:yellow lane edge line; 0:otherwise)	0	1	0.32	-

Table 2 The mean of retroreflectivity

Unit: mcd/m²/lx

Age (Month)	Lane Dividing	n	s.d.	White Edge	n	s.d.	Yellow Edge	n	s.d.
0	638.17	2	50.205	513.33	2	35.355	*	*	*
0.0028	526.67	3	76.812	415.67	2	70.239	*	*	*
0.0333	554.67	7	58.197	373.12	8	55.294	*	*	*
0.1333	526	2	29.227	435.17	2	142.6	*	*	*
2.5	283.95	14	49.396	118.14	14	57.4	177.4	10	34.913
3	199	6	51.792	169.61	6	54.287	173.22	3	7.456
4	379.74	23	87.911	294	24	102.417	278.33	12	42.248
9	72.8	20	21.795	149.8	20	67.776	90.38	20	37.044
12	54.48	9	15.059	64.87	10	18.841	95.33	10	46.521
13	36.45	11	30.003	62.38	12	34.226	83.04	12	50.459
24	57.22	13	18.258	68.65	26	22.675	60.15	26	15.268
Total	225.32	110	189.55	171.58	126	133.303	117.79	93	79.748

* Data not available

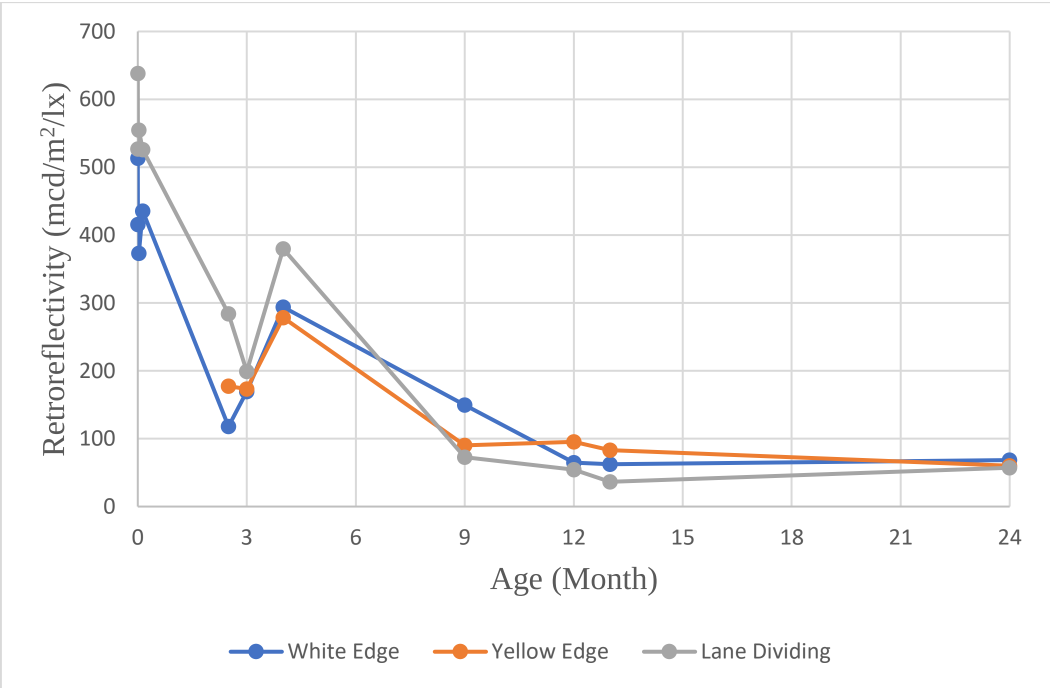

Fig. 4 Retroreflectivity by age in months

From the graph in Fig. 4, it can be observed that the retroreflectivity values of the freshly painted road markings are high, ranging from 370 to 640 mcd/m²/lx. However, within the first 3 months, the retroreflectivity values rapidly decrease. By the fourth month, the values start to increase again, and then gradually decline until the ninth month. After that, the retroreflectivity values of both the lane dividing lines and the lane edge lines adjacent to the median remain consistently below 100 mcd/m²/lx. Meanwhile, the retroreflectivity values of the lane edge lines adjacent to the sidewalk remain at an average of 150 mcd/m²/lx, decreasing below 100 mcd/m²/lx when the markings reach one year of age. Both the lane dividing lines and the lane edge lines have an average retroreflectivity value of approximately 60 mcd/m²/lx when they reach two years of age.

In the early stages, the retroreflectivity value of the lane dividing lines is higher than that of the lane edge lines adjacent to the sidewalk, mainly due to the different painting techniques used. The lane dividing lines are painted as dashed lines, while the lane edge lines adjacent to the sidewalk are continuous lines. During the painting process in the field, there are intermittent periods when the paint application and glass bead dispersion stop and resume. When the paint and glass beads are applied again, it results in a more consistent quality of markings compared to continuously applying the paint without interruptions.

From the graph in Fig. 5, it can be observed that the majority of the road traffic markings have a thickness not exceeding 3 mm, except for Bang Bon 5 Road (at 4 months old), which has traffic markings exceeding this thickness. Additionally, it is noticeable that road markings aged over 1 year tend to have a thinner thickness compared to those aged less than 1 year. Excessive thinness of the road markings can cause the glass beads to dislodge easily, leading to a reduction in retroreflectivity. Glass beads are crucial materials that aid in the retroreflection of road traffic markings.

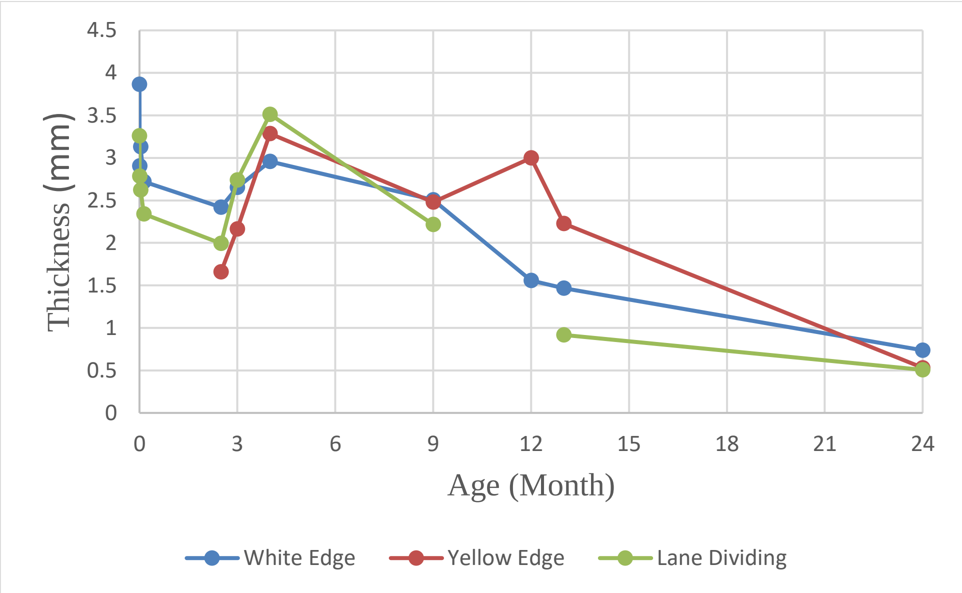

Fig. 5 Thickness by age in months

4.1 Retroreflectivity Based on Their Age

When analyzing the retroreflectivity values, age of the road markings, thickness, cleaning activities, and the position of the road markings using linear regression models, the results can be divided into two models: one for white road traffic markings and the other for yellow road traffic markings, as shown in Tables 3 and 4, respectively. The R-square values for the two models are 0.54 and 0.48, respectively.

Table 3 The model of retroreflectivity of white pavement markings based on their age

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	316.330	13.742		23.018	< 0.001
Age (Month)	-12.727	.978	-.603	-13.015	< 0.001
Line washing*	-117.715	19.654	-.275	-5.989	< 0.001
Lane dividing line**	32.697	14.836	.100	2.204	0.029

* Line washing = 1 if the line is cleaned and polished; else = 0

** Lane dividing line = 1 if the position of pavement marking is the middle line (dash line);
Lane dividing line = 0 if the position of pavement marking is an edge line (full line).

Table 4 The model of retroreflectivity of yellow pavement markings based on their age

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	140.206	28.500		4.920	< 0.001
Age (Month)	-5.062	1.208	-.467	-4.190	< 0.001
Thickness (mm)	22.303	8.419	.295	2.649	0.010

Both the white road traffic marking model and the yellow road traffic marking model show that as the age of the road markings increases, it significantly reduces the retroreflectivity values. Additionally, the white road marking model indicates that cleaning activities negatively affect the retroreflectivity values, and the lane dividing lines have higher retroreflectivity values compared to the lane edge lines adjacent to the sidewalk. On the other hand, the yellow road marking model also reveals that an increase of 1 mm in the thickness of the road markings leads to an increase of 22.3 mcd/m^2/lx in the retroreflectivity values.

4.2 Retroreflectivity Based on Traffic Exposure

When analyzing the retroreflectivity values based on traffic exposure, percent of trucks, thickness of the road markings, and the position of the road markings using linear regression models, the results can be divided into two models: one for white road traffic markings and the other for yellow road traffic markings, as shown in Tables 5 and 6, respectively. The R-square values for the two models are 0.61 and 0.82, respectively.

Table 5 The model of retroreflectivity of white pavement markings based on traffic exposure

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	213.191	29.831		7.147	< 0.001
Traffic exposure*	-1.994×10^{-5}	.000	-.444	-7.754	< 0.001
Percent of trucks	-15.707	2.049	-.346	-7.664	< 0.001
Thickness (mm)	50.950	9.190	.319	5.544	< 0.001
Lane dividing line**	58.362	14.897	.175	3.918	< 0.001

* Traffic exposure (veh) = ADT × Age × 30

** Lane dividing line = 1 if the position of pavement marking is the middle line (dash line);
Lane dividing line = 0 if the position of pavement marking is an edge line (full line).

Table 6 The model of retroreflectivity of yellow pavement markings based on traffic exposure

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	147.987	12.263		12.068	< 0.001
Traffic exposure*	-1.293×10^{-5}	.000	-.587	-11.143	< 0.001
Percent of trucks	-11.048	1.134	-.538	-9.744	< 0.001
Thickness (mm)	50.021	4.126	.663	12.123	< 0.001

* Traffic exposure (veh) = ADT × Age × 30

From the models in Tables 5 and 6, it can be observed that as traffic volume and the percentage of trucks increase, the retroreflectivity value decreases. The retroreflectivity values of lane dividing lines are higher than those of lane edge lines adjacent to the sidewalk. Additionally, when the thickness of the road markings increases by 1 mm, the retroreflectivity value increases by approximately 50 mcd/m^2/lx.

5. Conclusions and Recommendations

Road traffic markings provide crucial information for drivers to control their vehicles within lanes and select appropriate speeds corresponding to the road they are driving on. Unclear road markings can increase the risk of accidents while driving. The retroreflectivity value is one method that indicates the quality of road traffic markings.

The retroreflectivity values obtained from various road sections with differing ages of road markings within the range of 0 to 24 months. Apart from being influenced by the age of the road markings, retroreflectivity values are also affected by several other factors, including traffic volume, percentage of trucks, and the thickness of the road markings.

For this study, the selected road section with a 4-month age of road markings is Bangbon 5 Road. The retroreflectivity value of road markings on Bangbon 5 Road is higher than that of road markings with a 3-month age. This is because on this particular road segment, the traffic volume and the percentage of trucks are at moderate levels, and the thickness of the road markings is greater than 3 mm, which exceeds the average value. As a result, the retroreflectivity value of the 4-month-old road markings on Bangbon 5 Road is higher than the expected trend.

From the survey results, it was found that road markings degrade over time. White road markings are considered acceptable for use if their retroreflectivity value is not less than 75 mcd/m^2/lx until the ninth month, while yellow road markings are acceptable if their retroreflectivity value is not less than 50 mcd/m^2/lx and can be used for up to two years.

Road markings that are too thin will result in a rapid decrease in their useful life, as the glass beads may easily dislodge. When applying road markings, it is essential to control their thickness within the standard range (not less than 3 mm).

Cleaning road markings must be done with caution. Excessive abrasion of the surface can cause the glass beads to dislodge, leading to a reduction in retroreflectivity values.

6. Acknowledgment

The authors would like to express their gratitude for the financial support provided by the Department of Civil Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Thailand. They also extend their thanks to all the field staff and administrators from the Office of Traffic and Transport, Bangkok Metropolitan Administration, for their cooperation in providing data and granting permission to use the tools for conducting this research.

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SESSION 3.2B : AYRF 2023 RESEARCH PAPER PRESENTATION
From Paper ID: 2023-031, 2023-032, 2023-012, 2023-014

Paper ID	Paper Entitled	Presented by
AYRF 2023-031 Page 133-141	"Understanding Problems of Design Standard of Roundabouts in Thailand Using Comparison of Standards"	**Mr. Shogo ARAKAWA** Graduate School of Science and Technology, Nihon University, Japan
AYRF 2023-032 Page 142-150	"Survey of speed humps and bumps in Bangkok and analysis of effects by probe data"	**Mr. Hiroto SAKAI** Graduate School of Science and Technology, Nihon University, Japan
AYRF 2023-012 Page 151- 159	"May Electric Cargo Trucks Be Accepted in Developing Countries: A Case Study in Hanoi, Vietnam"	**Nguyen Thi Nhu** University of Transport and Communications, Vietnam
AYRF 2023-014 Page 160-168	"Enhancing Food Security in Hanoi Logistics and Transportation Chain for Pork"	**Mr. Do Mai Duong** University of Transport and Communications, Vietnam

Understanding Problems of Design Standards of Roundabouts in Thailand by Comparison of Selected Three Countries' Standards

Topic number:3, Paper Identification number: AYRF2023-031

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Abstract

In recent years, widespread roundabouts have been installed to create an intersection that allows vehicles to move through the intersection with minimal stopping worldwide. The criteria for ensuring the performance of roundabouts have been developed concerning the unique traffic states observed in each country. In Thailand, it is also proceeding to install roundabouts based on the standards. However, there are issues, such as the handling of the driving characteristics of motorcycles in the design of roundabouts in Thailand. This study clarified the problems that need to be considered in the design standards of Thailand through comparison with the standards of other countries and roundabouts introduced in Thailand. Additionally, the design of improved existing roundabouts was examined and compared traffic states by Mmicro traffic simulation software PTV VISSIM based on the criteria of each country. Consequently, there are problems with not considering motorcycles in the design procedure of the roundabout in Thailand. This study proposed necessary of the method of considering motorcycles and the calculation method for each geometric structure.

Keywords: Roundabout, Motorcycle, Thailand, Micro Traffic Simulation, Design Standard

1. Introduction

In recent years, roundabouts have been promoted as a viable alternative to traditional traffic signal intersections in many countries. Usually, due to different traffic situations in each country, roundabouts are designed according to standards depending on their traffic situation in each country. In Thailand, roundabouts are being implemented due to their cost-effectiveness and ability to control traffic flow safely and smoothly. Mainly motorcycles are widely utilized as the predominant transportation mode, leading to a unique traffic situation compared to developed countries.

However, the roundabouts in Thailand have been designed specifically for motorcycles, and there are issues that motorcycles and other vehicles are mixed running through roundabouts. Hence, the high risk of crashes is increasing on circular roads and their approaches at the roundabouts. A design standard for roundabouts needs to consider the traffic characteristics in Thailand for designing roundabouts with more safety and smoother traffic flow.

Therefore, this study aims to clarify above mentioned problems and factors considering the design standard of roundabouts in Thailand. This study compared the roundabout design standards between Thailand, Japan, and the United States. Additionally, the design of improved existing roundabouts was examined and compared traffic situations using micro traffic simulation software, "PTV VISSIM" based on the criteria of each country.

2. Literature Review

Kobayashi et al.[1] experimented with driving on aprons with different heights and materials by two types of vehicles, passenger cars and large trucks. They found that higher apron traversal speeds resulted in higher impact severity for both vehicle types in all cases of aprons.

Yoshioka et al.[2] analyzed characteristics of driving behavior in roundabouts with different geometric structures in Japan as the relationship between driving behavior characteristics and geometric designs. The results revealed that the corner curve radius of the inflow section and the intersection angle of the outflow and inflow sections are crucial factors influencing the lateral acceleration experienced by vehicles.

Also, Linh, et al.[3] clarified the microscopic characteristics of vehicles at roundabouts in Vietnam due to the increasing need for understanding the mixed traffic characteristics in developing countries. The results revealed that motorcycles continuously change speed and direction, and their maneuverability is limited by speed. Alfonso, et al.[4] compared the design standards for roundabouts in Italy and those in other countries. They identified that several issues in their design standards for roundabouts in Italy and proposed recommendations for its improvement.

However, there has been some analysis of the actual driving conditions of roundabouts, but none of these factors have been considered within the design standard in the existing studies. Therefore, this study clarified the problems of design standards of roundabouts in Thailand. Additionally, we proposed improving a design standard for roundabouts in consideration of traffic characteristics in Thailand.

3. Methodology

3.1 Outline of Analysis

Firstly, all roundabouts were observed to understand the situation of roundabout installment. Then, the observed roundabouts were classified based on three factors: the type of roundabout, the number of approaches, and the presence of a Motorcycle (MC) Lane. On the other hand, A comparative analysis was undertaken to evaluate the enhancements made in a roundabout geometric design in alignment with the respective design standards of different countries. Concretely, the current design standards of roundabouts in Thailand, Japan, and the United States were compared. Then, the roundabouts designed based on Thailand's design standards and the roundabouts installed in Thailand were compared in detail. Lastly, the traffic situation at the selected roundabout was analyzed based on image processing for video taken by UAV, and some countermeasures were evaluated by comparing traffic conditions using the Micro traffic simulation PTV VISSIM.

3.2 Roundabout in Thailand

This study firstly summarized the current distribution of roundabouts in Thailand and classified that. There are 2,231 roundabouts in Thailand. The results are shown in Fig. 1 to Fig. 3, described the classification of all roundabouts based on three key factors such as roundabout type, number of approaches, and the presence or absence of motorcycle (MC) lanes. In terms of roundabout typology, 93% of roundabouts have been installed as a 1-lane roundabout (Fig. 1). It was found that roundabouts with three and four approaches (for inflow and outflow) accounted for a large portion of approaches in Fig. 2. On the other hand, roundabouts with MC lanes has a significantly low percentage of only 0.18% (Fig. 3).

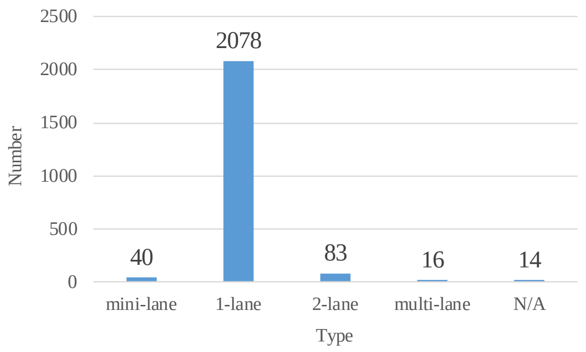

Fig. 1 Classification by roundabout types

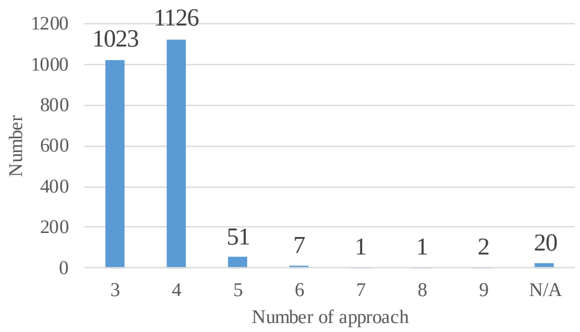

Fig. 2 Classification by number of approaches in roundabouts

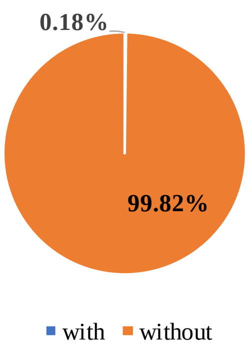

Fig. 3 Classification with MC-Lanes

3.3 Analysis Based on The Design Standard of Each Country

To compare the difference in design criteria for roundabouts, this study used the design standards in three countries; Guidelines for Designing a Roundabout (Thailand)[5), Roundabout Manual (Japan)[6), and Roundabouts: An Informational Guide (The United Status)[7). This study especially focused on the roundabouts design standard considering safety and smoothness in the design standards, such as the 1-lane roundabout in Japan.

Additionally, this study conducted a comparative analysis of the factors considered in each country following the guidelines and incorporated them into the micro-traffic simulation PTV VISSIM for evaluation.

3.4 Study Area

This study selected the roundabout located in Suranaree University of Technology, Nakhon Ratchasima, Thailand, one of 2,231 roundabouts in Thailand. This roundabout developed Thailand's design standard and has some geometric structure issues.

This study first collected the traffic volume and analyzed the characteristic driving behavior at this location using video data for one hour of traffic volume from Unmanned Aerial Vehicle (UAV).

Fig.4 Roundabout in Suranaree University of Technology

4. Results

4.1 Comparison of Design Standards

The design procedures for roundabouts in three countries are shown in Fig. 5 to Fig 7. Also, Fig. 8 to Fig. 10 show a comparative analysis of the design of the roundabouts by each country's design standard. According to Fig 5 (Thailand's design procedure), the design procedures do not incorporate specific considerations for motorcycles, and the design criteria do not explicitly account for motorcycles. Likewise, other countries' design standards do not include explicit protocols for considering motorcycles. This table provides an overview of the geometric attributes of roundabouts, designed by the respective design standards. Concerning the outer diameter, the roundabout constructed per Thailand's design standard shows a diameter of 50 meters, which is more significant than in other countries. Also, the height of the apron is 5.0 cm, while in other countries, it is 2cm or 3cm, indicating that Thailand has set a higher apron height compared to other countries. The travel speeds on circular roadways reveal a consistent range of 25-35km/h across all countries. Furthermore, the travel speed of each vehicle was decelerated below 20km/h at the approach of the intersection in all three countries. Moreover, it has been revealed that the entry speeds at roundabouts in Thailand are notably higher compared to other countries. The reason for that is related to the difference in the scale of the roundabouts and resulting in lower vehicle density within the circular road. Consequently, vehicles entering the roundabout find it easier to merge into the circular path, potentially leading to higher entry speeds.

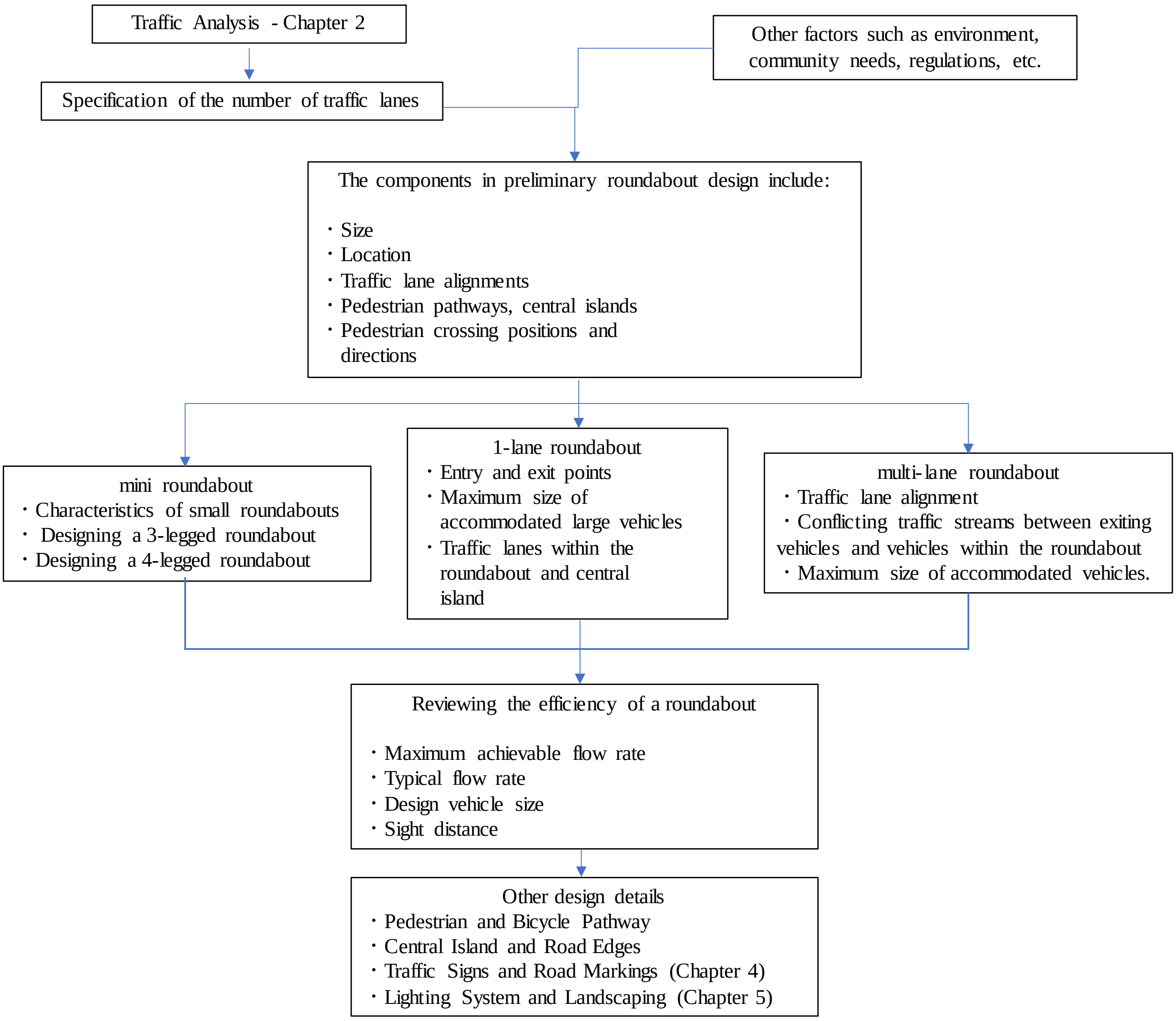

Fig. 5 Design standard of a roundabout in Thailand

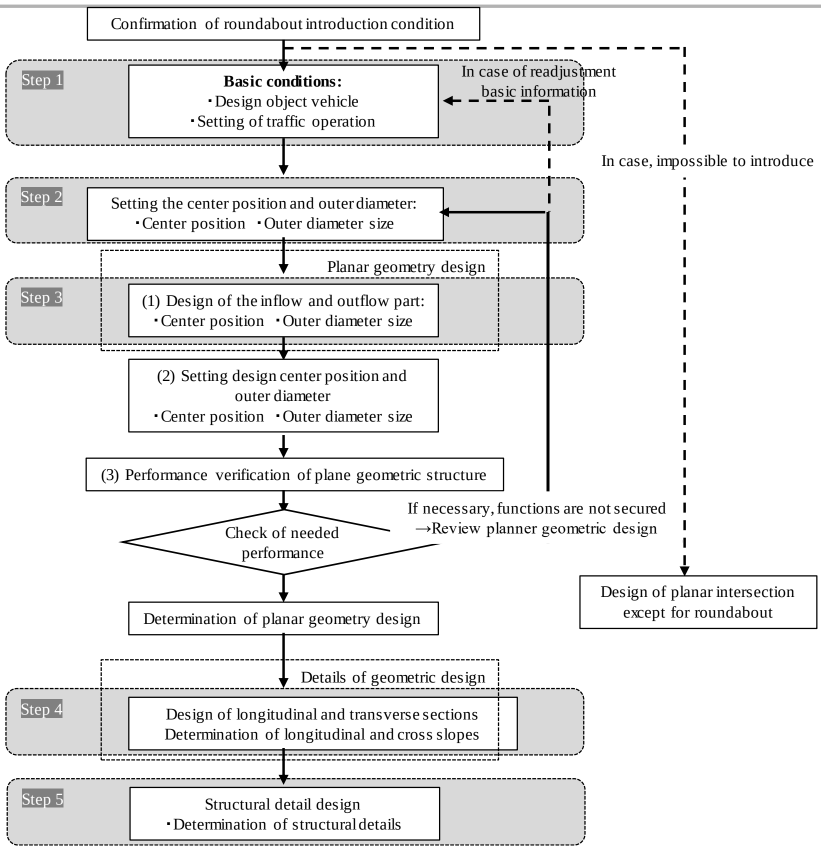

Fig. 6 Design standard of a roundabout in Japan

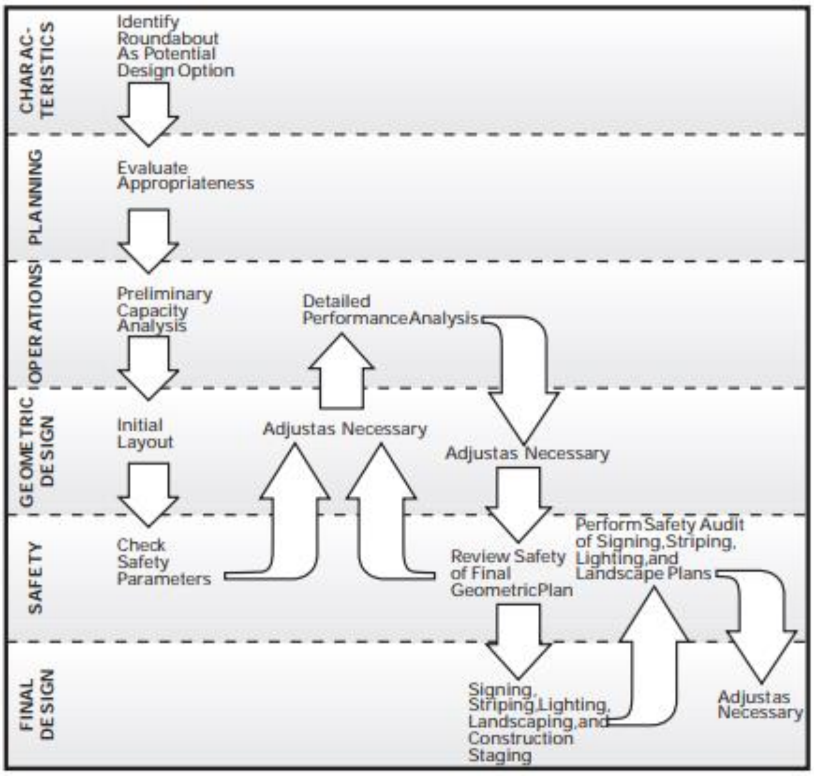

Fig. 7 Design standard of a roundabout in the United Status

Table 1 Comparison of roundabouts structure in Thailand, Japan, and the United States

	Thailand	Japan	America
Number of lanes on circular road	2-lane	1-lane	2-lane
Outer diameter	50m	28m	45m
Central island diameter	28.4m	14m	21m
Width of circular road	4.3m	5.0m	5.0m
Width of apron	2.2m	1.5m	2.0m
Height of apron	5.0cm	5.0cm	3.0cm

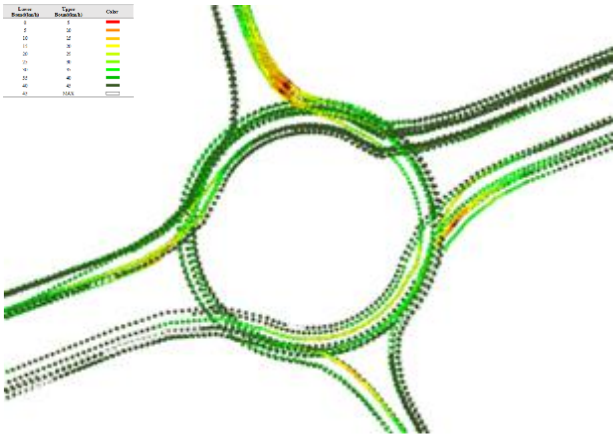

Fig. 8 Simulation diagram (Thailand)

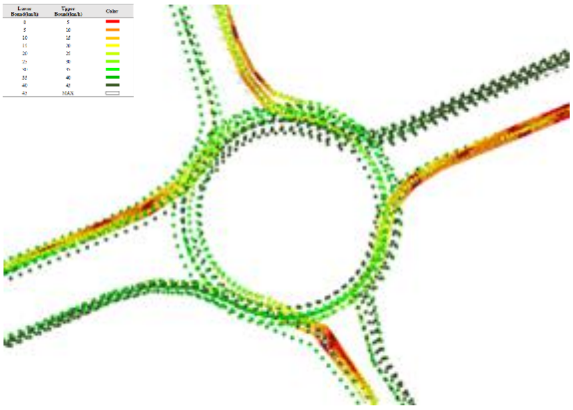

Fig. 9 Simulation diagram (Japan)

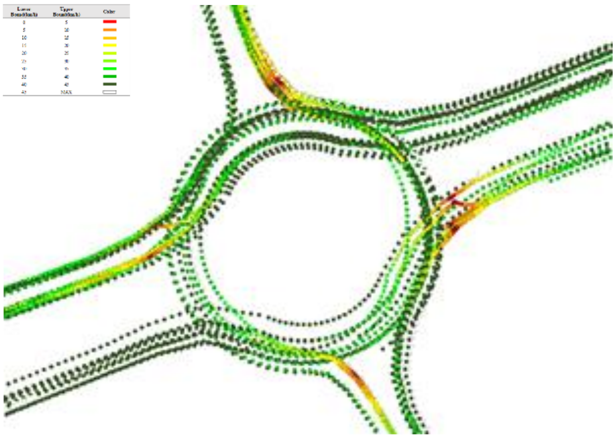

Fig. 10 Simulation diagram (The United Status)

4.2 Analysis Results of Roundabout of Case Study

The characteristics of the traffic situation in the study roundabout were analyzed based on the recorded video data. The hourly traffic volume by direction at each inflow site has shown in Table 3. Also, the modal share of vehicles at the intersection has shown in Fig. 11. Table and Figure show how the total traffic volume counted for 1,452 vehicles from the approach on the west side, which the traffic volume is roughly three times higher than the other approaches. In addition, the motorcycle occupied 34.5% of the total traffic volume at this intersection. Fig. 12 shows 51% of the total number of non-large vehicles passing on the apron. Fig. 13, a scene from the video data, was recorded at the intersection. It is also found that multiple motorcycles are observed traveling side by side within a single lane.

Based on the design criteria of the roundabout and Thailand, Table 4 summarizes the roundabout's geometric structure. The apron at the two roundabouts is one obvious distinction. The roundabout built according to Thailand's design standards has a width of 2.2 meters and a height of 5.0 centimeters, while the roundabout built at the target location has a broader width of 4.5 meters and a height of 0 meters, suggesting a lower apron height in comparison to the roundabout built according to Thailand's standards. Even though both roundabouts were created using Thailand's specifications, tiny differences in numerical values can be seen when examining the overall geometric structures. Each element's design requirement's ambiguity may be blamed for this difference. Thailand's roundabout design criteria offer a conceptual grasp of the design approach but do not offer detailed calculating techniques for different geometric structures. Using the apron as an example, Thailand's design guidelines state that the turning radius of trucks determines the apron width, but they do not specify how this calculation is made. Therefore, the numerical values for diverse geometric structures may become unclear under the same site conditions, resulting in variances in the numbers given by various designs.

Table 2 Traffic volume in roundabout

	North	East	South	West
Left turn	96	84	128	192
Straight	108	176	52	1080
Right turn	108	84	128	180
U-turn	0	116	0	0
sum	312	460	308	1452

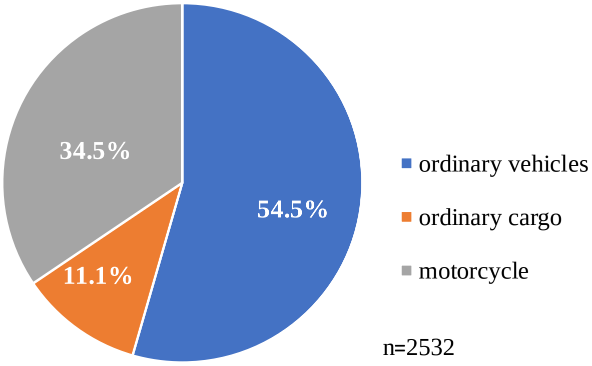

Fig. 11 Ratio of car types

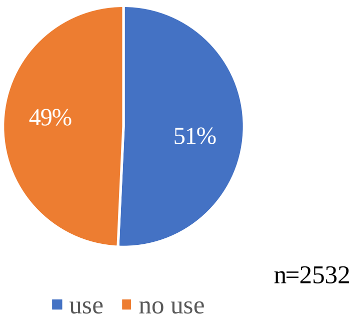

Fig. 12 Aprons usage in roundabout

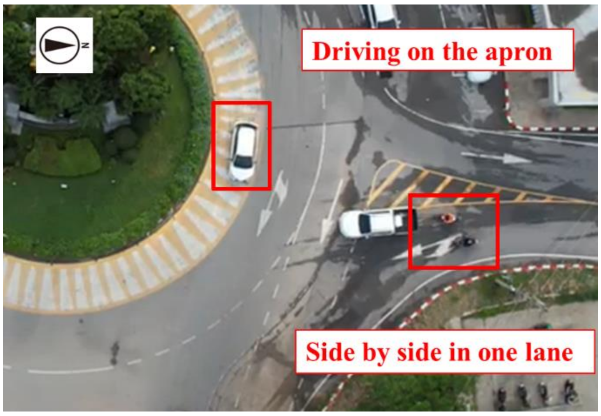

Fig.13 Movie screenshot of the North approach

Table 3 Comparison of target roundabout and standard in Thailand

	Thailand	Target RAB
Number of lanes on circular road	2-lane	2-lane
Outer diameter	50m	45m
Central island diameter	28.4m	20m
Width of circular road	4.3m	4.0m
Width of apron	2.2m	4.5m
Height of apron	5.0cm	0m

A micro-traffic simulation was employed to conduct a comparative analysis of the current situation of the roundabout and the design of the roundabout by the design standard of Thailand, as shown in Fig. 14 and 15. These Figures also illustrate the travel speed, which was classified by the same standard as Table 2. Regarding the travel speed within the circulatory roadway, it is evident that the target location exhibits speeds ranging from 20 to 25 km/h. Conversely, the roundabout constructed by Thailand's design standard demonstrates travel speed ranging from 30 to 40 km/h.

Additionally, both roundabouts decelerate as they approach the intersection considering the speeds at the entry, but the target location has speeds of 0-15 km/h, while the roundabout created using Thailand's design standard has speeds of 15-20 km/h, indicating that the circular roadway has lower entry speeds. From these observations, it can be concluded that the average travel speed at the intersection is lower, indicating a difference in the smoothness of the intersection.

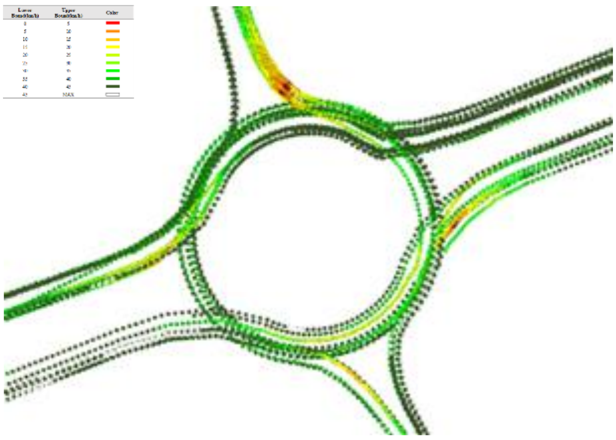

Fig. 14 Simulation diagram (Thailand)

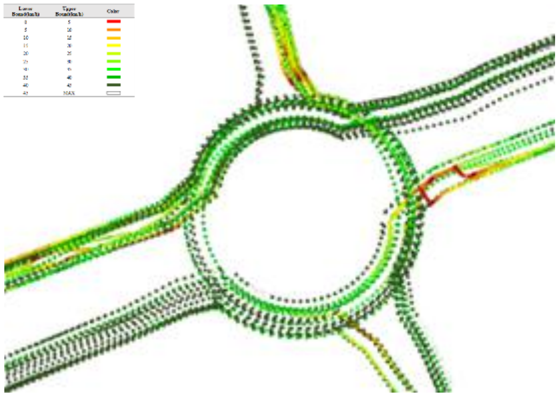

Fig. 15 Simulation diagram (study roundabout)

5. Conclusion

This study clarified the problems of the design standards for roundabouts in Thailand. For example, concerns include the lack of consideration for motorcycles in the design process and the ambiguity of numerical values within the design standards. In order to clarify the difference in traffic states by the design standard of Thailand, Japan, and America, this study compared the traffic states as the case study of the roundabout in front of the Suranaree University of Technology to installation based on individual design standard and current situation by PTV VISSIM. From these analysis results, it is necessary to mainly consider motorcycles and calculate specific numerical values for each geometric structure as essential items when formulating design standards for roundabouts in Thailand.

In particular, many points have not been clarified regarding the method of considering motorcycles, such as the driving characteristics of motorcycles at roundabouts, specific measures when considering motorcycles, and the effects of their introduction, such as MC lane. This study concluded that it would be essential to pay attention to how motorcycles drive in roundabouts, understand how they drive in roundabouts, and add the procedure in design standards for the consideration of motorcycles. v

6. Acknowledgment

Some of the analysis in this paper was carried out based upon the outcomes from ATRANS Roundabout Research Project. The authors would like to express our appreciation for this project.

Especially, we would like to thank Prof. Dr. Sittha Jaensirisak, Dr. Tuenjai Fukuda, Prof. Dr. Atsushi Fukuda for support in advising, and Dr. Ratthanaporn Kasemsri provided the UAV video data in Nakahon Ratchasima, and Dr. Phongphan Tankasem, Dr. Thanapol promraksa, Dr. Piyapong Suwanno, Mr. Chaiwat Yaibok for analysis of nationwide roundabouts situation.

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Survey of Speed Humps and Bumps in Bangkok and Analysis of Effects by Probe Data

Paper Identification number: AYRF2023-032

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Abstract

Speed humps and bumps are widely used as traffic calming devices on Local Government Roads (LR) throughout Thailand, including in Bangkok's central area. However, the absence of installation guidelines has resulted in limited engineering-based designs. Moreover, these devices are installed in diverse locations and shapes, with no consolidated information on their placement. The objective of this study is twofold: firstly, to comprehend the distribution and condition of these devices in Bangkok's central area, and secondly, to verify their speed reduction effectiveness using probe data. The results revealed a total of 1400 devices, with the majority installed on pass-through roads. Only a mere 2.7% of all devices had speed humps with road markings and signs on both sides. Furthermore, 290 devices (20.67% of the total) were found to be damaged, raising concerns regarding device efficacy and safety. To ensure their effectiveness and safety, it is essential to establish manuals and management systems for device installation and operation. Subsequently, statistical analysis of ITIC probe data was conducted, dividing sections into deceleration and acceleration areas around devices and sections with free-flowing speeds between devices. For low bumps with low height and short length, no statistically significant difference in speed reduction effect was observed. Conversely, speed humps with uniform road markings, sufficient height, and length showed a statistically significant difference, revealing a maximum speed reduction effect of up to 40%. Therefore, ensuring the effectiveness and safety of the devices is of utmost importance, and proper maintenance and management are essential, not just installation. Moreover, it has become evident that utilizing probe data can assist in streamlining these processes.

Keywords: Speed hump, Speed bump, Traffic safety, Probe data

1. Introduction

Road deaths are on the rise, especially in Southeast Asia. According to WHO (1), Thailand has 32.7 road deaths per 100,000 population, which is the 9th highest in the world and the highest in Southeast Asia. Therefore, Thailand is now urgently considering traffic safety measures.

According to Department of Rural Roads, Ministry of Transport of Thailand (2), The total length of roads in Thailand is 696,689 km, of which 51,816 km are under the jurisdiction of the Department of Transport (DOH), 47,303 km are under the jurisdiction of the Department of Provincial Roads (DDR), and the remaining 597,570 km (about 86%) are local roads (LR). According to the Thai National Police (3), there were a total of 83,508 traffic accidents nationwide in 2022, of which 23% were reported to be caused by speeding (4). This study, therefore, focused on humps, one of the traffic safety measures that could replace speed control on the LR, which has the longest road length. Speed control devices in LR include speed humps (including bumps and speed tables), rumble strips, and color pavement. Among them, there is a speed hump as a device that is most common and widely spread all over the country. In developed countries, guidelines for design and installation are created based on various studies, and devices are often installed based on these guidelines. On the other hand, in Thailand, some of them were designed by engineering, but there are also many that were installed voluntarily by residents. Their installation locations, shapes, installation conditions, etc. are not fully understood. In addition, there are some places that have deteriorated over the years since they were installed due to lack of proper maintenance after installation. In situations where unevenness occurs and the height of the hump is uneven, it is seen that some motorcycles are mediocre and wobbly as they run through areas with low unevenness. There may be.

Therefore, this study first investigates how many speed humps and bumps are installed and in what locations in Bangkok, using the Street View function of Google Map. Then, by analyzing taxi probe data in several selected sections and examining the behavior of vehicle speed near speed humps, this study aims to clarify the possibility of using probe data to understand the effect of speed humps and bumps on speed suppression.

2. Literature Review

Parkhill et al. (5) organized the experience of agencies implementing speed humps through extensive literature research to update the Recommended Practice published by the Institute of Transportation Engineers (ITE) in 1997. A literature survey was conducted by an online survey covering North American and international jurisdictions and yielded nearly 300 responses. Analysis showed that most agencies installed speed humps 3 to 3.5 inches (76 to 90 mm) high with travel lengths of 12 to 14 feet (3.7 to 4.3 m). Speed bump geometries were generally found to be 3 to 6 inches (76 to 152 mm) high with travel lengths of 1 to 3 feet (0.3 to 1 m). In addition, It was found that speed humps and bumps have critically different impacts on the vehicle. On residential roads, vehicles slow down to about 20 mph (32 km/h) when speed humps are installed at appropriate intervals. Speed bumps, on the other hand, cause the driver significant discomfort with the vehicle generally slowing down to less than 5 mph at each bump.

Satiennam et al. (6) studied three-speed humps and three-speed bumps within the campuses of Khonkaen University and Mahasarakham University in Thailand. They investigated the impact of these devices on vehicle speed. Average speeds were statistically compared for 12 sections at 10-meter intervals, differentiating between cars and motorcycles. The study found that smaller speed bumps effectively controlled the speed of motorcycles, but they had diverse effects on drivers' behavior. Furthermore, the study indicated that the impact of these devices on motorcyclists was limited to a short distance (approximately 20 to 30 meters) before and after the device.

Hallmark et al. (7) evaluated the effects of temporary speed humps and speed tables on vehicle speed, speed profiles, and traffic volume in several local cities in Iowa, USA. These temporary devices were made of recycled rubber and were movable. The results showed that the speed reduction effect was limited to the immediate vicinity of the devices. The number of vehicles exceeding the speed limit decreased significantly in the vicinity of the devices. However, the study pointed out that continuous device installations would be necessary to achieve speed reduction throughout the entire block. Regarding the spacing between devices, the study suggested that the driver's choice of speed could be influenced by factors such as road width, roadside environment, road shape, adjacent land use, and trip type, and thus, the optimal spacing of devices would vary depending on the road conditions, necessitating adjustments according to the situation.

Kojima et al. (8) conducted experiments in Tokyo, Japan, using sine-wave-shaped, rubber-made, movable speed humps to study the appropriate spacing of speed humps from the perspectives of noise, vibration, and speed reduction effects. The results showed that reducing the spacing of the humps increased the overall speed reduction effect along the section, and with 60-meter intervals, the entire section could maintain speeds below 30 km/h. However, the experiment also resulted in a surge of complaints due to noise caused by vehicle acceleration after passing the humps. To address this issue, a re-experiment with 20-meter intervals successfully suppressed the acceleration noise, reducing noise levels effectively.

Namee et al. (5) conducted a traffic audit and investigation of speed humps installed before intersections with a high occurrence of accidents within the premises of Thammasat University in Thailand. The study confirmed that the devices had a speed reduction effect within a distance of about 20 meters before and after the device, and it was found that vehicles tended to accelerate again before reaching the intersection. Therefore, the study suggested that improving the speed reduction at the intersection would require relocating the speed humps to the corners of the intersections or increasing the height of speed tables throughout the entire intersection area.

Table 1 Study area overview

	Road length [m]	Road width [m]	Walk way	Inter section	Speed hump/ bump	Hump/ bump length	Hump/ bump height	Installation interval (Ave.) [m]	Road sign	Road sign painting
Field 1	650	6	X	6	8	1.5	High	85	X	○
Field 2	750	6.5	○	6	0	N/A	N/A	N/A	N/A	N/A
Field 3	400	4	X	2	3	0.5	Low	153	X	X
Field 4	800	5	○	0	8	2.0	High	107	X	○
Field 5	1000	6	○	4	10	2.5	High	108	○※	○
Field 6	1000	7	○	1	X	N/A	N/A	N/A	N/A	N/A
Field 7	400	4	X	2	2	2.0	Mid.	250	X	○

※Only one sign is placed at the entrance of the soi.

3. Methodology

3.1 Speed Humps and Bumps Classification

The survey area for this study covers approximately 60 km^2, located within the area inside the MRT Blue Line and to the east of the Chao Phraya River. Google Street View was used for the survey. Fig. 1 shows an example of a speed hump in the city of Bangkok. The site is marked with a center line and signs indicating the presence of speed humps on both sides of the travel direction. In addition, there are clear road surface markings. Using this site as a model case, the study area will be classified based on the number of speed humps and bumps, the presence or absence of road markings, the presence or absence of road signs, the condition of the paint on the road markings, and the condition of damage to the road markings, in order to clarify their characteristics. Additionally, devices with problems in terms of hazards and safety will be investigated.

Fig. 1 Example of speed hump

3.2 Speed Analysis from Probe Data

Seven road segments were selected as case studies on single-lane roads where it is inferred that deceleration for overtaking oncoming vehicles is less likely to occur in Bangkok city. Five of these roads have a continuous installation of similar-shaped speed humps, while the other two roads have a similar road profile, but no traffic calming devices installed. Table 1 presents an overview of each road segment, including the selected sections for analysis, the installation status of speed humps, and other relevant details of the study area. The number of "Intersections" represents the count of confirmed crossings, inflows, and outflows observed in the probe data. For the analysis of vehicle speed, ITIC probe data was used, recorded during a week from

September 1 to September 8, 2019. The sections within 25 meters before and after each speed hump are defined as the "SH-deceleration section," and the sections from 25 meters before one-speed hump to 25 meters after the next speed hump are defined as the "SH to SH section." Fig. 2 illustrates this concept diagram. A statistical comparison of driving behaviors in the two divided sections is performed to analyze the effectiveness of the speed hump installations. Furthermore, sections near intersections with high inflow and outflow are excluded from the speed analysis as the intersections might influence speed changes. Additionally, data from stationary vehicles (0 km/h) are also excluded.

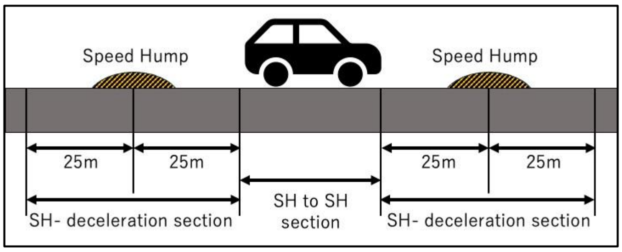

Fig. 2 Analysis sections for field survey results

3.3 Field Survey

To verify the accuracy of the probe data, on-site surveys were conducted. During the on-site surveys, smartphones were mounted on the dashboard of vehicles, and the target roads were driven. For data collection, the smartphone application 'Bump Recorder,' capable of measuring road surface characteristics for pavement flatness, was utilized. This application utilizes the gyroscope sensor built into smartphones to estimate vertical displacement (BumpH). And it automatically estimates and corrects vehicle characteristics such as suspension springs and dampers. Alongside, the application records information such as time, latitude, and longitude. Fig. 3 shows a picture of field survey. The recorded data is stored in the cloud and can be downloaded as a text file. In this experiment, the section of Field 7 in Table 1 was actually driven.

Fig. 3 Field survey

4. Results

4.1 Survey Results of Speed Hump Installation Status

The results of the survey are presented in Fig. 4, with "Dead-end road" represented in red and orange, and "Possible to pass through" in blue and light blue. There were 313 locations classified as "Dead-end road" and 1090 locations classified as "Possible to pass through," resulting in a total of 1400 discovered devices. These findings suggest that most of the devices are installed in locations with passing traffic. Among them, speed humps are represented by circular markers, and speed bumps by triangular markers, allowing for further classification. As there are no specific installation guidelines for traffic calming devices in Thailand, to differentiate between speed humps and speed bumps, visual observation was conducted, and the devices that appeared similar were recorded. The results are shown in Table 2. Comparing the survey results with the general design criteria for speed humps and bumps in overseas countries, as proposed by Parkhill et al. (1), many of Thailand's devices were found to be larger than the typical speed bumps found globally and smaller than typical speed humps.

Table 2 Classification of traffic calming devices

Situation	Locations	Percentage (%)
[SH] Possible to pass through	464	33.1
[Bump] Possible to pass through	626	44.6
[SH] Dead-end road	145	10.3
[Bump] Dead-end road	168	12.0
TOTAL	1403	

Table 3 then shows the classification results for the 1403 device locations found in the survey.

Firstly, safety markings are essential tools to alert drivers and riders to the presence of speed humps and bumps on the road. However, surprisingly, 856 locations, approximately 61% of the devices, lack any safety markings. As shown in Fig. 1, only 38 locations, a mere 2.7% of the total, have signs indicating the presence of speed humps on both sides of the road, along with road markings. This survey result suggests that many of the devices installed for traffic safety might actually pose risks instead.

Next, let's discuss the damaged devices. It was found that 290 devices, accounting for 20.67% of the total, have suffered damage. Among them, catastrophic damage has resulted in the loss of the function as a speed hump or bump, requiring urgent repair. Heavy damage refers to situations where a part of the device is damaged, and the hump height is not consistent. Additionally, some devices might have been damaged during underground piping works and have not been repaired. Motorcyclists, in particular, might choose to ride over the lower location of damaged humps, which could promote meandering driving and potentially lead to accidents. Other noteworthy points include "Especially low humps," "Paint is thin," and "Commercial bumps."

"Especially low humps" are considered to have a weak speed reduction effect, so speed analysis will be conducted in the following section 4.2. Regarding "Paint is thin," as already discussed, repainting should be done to ensure drivers and riders are aware of the device's presence. "Commercial bumps" are devices designed and sold to reduce vehicle speed to 8 km/h or below. They are intended for use in parking lots or private driveways, and their installation on public roads might unnecessarily decrease vehicle speeds, posing potential risks.

Table 3 Devices classification results

Situation	Locations	Percentage (%)
○**Safety markings**		
Road sign painting	480	34.21
Road sign	67	4.78
Nothing (No painting, No sign)	856	61.01
↓Details (painting and sign)		
Road sign painting only	430	30.65
Road sign painting & sign (Both way)	38	2.71
Road sign painting & sign (One way)	12	0.86
Road sign only	17	1.21
○**Damaged**		
No damage	1113	79.33
Light damage	98	6.99
Heavy damage	119	8.48
Catastrophic damage	73	5.20
→Damaged total (Needs repair)	290	20.67
○**Other (The focus should be on.)**		
Especially low humps	205	14.61
Paint is thin	96	6.84
Commercial bumps (recommended for use in parking lots, etc.)	42	2.99

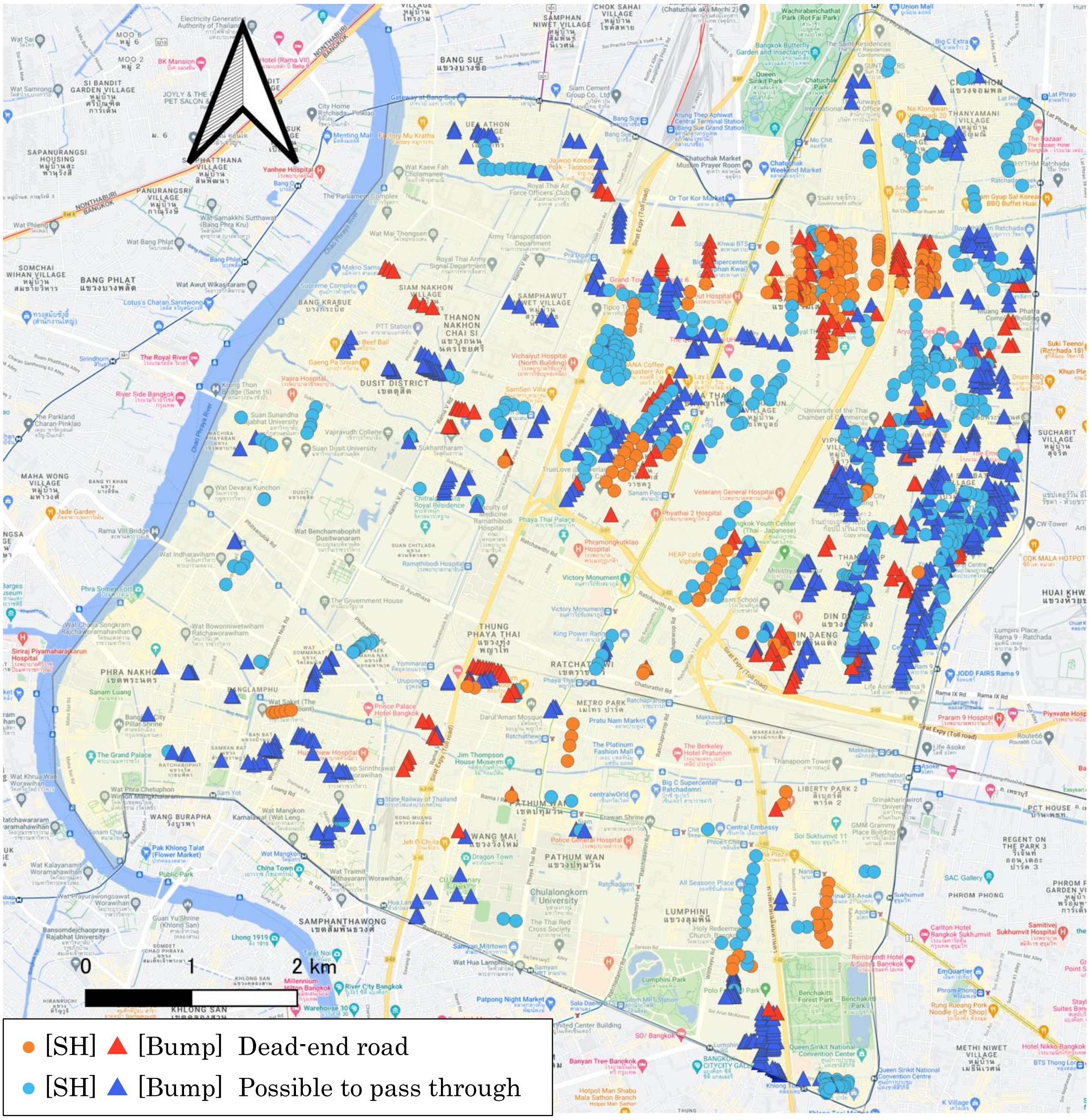

Fig. 3 Map of speed hump bump installations

Table 4 Results of speed analysis from probe data

		Sample size	Max [km/h]	Min [km/h]	Mean [km/h]	85th percentile [km/h]	S.D.	P-Value
Field 1	SH to SH section	225	42	1	20.4	28.0	7.79	0.00**
	SH- deceleration section	402	39	1	18.2	25.0	6.65	
Field 2	Section with no SH and intersection (310m)	506	65	1	26.7	38.0	11.98	N/A
Field 3	SH to SH section	161	34	1	13.2	21.0	7.23	0.75
	SH- deceleration section	113	33	1	13.5	22.0	6.94	
Field 4	SH to SH section	390	41	1	20.6	28.0	7.53	0.00**
	SH- deceleration section	464	41	1	16.8	24.0	7.21	
Field 5	SH to SH section	162	48	2	22.3	31.0	9.79	0.00**
	SH- deceleration section	212	43	1	19.1	26.0	7.11	
Field 6	Section with no SH and intersection (520m)	323	54	1	26.8	40.0	12.01	N/A
Field 7	SH to SH section	250	43	1	22.8	31.0	8.81	0.00**
	SH- deceleration section	159	35	3	17.9	24.0	6.51	

Table 5 Results of speed analysis from field survey data

		Sample size	Max [km/h]	Min [km/h]	Mean [km/h]	85th percentile [km/h]	S.D.	P-Value
Field 7	SH to SH section	23	28	18	24.1	27.8	3.46	0.00**
	SH- deceleration section	5	22	11	16.5	20.4	4.93	

4.2 Results of Speed Analysis of Probe Data

The results of the speed analysis from the probe data are presented in Table 4. First, the sections compared with and without devices, specifically Field 2, Field 6, and others. It was observed that in road sections without devices, the maximum speed, mean speed, and 85th percentile speed were consistently 10-20 km/h higher than those in sections with installed devices. This indicates that the installation of traffic calming devices leads to overall speed reduction in the sections.

Next, Field 3, Field 1, Field 4, and Field 5 are compared. Field 3 represents low bumps with no road markings or signs, short length, and low height. The statistical analysis of the speed data in SH to SH sections and SH-deceleration sections showed no significant differences. Field 1, Field 4, and Field 5 represent speed humps with uniform road markings, sufficient height, and length. The analysis revealed a statistically significant difference of 1%. Field 7 has a medium hump height, but similar effects were observed. All these, it was evident that there is a speed reduction effect of 10.7-33.0% when vehicles cross the devices. The 85th percentile speed was found to be below the recommended 30 km/h for all locations. Since no differences were observed by the presence or absence of sidewalks or by the average Installation interval, it is necessary to study these effects in the future.

Based on these results, continuous and planned installation of devices has the potential to contribute to a maximum speed reduction of around 40%. Furthermore, this analysis demonstrates the possibility of analyzing the speed reduction effects of speed humps and bumps using probe data. This not only significantly reduces the efforts required for on-site verification of device speed reduction effects but also enables comparisons between pre-installation, post-installation, and long-term installed conditions.

4.3 Comparison of Probe Data Analysis and Actual Field Survey Data

The results of the field survey are represented in Table 5. The analysis was performed in the same way as the probe data analysis. Statistical analysis of the probe data speeds in the "SH to SH section" and "SH- deceleration section" revealed no significant differences. This indicates that the speed suppression effect of speed humps was also evident from the field survey. Here, T-tests are performed for each "SH to SH section" and "SH- deceleration section" for the relationship between ITIC probe data and Bump recorder. The results P-values are shown in Fig. 4.

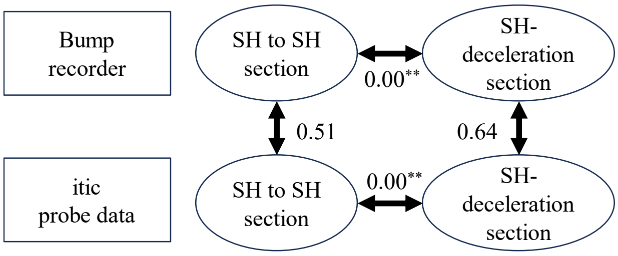

Fig.4 Relationship between ITIC probe data and Bump recorder (P-Value)

The relationship between "bump recorder" and "ITIC probe data" was found to be statistically insignificant with P-Values of 0.51 and 0.64. Therefore, the ITIC probe data and bump recorder results show the same trend. As for "BumpH," it was difficult to obtain useful data because it detected numerous vibrations caused by factors other than speed humps, such as road damage. Methods for determining bump height and bump location using a smartphone application will be the subject of future study.

5. Conclusion

The central area of Bangkok was defined as the study area, and within that area, the survey and classification were based on the number of installed spit humps and bumps, the presence or absence of road markings, the presence or absence of road signs, the condition of the road markings' paint, and their damaged condition. A total of 1403 devices were discovered, and it was found that most of them were installed on pass-through roads. Only a mere 2.7% of all devices had speed humps with road markings and signs on both sides. On the other hand, 290 devices (20.67% of the total) were found to be damaged, and 73 of them had completely lost their function as speed humps or bumps, requiring urgent improvement. Several other devices with potential traffic safety issues were also found. Ensuring the effectiveness and safety of the devices requires not only proper installation but also adequate maintenance.

Next, the ITIC probe data was used to analyze the vehicle's travel speed. In roads without traffic calming devices, the maximum speed, mean speed, and 85th percentile speed were found to be consistently 10-20 km/h higher compared to sections with installed devices. In the section where the device was installed, the section 25 m before and after the speed hump was defined as "SH-deceleration section" and the section 25 m before and after the speed hump and up to 25 m before and after the next speed hump was defined as "SH to SH section". Statistically analyzed results showed that for low bumps with low height and short length, there was no significant difference in speed reduction effect. However, for speed humps with uniform road markings, sufficient height, and length, a statistically significant difference of 1% was observed. Therefore, using probe data, it was confirmed that continuously planned speed humps have a speed reduction effect in the sections before and after them.

Speed humps are the most common traffic calming devices used globally to control traffic volume and reduce vehicle speeds within residential roads. Understanding and evaluating the current installation status can assist in appropriately placing traffic calming devices and contribute to promoting traffic safety. It has become evident that utilizing probe data can assist in streamlining these processes.

As a future study, we believe that it is necessary to analyze the driving behavior and speed suppression at speed bumps separately for two-wheeled vehicles and four-wheeled vehicles, and to examine the effects of introducing speed bumps in traffic safety measures in more detail.

6. Acknowledgment

The authors thank Mr. Tsumita for his advice and for providing probe data.

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May Electric Cargo Trucks be Accepted in Developing Countries: A Case Study in Hanoi, Vietnam

Topic number: 5/6, Paper Identification number: AYRF2023-012

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Abstract

On July 22, 2022, the Prime Minister of Vietnam issued Decision No. 876/QD-TTg, approving the action program on the transition to green energy. This programme aimed to reduce carbon and methane emissions in the transport sector, with a target of converting 100% of motorized road vehicles to electricity and green energy by 2050. However, achieving this transformation requires considering user psychology. This article utilizes the Technology Acceptance Model (TAM) to examine the factors influencing the adoption of electric light trucks. Based on a survey of 219 freight carriers using internal combustion engine vehicles (ICEVs) in Vietnam. The analyses reveal that attitudes play a significant role in whether cargo carriers' preference for E-cargo over ICEVs. The perceived ease of use also has a strong impact on carriers' acceptance of electric trucks. While, the perceived usefulness of electric trucks was found to positively affect the intention of using E-cargo, but not as strongly. Overall, this study has important implications for the development of effective policies towards green road freight.

Keywords: electric truck, theoretical model of technology acceptance, green road freight, road freight transport.

1. Introduction

In 2014, the transport sector accounted for about 22% - 23% of total CO2 emissions from fuel combustion worldwide, with road transport alone responsible for 20% [1]. To address the global challenges of green house gas (GHG) emissions, air pollution, and fossil fuel dependence, governments in different countries and regions are actively seeking cleaner and more sustainable transportation options. According to a report by the European Environment Agency on electric vehicles (EVs), the GHG emissions of EVs are approximately 17-30% lower than those of petrol and diesel vehicle [2]. As a result, electric cars, vans, trucks, and buses are expected to play a crucial role in mitigating the adverse impacts of road transport on human health, the environment, and the climate.

In Vietnam, road transport accounts for nearly 92.9% of the total cargo volume, 26.5% of the ton-kilometers of freight and road-based freight transport contributes nearly 7.2% of the country's emissions, while the entire transportation sector accounts for around 9% of Vietnam's emissions (NDC 2020 & WB, 2019). To alleviate the impact of climate change on road transport, a transition towards green commercial transport is imperative. This is reflected in Decision No. 876/QD-TTg. However, most research and policies in Vietnam are aimed at reducing emissions in the field of passenger and personal transport rather than goods transport. Meanwhile, studies conducted by Liu and Song in 2018 have confirmed that electric trucks (ETs) present an appealing alternative for urban logistics contributing to a reduction in fuel consumption and greenhouse gas emissions [3]. Similarly, Pelletier et al., (2018) have also suggested that ETs are suitable for distribution in urban areas [4]. Moreover, Iwan et al. (2021) have reported that electric small vans can effectively handle courier deliveries. Nonetheless, some barriers hinder the widespread adoption of electrification in the freight sector, including high investment costs, time-consuming charging processes, uncertain technology, lower efficiency, speed, and payload compared to diesel trucks, issues with operating reliability, inadequate infrastructure, and lack of support from the power grid. [5]–[8].

[9] have stated that, for the continued success of the sustainable transportation industry, consumer acceptance is crucial. In other words, to promote the adoption of ETs, it is essential to understand how consumers perceive EVs and the potential drivers and barriers affecting their adoption [10].

Several studies have examined the impact of psychological factors on consumers' intention to use EVs and ETs. For example, [11] investigated the intention to use ETs of urban delivery truck drivers in China, through an expanded unified theory of acceptance and use of technology model with 5 constructs including Technology Anxiety, Performance Expectancy, Facilitating Conditions, Social Influence and Effort Expectancy; [8] extended the technology acceptance model (TAM) to investigate the factors influencing the acceptance of EVs as replacements for motorcycles in the last mile delivery sector.

According to the report "Electric vehicle consumer survey" by Indochina Research in Viet Nam, the majority of people in Vietnam believe that EV is a new technology and will develop in the future. However, there has not been any research examining whether ETs are accepted by consumers in Vietnam. Therefore, we intend to utilize the TAM to explore the factors influencing user psychology. A survey was conducted in Hanoi, Vietnam, targeting light truck drivers (under 15 tons), and 219 valid samples were collected for analysis using structural equation modeling (SEM) and confirmatory factor analysis (CFA).

The remainder of the paper is structured as follows: Section 2 presents the theoretical framework for model design and research hypothesis. The research methodology, encompassing questionnaire design, data collection, and data analysis, is outlined in Section 3. Section 4 elaborates on the results derived from the data analysis. In Section 5, the discussion and implications of the findings are presented. Section 6 concludes the paper.

2. Theoretical Framework for Model Designing and Research Hypotheses

2.1 Technology Acceptance Model

To explain the acceptance of a technology, Davis (1989) proposed the TAM (Figure 1). The model suggests that the initiation of adoption of a new product or technology is based on perceptions of its ease of use and perceived usefulness. These perceptions subsequently shape users' attitudes toward the product, which, in turn, influence their behavioral intentions and actual behavior. The perceived usefulness and ease of use of a product/service depend on external factors such as product knowledge, training, technology, system quality, or different concepts in the user system as a worldview influencing consumer perception. [12]

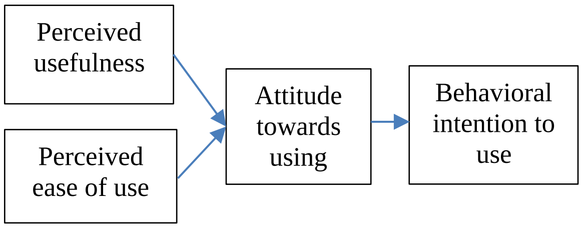


Fig. 1 The original technology acceptance model

Numerous scholars have employed the TAM model and expanded it by incorporating additional factors to explain a range of influences on attitudes and intentions towards EVs [8], [13]. These factors have been found to be associated with the intention to use EVs and ETs in various studies. For example, financial factors have shown to influence users' intention [8], [13]–[17]; perceived risks of EVs, such as increased costs, extended operation time, limited charging station infrastructure, and low reliability, have also been identified as influential factors [8], [11], [13], [18]; Additionally, product knowledge has been included in the model to examine its impact on risk perception, attitude towards EVs, and intention to use them [13], [14]. In summary, it can be observed that there is a relationship between psychology, attitudes, and the intention to use EVs. Therefore, we also study the psychology of carriers through the use of the TAM model. These factors include the perceived usefulness, perceived ease of use, attitude and intention.

2.2 Research Hypotheses

1. Attitude (AT)

Attitude refers to "the degree to which an individual expects the outcome of an activity" [19]. According to Davis, 1989 an individual's attitude towards a specific technology positively influences their intention to adopt that technology. In the context of EVs, the positive impact of attitudes on the intention to use EVs has been supported by [8], [20], [21]. Therefore, we hypothesize that:

H1: Attitude towards ETs has a positive impact on users' intention to use ETs.

2. Perceived usefulness (PU)

Perceived usefulness is defined as "the degree to which individuals believe that using a particular system will improve their job performance" [6]. Davis, 1989 also highlighted that perceived usefulness directly influences individuals' attitude towards technology and their acceptance. In the context of EVs, we hypothesize that the more benefits consumers perceive from EVs, the more positive attitude they have and subsequently foster an intention to use EVs. Hence, we propose these hypotheses:

H2a: There is a positive relationship between perceived usefulness and intention to use ETs

H2b: There is a positive relationship between perceived usefulness and attitudes towards ETs.

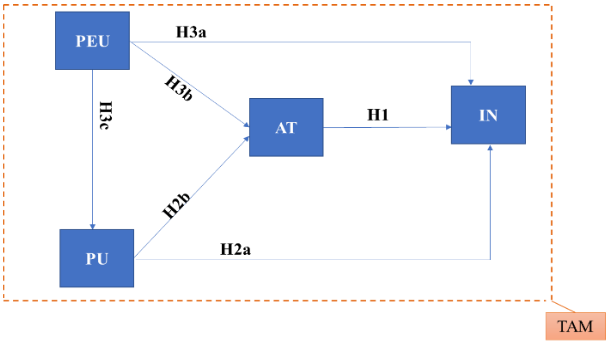


Fig. 2 Research framework on intention to use ETs

3. Perceived ease of use (PEU)

Perceived ease of use is defined as "the degree to which one believes that using a particular system will be effortless" [12]. In Vietnam, although ETs have not been put into operation yet, the prevalent use of electric bycicyles, motorbikes, cars, buses, taxis and cargo handling vehicles have formed certain judgments about the ease of use of electric cargo trucks. Perceived ease of use is found to be associated with perceived usefulness and attitude [22]. Some studies suggest a positive relationship between perceived usefulness and the intention to use new technology, including ETs [8], [11], [23]. In this study, perceived usefulness refers to the extent to which drivers assess the ease or difficulty of using ETs for transporting goods. We posit the following hypotheses:

H3a: There is a positive relationship between perceived ease of use and the intention to use ETs.

H3b: There is a positive relationship between perceived ease of use and attitudes towards ETs.

H3c: There is a positive relationship between perceived ease of use and perceived usefulness.

3. Data and Methodology

3.1 Survey Design

We have developed a survey consisting of two sections for data collection purposes:

The first section comprises demographic inquiries concerning age, gender, education level, daily mileage, and the type of truck used.

The second section comprises a series of questions designed to elucidate the independent variables incorporated in our hypothetical research model. These variables are assessed through multiple scales and components. Each item within the scales is measured using a five-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree").

3.2 Sample and Data Colletion

The survey was conducted in Hanoi, the capital city of Vietnam, known for being the largest urban area in terms of land area and the second largest in terms of Gross Regional Domestic Product (GRDP), with a population of 8.4 million people. The city is home to 10 industrial parks, 70 industrial clusters, and 144,741 businesses, which significantly contribute to the highly developed transportation activities, particularly in road freight transportation. The total volume of goods transported in Hanoi in 2021 reached 129,989.30 thousand tons, of which road transportation accounted for 126,927.50 thousand tons of cargo transportation [24].

Prior to the formal survey, preliminary interviews were conducted with seven small truck drivers in Hanoi using a paper questionnaire to gather their feedbacks on the questionnaire. Subsequently, we revised the questions to enhance clarity. The official survey was carried out from March 6, 2023, to April 27, 2023. A total of 235 responses were collected, comprising 109 responses from face-to-face interviews and 126 responses from the online questionnaire platform (Google Form). Six responses were excluded due to unreliability reasons (owing to identical answers across most questions), and 10 responses were excluded as they were from individuals who did not match the target respondents. Specifically, responses from individuals using heavy-duty trucks weighing over 15 tons, container transport vehicles, and long-haul vehicles traveling from North to South were excluded. The valid response rate of the questionnaire was 93.2%.

Table 1 Demographic results of interviewed drivers

Indicator		Frequency	Percent (%)
Gender	Female	12	5.5
	Male	207	94.5
Age Group	18 - 20 years	7	3.2
	21 – 30 years	111	50.7
	31 – 40 years	60	27.4
	40 - 50 years	29	13.2
	Over 50 years	12	5.5
Education Level	High school or below	71	32.4
	Intermediate, College	120	54.8
	University and above	28	12.8
Daily Mileage	Less than 100km/ day	60	27.4
	100 -150 km/ day	95	43.4
	150- 200 km/ day	54	24.7
	Above 200 km/ day	10	4.6
Type of truck used	Small truck < 1.5 tons	83	37.9
	Small truck 1.5 < 3.5 tons	91	41.6
	Medium truck 3,5- 15 tons	45	20.5

Table 1 shows that men make up the majority of the respondents, 94.5%. Among delivery truck drivers in Hanoi, the predominant age group falls between 21 and 30, with significant proportion possessing intermediate or college-level education. Most of the delivery drivers in the city drive less than 200km per day, only 4.6% of the respondents drive over 200km per day. This pattern alligns with the urban goods transport context, where a higher number of short-distance trips are typical. Cargo means of transport observed in Hanoi are mainly small trucks weighing under 3.5 tons, comprising of 79.5% of cargo vehicles.

3.3 Structural equation modeling

This study employs SEM to investigate the causal relationships among various constructs. SEM is a statistical technique that integrates two essential models: the measurement model and the structural model. The measurement model utilizes Confirmatory Factor Analysis (CFA) to establish latent constructs from observed variables. Subsequently, path analysis is used to examine the causal relationships between the identified latent constructs in the structural model. This analysis helps to elucidate the interconnections and dependencies among the latent variables, providing insights into the causal mechanisms (Kline R.B, 2015). In our study, we developed four measurement models, with a topology model of those four measurement models.

4. Data Analysis Results

4.1 The measurement model

Firstly, we employed SPSS 26 software to conduct CFA and assess the reliability of the measures using Cronbach's α coefficient. The validity of the measures was evaluated using Standardized Regression Weights, commonly referred to as factor loadings. According to Fornell and Larcker (1981), a threshold of 0,70 for normalized factor loadings ensures satisfactory validity [25]. However, other studies [26]–[28] have suggested that factor loadings above 0.5 can still yield reliable results. Therefore, we choose a more conservative criterion, setting the upper threshold for factor loading at 0.6, which is more stringent than the cut-off threshold used in other studies.

Convergence of the model was evaluated using two indicators: Combined Reliability (CR) and Average Variance Extracted (AVE), calculated through the AMOS software. For better results, a CR value above 0.7 is recommended [29] while an AVE value of at least 0.50 is considered acceptable [29]

Table 2 displays the results, indicating that all items have normalized factor loadings exceeding 0.6, demonstrating good convergence. The AVE values range from 0.680 to 0.802, surpassing the standard threshold of 0.50. Additionally, both the Composite Reliability (CR) and Cronbach's alpha coefficient values exceed the acceptable threshold of 0.7 [25]. These findings affirm the appropriateness of the research model.

Table 2 The results of the measurement model: reliability and validity

Constructs	Measurement items	Symbol	Factor Loading	AVE	CR	Cronbach alpha coefficient
Attitude towards ETs (AT)	I am interested in using ETs in the city or for short and medium distance	AT1	0.87	0.762	0.928	0.927
	I support the use of ETs in the city or for short and medium distances	AT2	0.89			
	I think it is a good idea to use ETs in the city or for short and medium distances	AT3	0.91			
	In my opinion, the idea of using ETs in the city or for short and medium distances is very wise	AT4	0.82			
Perceived usefulness (PU)	I think that using ETs will save the cost and improve energy efficiency	PU1	0.84	0.680	0.862	0.739
	I believe that using ETs will improve freight efficiency and quality of life	PU2	0.67			
	I believe that using ETs will reduce emissions and environmental pollution	PU3	0.94			
Perceived ease of use (PEU)	I think that charging of ETs is easy	PEU1	0.83	0.713	0.882	0.876
	I think it is easy to use ETs	PEU2	0.91			
	I think it is easy to maintain ETs compared to combustion engine trucks	PEU3	0.79			
Intention (IN)	I am willing to buy ETs in the near future to replace combustion engine trucks	IN1	0.92	0.802	0.890	0.894
	I plan to use ETs in the next three years	IN2	0.87			

Discriminant validity, which measures the degree of statistical difference between two constructs, was evaluated using the Formell-Larcker criteria. Table 3 demonstrates that the square root of each latent construct's AVE was greater than the inter-construct correlation values of that same construct and other measured constructs, demonstrating a good discriminant validity.

Table 3 Means, standard deviations and correlations.

Variables	Mean	SD	AT	PEU	PU	IN
AT	3.38	0.79	0.873			
PEU	3.06	0.78	.574**	0.824		
PU	4.27	0.48	.441**	.424**	0.845	
IN	3.06	0.89	.742**	.692**	.536**	0.895

*Note: Significant at: * p < 0.05 and **p < 0.01. The diagonal (bold) elements are the square roots of AVEs and the off-diagonal elements are the correlations among constructs.*

4.2 The Structural Model

The analysis of the structural model and hypothesis testing were conducted using the AMOS software. The overall fit of the model was deemed satisfactory. The Chi-square ratio to degrees of freedom (χ2/df) was 1.470, which falls below the threshold value of 3.0 [30]. The GFI, CFI, and TLI achieve values of 0.951, 0.989, and 0.984, respectively, meeting the requisite acceptability criterion of a minimum value of 0.8 [31]. Additionally, the model-fit indices, such as RMSEA at 0.046, were below the accepted threshold of 0.08 [32]. These results confirm the appropriateness of the model (Figure 3).

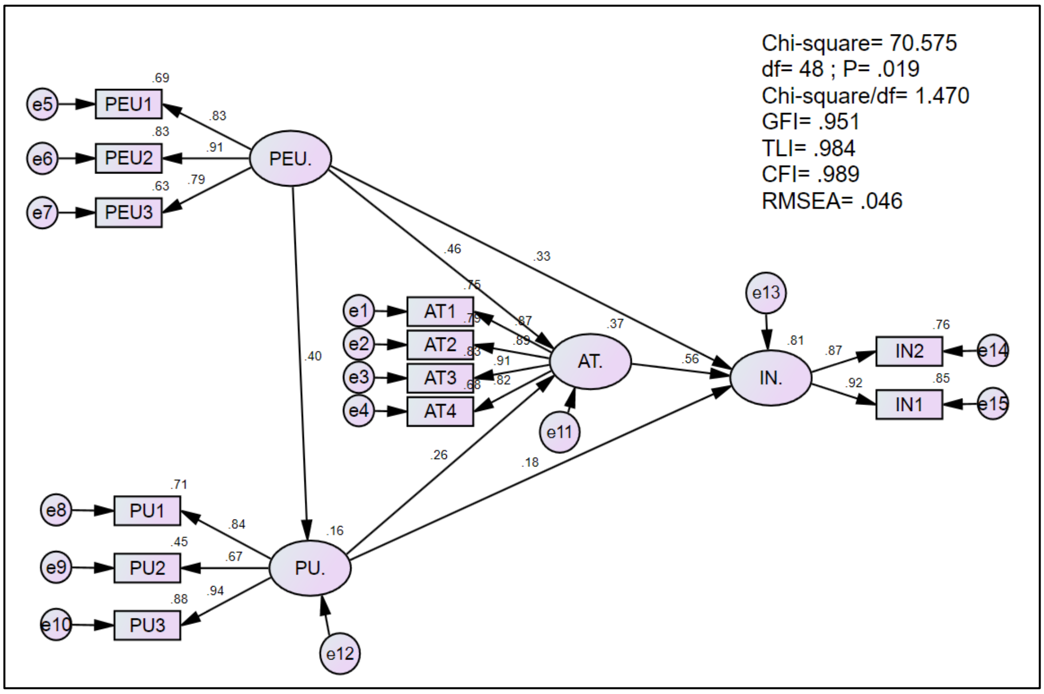


Fig. 3 Results of reasearch model on AMOS 20

The results of structural model analysis prove that all 6 hypotheses are significant (Table 4 and Figure 3).

Table 4 Results of structural model analysis

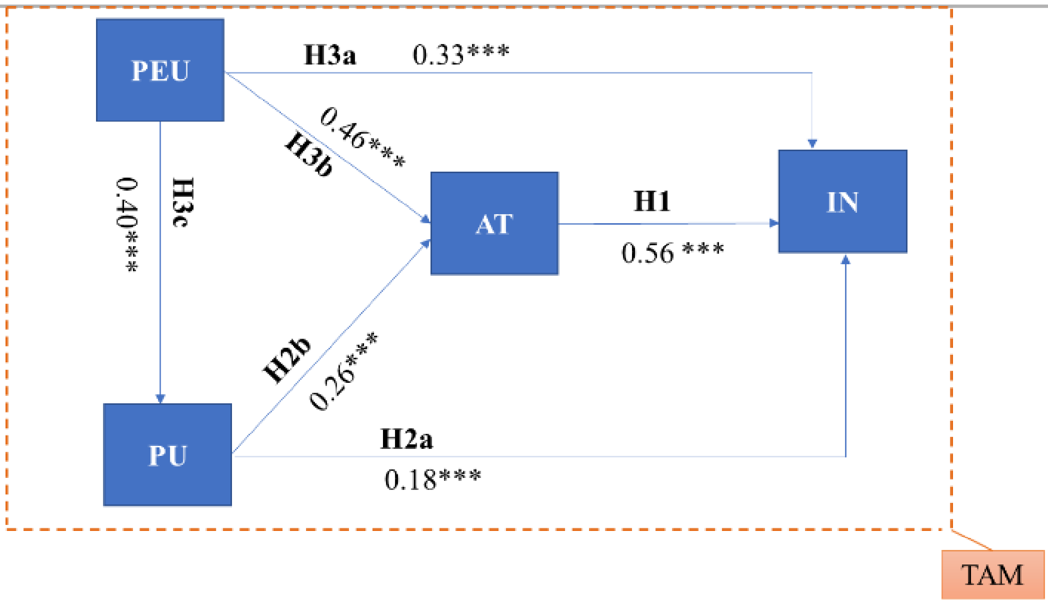
No.	Hypothesis	Path coefficient	p-value	Results (p<0.1)
1	H1: AT-->IN	0.56	0.000	Yes
2	H2a: PU→IN	0.18	0.000	Yes
3	H2b: PU→ AT	0.26	0.000	Yes
4	H3a: PEU→IN	0.33	0.000	Yes
5	H3b: PEU→AT	0.46	0.000	Yes
6	H3c: PEU→ PU	0.40	0.000	Yes

5. Discussion and Implications

5.1 Discussion

This study aims to investigate the potential acceptance of Ets in Vietnam, given the gradual implementation of green transporatation policies. Additionally, the research explores the influences of factors such as Attitude, Perceived Usefulness, and Perceived ease of use on carriers' intention to use electric vehicles in Vietnam, based on survey responses from 219 truck drivers.

Notably, the average attitude score (3.38) indicates that people's attitudes towards ETs are neither lean entirely positive nor entirely negative. However, path analysis reveals that the attitude is the most significant predictor of the intention to adopt electric trucks ($b_{Ha} = 0.56$, $p < 0.000$), meaning that if carriers perceive more positive aspects of ETs, they tend to adopt them. This finding is consistent with previous studies on [8], [13], [20], [21]



*Coefficients are showns along the paths; ***p<0.001;*
AT: Attitude; PEU: Perceived ease of use; PU: Perceived usefulness; IN: Intention

Fig. 4 The results of the structural model analysis of the original hypothesized model

Perceived Ease of Use emerges as the second significant predictor of the intention to adopt ETs (b_{H3a}= 0.33, p<0.000), despite the perception that electric trucks are not substantially easier to operate than internal combustion engine cars (mead = 0.306). The results indicate that increased perceive utility from electric trucks corelates with higher adoption rate. Strategies that emphasize the utility of electric trucks for carriers can potentially enhance their acceptance, reaffirming ealier studies by [8], [12]

Contrary to initial expectations, the perceived benefits of electric vehicles were overestimated (mean = 4.27; SD = 0.48), higher than the mean score of intention to use electric vehicles. This suggests that the Perceived usefulness score does not completely reflect the significant change in intention. The observation stems from the survey of Hanoi context, a city known for its high levels of air pollution level in Vietnam. In this case, Ets are widely perceived as highly beneficial. However, the decision to opt-in to Ets seems to be driven by factors such as performance, ease of operation, attitudes and preferences towards electric trucks rather than environmental concerns. This finding diverges somewhat from prior research results [8]

5.2 Implications for Practice

The decision-making process behind electric truck purchases is significantly influenced by the emotional and psychological factors of buyers. The Vietnamese government has taken steps to establish a regulatory framework, incentivize electric vehicle production and charging infrastructure. However, there still remains a dearth of research delving into the intricate dynamics of technology adoption and user behavior. Consequently, our study endeavors to furnish policymakers and ET manufacturers with additional insights into the acceptance of ETs within the Vietnamese market, as well as the factors influencing the intention to use ETs as a replacement for ICEVs. From there, helping the government and manufacturers develop policies and strategies in line with the psychological characteristics of the Vietnamese market, in order to promote the the electrification roadmap of the freight transport sector.

Firstly, although the majority of respondents expressed potential interest in purchasing an electric vehicle in the future (Mean IN1 = 3.25, SD = 0.96), a notable decline was observed when contemplating a purchase within the next three year (Mean IN2 = 2.85, SD = 0.92). This hesitancy suggests a need for extended deliberation. Therefore, we suggest that electric vehicle manufacturers should intensify mass communication efforts, offer training opportunities, and facilitate test drives for ETs. These campaigns will enhance carriers' attitude toward electric vehicles, as well as feel the ease of use, thereby promoting the intention to use electric trucks.

Secondly, the convenience and simplicity of vehicle charging maintenance also weild a possitive impact on attitudes and intentions toward electric trucks. Therefore, investment in charging infrastructure and maintenance services become imperative to attract potential customers. Advancement in battery technology, aimed at reducing charging durations and extending driving ranges, should remain a focal point of development.

Thirdly, the perceived benefits of electric trucks, such as improved energy efficiency and positive impact on the envionment, correlate with increased acceptability. Therefore, urban authorities should consider policies that prioritize the use of ETs in restricted truck zones and during noctunal hours due to the noiseless operation of electric trucks.

Finally, given the contructive role of awareness in shaping perception of ET usefulness, there is a pronounced need for comprehensive environmental campaigns and promotional initiatives to underscore the positive contributions of EVs to both individuals and society as a whole.

We expect these solutions will increase the acceptability of ETs in Vietnam market in particular and emerging markets in general.

6. Conclusion

Electric freight vehicles have emerged as a promising solution to cut carbon emissions in the transportation sector. However, beyond technical assessment, the application of electric vehicle technology must also take into account the readiness of transport entities to embrace and utilize electric freight vehicles. Using Davis (1989) Technology Acceptance Model, this article attempts to delve into user sentiments regarding electric trucks. Three key variables including attitude, perceived usefulness, and ease of use, demonstrate a positive association with the intention to intergrate electric trucks. This paper not only unveil compelling insights but also furnish recommendations to foster the future electrification of urban freight.

Despite its notable contributions, our study is not without limitations. Firstly, certain influencing factors such as perceived risks, financial support policies, social considerations and knowledge remained unexplored in the context of electric truck usage intentions. Secondly, the survey sample mainly focuses on urban areas with no difference between the types of goods transported. Therefore, the findings cannot be fully representative of all freight transport sectors. Therefore, it is necessary to conduct more comprehensive and in-depth studies to overcome these limitations.

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Enhancing Food Security in Hanoi Logistics and Transportation Chain for Pork

Topic number: 5, Paper Identification number: AYRF2023-014

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Abstract

Food security is an essential factor of the food supply and transportation chain since it deals with avoiding and controlling infectious diseases that can harm animal health, human health, and economic performance. The pork production chain is a complex system covering numerous participants, including farmers, transporters, slaughterhouses, processors, traders, and consumers, as well as environmental variables and biology that might influence pathogen transmission and dissemination. A comprehensive food security approach necessitates the cooperation and coordination of all stakeholders in the whole chain of production, transport and distribution, as well as the adoption of standards and best practices at each stage of the process. Food security also contributes to improving the quality and safety of pig products, boosting consumer confidence and market competitiveness. In this paper, we investigate the primary food security issues and hazards in the chain of the pork transportation and logistics and present a system for evaluating and improving food security procedures at various stages of the chain. Influencing factors are taken into consideration. Recommendations for ensuring food security in each stakeholder in the chain are raised finally.

Keywords: transportation chain, logistics chain, logistics and transport management, food security

1. General Introduction

1.1 Definition and Terminology

In recent years, countries, particularly developing ones, have paid close attention to the issue of food security. At the same time, due to the complexity of economic and environmental challenges, people in developing nations place a high value on food safety. Furthermore, access to safe food is becoming a fundamental human right. In fact, the globe has been experiencing massive food and food-related crises. According to a recent World Health Organization (WHO) report, foodborne infections impact more than one-third of the developed world's population each year. Every year, an estimated 600 million people, or one in every ten people worldwide, become ill after eating or drinking, and 420,000 die [1]. Food poisoning and food-borne disorders are becoming increasingly widespread in many nations. As a result, food security and food safety are inextricably linked and go hand in hand. All stakeholders, including national and international organizations, are responsible for ensuring food safety and limiting the effect of food-related risks.

Food security is a holistic term that includes policies and regulations to protect humans, food, agriculture, and the environment from potential biological threats intended to harm innovations, standards, and practices that are utilized to secure pathogens, poisons, and delicate advancements from unapproved access, abuse, theft, or deliberate discharge [2].

The Food and Agriculture Organization of the United Nations (FAO) defines food security as offering a comprehensive and integrated approach to the study and management of life and food safety concerns, health of people, animals, and plants as well as food security.

Food handling, processing, preservation, and storage by means of methods of prevention and control of diseases caused by food are all covered by the science of food hygiene and safety, or food safety in a restricted sense. A variety of processing procedures must be followed in order to avoid major possible health hazards when it comes to food hygiene and safety **Error! Reference source not found.**.

Food security means that a nation can effectively prevent and respond to threats from dangerous biological factors, that biotechnology can develop steadily and healthily, that people's health and the ecosystem are relatively free from danger and threats, and that biological science can be used to maintain sustainable development **Error! Reference source not found.**[5].

Food security in the pork supply chain

Since the 1960s, pig farming has progressively evolved into a large-scale business from a system of modest family farms. This development underscores the need for new approaches to the management of health and disease. In the 1980s, Concepts like "minimal disease" and "specific-pathogen free farms" were popular and gave rise to the present idea of biosecurity [6][7]. Early publications defined food security as ¨the security form of transmission of infectious diseases, parasites and pests [8].

To provide food security for pork, Gamble (1997) contends that food security application in animals is essential, but that food security management during slaughter and processing also improves effectiveness in maintaining safety [9]. To ensure food security, the food security issue is being developed and broadened for consumers.

Therefore, maintaining food security from the pig farm through the slaughter process and distribution to the consumer is necessary to guarantee food security for pork.

1.2 Factors Affecting Food Security in The Pork Supply Chain

The five primary steps of a pork supply chain are input materials, producers, traders, slaughters/processing, channel, and consumers (additional information provided below).

Input materials

The introduction of additional pigs to the farm has the highest risk of transmitting a new disease gene [10][11][12][13]. The chance of infection penetration increases with the rate at which new pigs are introduced; in addition, the harder it is to maintain herd immunity against pathogens that are endemic to farms, the greater the replacement rate.

Producers

There are two main categories of factors that affect internal food security for livestock farmers: external factors and internal factors [14]. Alternative breeds, seclusion, and the usage of semen are examples of internal influencing elements. Other internal influencing factors include people, vehicles, the manner in which animals are moved, neighborhoods (whether those within a country or from neighbors), food, and drink. Management techniques (the major goal is to control the flow of animals to avoid mixing pigs from various age groups); facilities, washing and disinfection; and staff are examples of internal influences

Traders

The majority of food security non-compliance happens with local vendors. Their pork industry is still manual, out-of-date, and non-compliant; examples include buying pigs based solely on appearance, lacking in documentation, using subpar transportation, etc.

Slaughter/ Processing

Several variables can impact food security during processing and slaughter. The degree of pollution is one of the most crucial issues. The shelf life of meat and meat products can be considerably impacted by initial bacterial counts brought on by contamination throughout these stages as well as additional contamination during storage. Other significant elements that may influence the growth of bacteria in meat are temperature, pH, and relative humidity [15].

Channels

Distribution channel food security primarily happens during delivery to retailers and seller stockpiling. In order to stop the spread of infections and other contaminants, facilities and vendors failed to follow the correct cleaning and disinfection measures. The danger of contamination can also be increased by a significant number of workers not using the correct personal protective equipment (PPE), as well as not practicing good hygiene and hand washing.

2. Current Situation of Biosafety in The Pork Supply Chain in Hanoi

The current situation of biosafety in the pork supply chain in Hanoi has been summarized from (i) on-desk revision over reports and statistical yearbooks of Hanoi pork production, distribution, and consumption; and (ii) an interview on experts' opinions over food security.

2.1 Current Status of Pork Distribution Channel

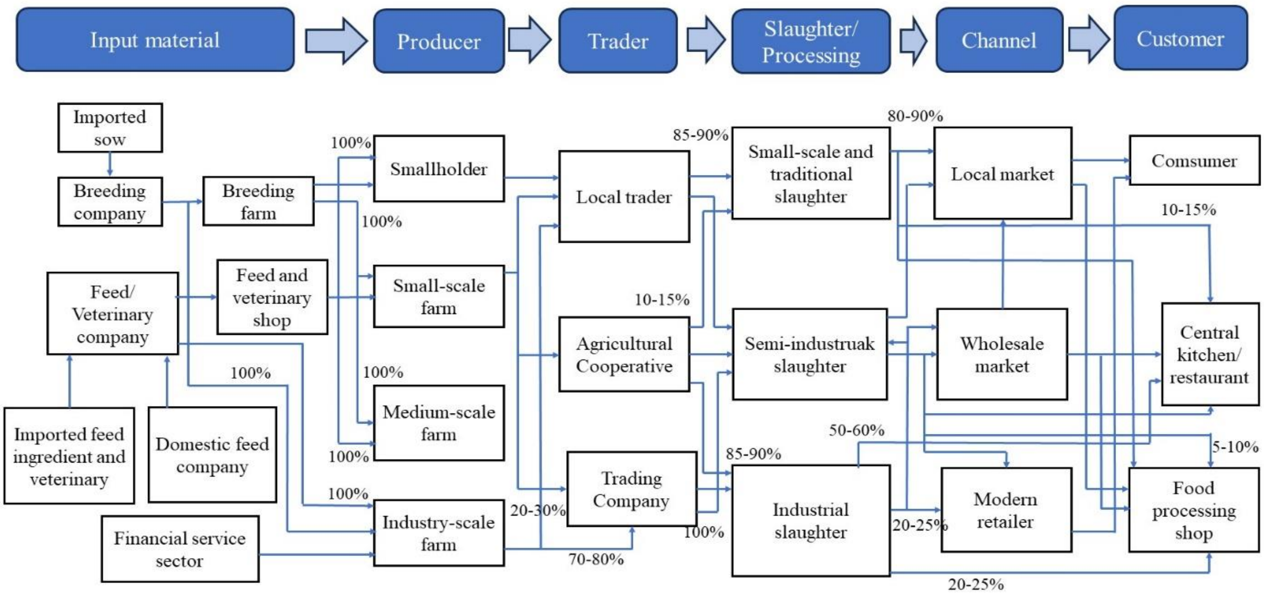

Fig. 1 Mapping pig supply chain in Hanoi

Source: Modified from [16] [17]

The general pork distribution process includes the following components

Breeding farms: Breeding pig facilities might be privately owned, domestic businesses, or businesses with foreign investment. Numerous domestic livestock farms also outsource for livestock businesses.

Breeding company: A domestic or foreign business (FDI) that imports, raises, and processes commercial piglets.

Livestock feed companies are domestic and international businesses (FDI) that provide animal feed to farms, breeding facilities, and brokers who deal in agricultural products.

Veterinary drug companies: Domestic and foreign companies (FDI) that wholesale animal feed for pig breeders, pig breeders and agents dealing in agricultural materials.

Animal feed and veterinary agents: Agents offer veterinary medicines and animal feeds to livestock operations at retail pricing.

Smallholder: Livestock operations with less than 30 pigs, and 80–90% of the pigs' heads are sold to local merchants [16][17]. This indicates that the entire volume is directed toward conventional (local markets). Only 10–20% of all pig heads were at that time given to semi-industrial slaughterhouses [16][17]. The wholesale market, contemporary retail market, and local market are the three markets that purchase the meat from industrial slaughter.

Small farm: A pig farm that raises between 30 and 100 pigs. They may belong to farmer groups, cooperatives, or neither (non-linkage).

Medium-scale farms housing between 100 and 500 pigs for meat: a hog farm that houses more than 300 breeding pigs, or between 100 and 500 total hogs. It contains farms that adhere to the requirements for "farm scale" as forth by the Ministry of Agriculture and Rural Development (MARD).

Industrial-scale farms or large-scale farms with more than 300 sows or more than 500 porkers have the characteristics of using imported breeds, and industrial feed, and performing well in the prevention of animal diseases. These large-scale pig farms typically collaborate on marketing strategies with major firms that are experts in animal feed, like CP Livestock Joint Stock Company and Deheus Company. Large-scale farms choose trading companies as their buyers; approximately 85–90% of all pig heads are sold by verbal agreements from the start [16][17].

Traders: Those who purchase live pigs or carcasses from farmers can be classified as provincial, interprovincial, or district traders.

Cooperatives: According to the Law on Cooperatives, "a cooperative is a collective economic organization, co-owner, legal person, established voluntarily by at least 07 members and cooperates and supports each other in production activities. Cooperatives that produce and trade breeding pigs and meat pigs fall under this definition.' On the principles of autonomy, self-reliance, equality, and democracy in cooperative administration, production, business, and job creation are undertaken in order to meet the requirements of all members.

Slaughter companies of industrial slaughters: A domestic or foreign company that purchases pigs from livestock farms; directly slaughter, process or hire other slaughterhouses and sell processed pork and pork products.

Illegal slaughters, traditional slaughters or small-scale slaughters: They dissect at smallholders' houses with a quantity of less than 10 animals/time, without a state slaughter permit.

Slaughter distribution or semi-industrial slaughter: apply the slaughter standards of the Ministry of Agriculture and Development and the Government regulations on animal health. Sanitary conditions in large-scale pig slaughterhouses, which may involve semi-industrial, conventional, or contemporary industrial slaughter on a massive scale. Modern industrial slaughter complies with government laws on veterinary hygienic conditions for pig slaughterhouses, cold storage, and chain slaughter as well as the criteria set by the Ministry of Agriculture and Development.

In addition, a significant portion of the market (90.84% and 7.07% in 2021 [17]) as well as the amount of pork produced by these two subjects are owned by smallholder farmers and small-scale farms. Therefore, when only one of these two item functions as a producer in the chain, we concentrate on the supply chain.

Producers covering only Smallholders

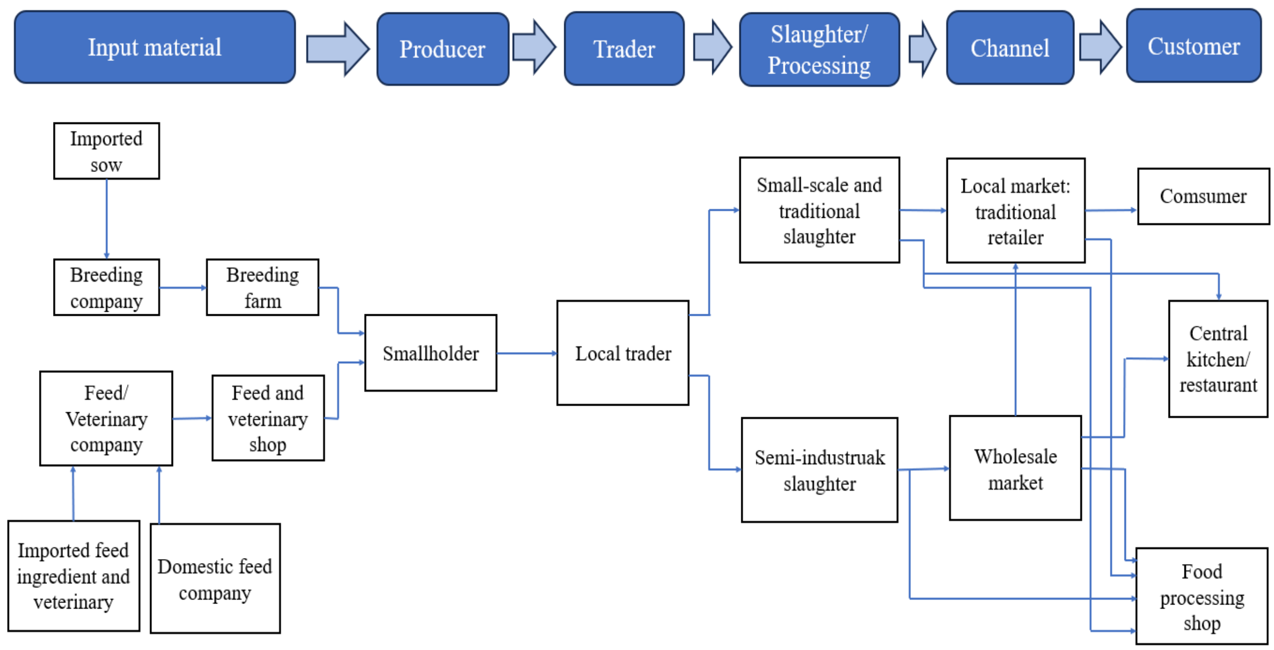

Fig. 2 Pig supply chain of non-linked smallholders in Hanoi
Source: Modified from [16][17]

Producers covering only Small-scale farms

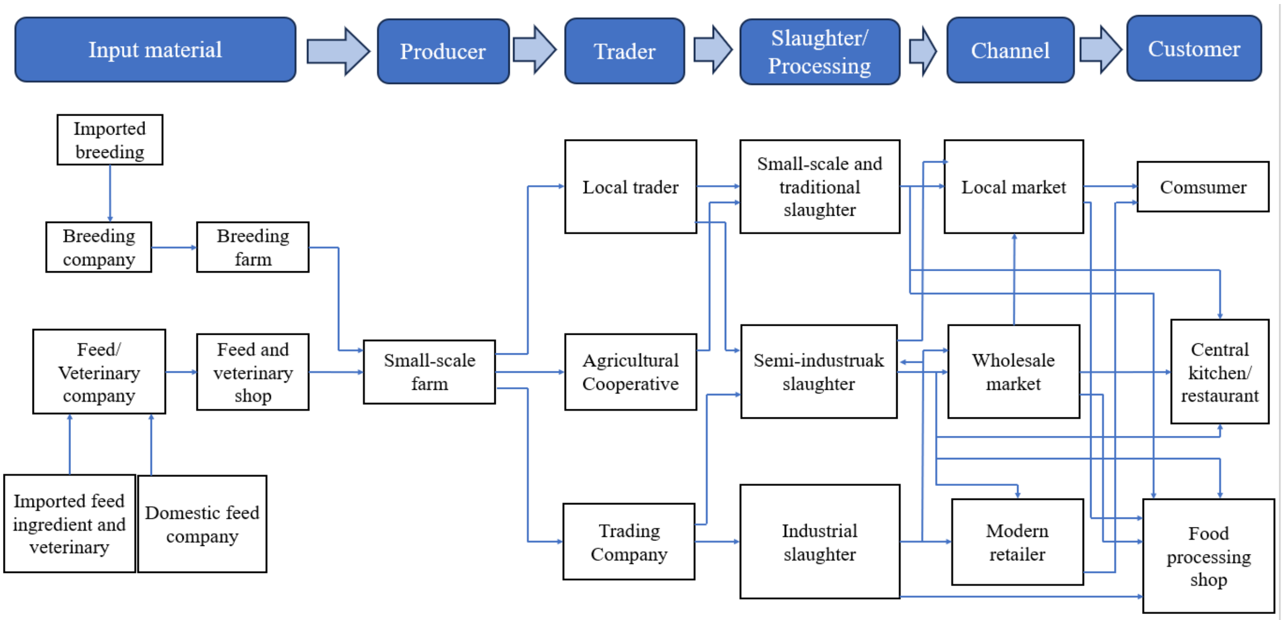

Fig. 3 Pig supply chain of non-linked small-scale farms in Hanoi
Source: Modified from [16][17]

2.2 Primary Evaluation

It can be seen from the figure above, Hanoi pork supply chain is fairly intricate. The supply chain typically comprises of 5 major stakeholders: materials suppliers, producers, traders, slaughter/processors, distributors and customers. Each stakeholder is flexible based on the presence of components in the chain and can comprise all smaller components or possibly less depending on various distribution channels.

With only "small households" and "small-scale farms" making up the "producer" chain for the two primary supply chains in Vietnam, the supply chain becomes more straight-forward and has fewer participants. Due to their tiny size, they primarily rely on their own resources without outside financial assistance. However, their goods are sent to customers, markets, dining establishments, and prepared food retailers.

The supply chain consists only small households in the producer stage

The majority of the small-scale, local transactions between supply chain components occur at the local level. The principal commodities handled are live pigs, carcasses, offal, blood, pork, and processed pork products. The chain's livestock operations frequently purchase input supplies including feed, piglets, and veterinary medications at nearby wholesalers or retailers. This supply chain's smallest merchant is a trader-cum-slaughterer (trader combined with slaughterer). There are two outcomes after a deal is reached with the smallholders. They kill pigs at the farmer's home at midnight, between 2 and 4 in the morning, usually in batches of less than 10. In another case, pigs were picked up in the afternoon and transported to the slaughterhouse; the trader-slash-slaughterer paid for the afternoon, and the pigs were then killed there. Slaughterhouses and traders selling whole pigs for slaughter or providing traditional retailers and communal cooks with meat, blood, and organs. Motorbikes are used to deliver carcasses to conventional retailers.

However, the connections and communication between smallholder farmers along this supply chain are highly shaky, particularly during the production phase. They are not focused on production, do not share best practices to enhance production techniques, do not make investments, and have no influence over the setting of product and material pricing. Smallholder farmers have the advantage of making the best use of labor, land, and food waste, but they invest little money and no technology.

The supply chain consists only small-scale farms in producer stage

Small-scale farms are also rather prevalent; typically, these businesses combine producing pigs using the V.A.C model with cultivating fish, poultry, and orchards. Small farms sell to neighborhood retailers, agricultural cooperatives, or businesses. Similar to the predicament of the small merchants above, two circumstances arise for local traders after the deal is completed. The selling prices for the hubs and central kitchens are likewise determined by these traders. These farmers face challenges such as a lack of funding for production expansion, difficulty obtaining favorable loans, and immediate payment of food buying agencies. The price is determined by the trader; there is no farming contract. These farmers also get money from other sources like cultivating fruit trees and keeping livestock like pigs, fish, chickens, or ducks. These farmers are risk averse and do not want to spend money to increase the size of the pig herd.

2.3 The Current Condition of Food Security in Hanoi's Pork Supply Chain

The variety of cuisine available on the market in Vietnam is growing. However, product distribution on the market today is still haphazard; the majority of these products are supplied by individual business households on the consumption network at traditional markets.

Pork is the main product in almost every Vietnamese meal, accounting for 72% of total meat consumption [17]. Pork demand is expanding on a daily basis, both in quantity and quality. Simultaneously with an increase in productivity and quality to meet market demand, pig farming in our nation has displayed highly insufficient repercussions, the most serious of which is the unsafety of pork products, inflicting detrimental effects on human health. Food poisoning caused by eating pork with antibiotic residues, super-lean pork, and so on has become increasingly common in recent years, generating concern for the entire society.

Vietnam today has at least 1.5 million people affected with food-borne diseases each year, with a cost of over 100 billion VND in damages [18]. The mass use, lack of selection of technical developments in chemistry and biotechnology, as well as antibiotic guidance and management, remain slack; the use of adjuvants in pig feed is extremely arbitrary. It has since left chemical and antibiotic residues in livestock products, causing considerable harm to people's health. Furthermore, the situation of profiteers who carry out the slaughter procedure without cleanliness and food safety, inject tranquillizers, and pump water into the pig's body before slaughter has lately been discussed in the media. With a population of around 7 million, Hanoi is one of the major cities in general. The issue of food safety and hygiene for pork in Hanoi is one of the most urgent ones at the moment due to the city's relatively high pork consumption. According to the Hanoi Veterinary Sub-Department's 2014 study findings, out of 1500 pork samples collected in Hanoi, 30% of the samples tested positive for clenbuterol, with 100% of the substance remaining in the animal's body and 60% remaining in the liver and kidneys even after cooking [19].

Through surveys and interviews conducted at the Vietnam-Germany Hospital and Hanoi K Hospital, as well as information obtained from the General Department of Market Management, 20 supermarkets, 30 traditional markets, and 93 butchers in Hanoi, the following outcomes were attained results stated below:

Current status of food hygiene and safety of pork sold at markets

Pork is typically very high levels of surface microbiological contamination that exceed acceptable norms, and there is a noticeable contrast between the centralized market and the retail market. Pork samples from concentrated and retail markets were more than 92% more likely to be contaminated with total aerobic bacteria than was permitted.

Factors impacting the safety and hygiene of food

There was no discernible difference between the two types of markets in terms of the rate of coliforms infection above the permissible level in the water used to wash meat and utensils at the meat booths (75.77% at the retail market and 80.48% at the centralized market). At the research markets, phytoplankton concentrations of above 10 CFU/cm and Enterobacteriaceae concentrations of over 1 CFU/cm were present in all samples (knife and cutting board). This disproves the butchers' knowledge of practice of washing knives and cutting boards. As a result, there will be a higher chance of microbial cross-contamination in the markets, and the instruments won't be properly cleaned.

Small marketplaces have a higher proportion of butchers carrying meat using crude methods than organized markets. Only the centralized market (10.11%) uses cold storage for pork when moving meat from the abattoir to the market. While the meat stalls in concentrated markets frequently utilize ceramic tiles as the tabletop (55.85%), the meat counters in retail markets are mostly made of wood (70.15%). In particular, the washing equipment at the counter (30.28% for the retail market and 90.50% for the centralized market) and the disinfectant spray (5.09% for the retail market and 50.44% for the centralized market) are more complete in the concentrated market than in the retail market. Therefore, compared to the retail market, the centralized market has more elements to ensure food safety and hygiene.

The proportion of butchers who transport pork using motorcycles and open-box trucks is still significant (44.44% and 83.33%, respectively). When being transported from the slaughterhouse to the market, fresh pork is less likely to be chilled (0% and 25.11%). The practice of displaying meat for sale on cardboard is common among butchers (42.42% and 44.44%). Furthermore, only a small percentage of markets (36.36% and 55.56%) have established daily rubbish pickup. The aforementioned elements play a part in why pork does not guarantee food safety and hygiene.

Food safety awareness and practice of butchers

Compared to retail marketplaces, butchers are more likely to apply labor protection at concentrated markets, particularly the use of aprons (25.75 % for small markets and 77.78 % for small markets). masks (30.56% for retail markets and 80.85% for centralized markets), gloves (60.52% for retail markets, 74.81% for centralized markets), and gloves (60.52% for retail markets). In the concentration market as opposed to the retail sector, a greater percentage of butchers remove their work attire when using the restroom. Furthermore, compared to the centralized market, the retail market's butchers' tendency to wash their hands with soap and to clean their workspace, tools, and countertops is significantly less common. This can be because management and market inspection teams visit centralized marketplaces more frequently than retail markets.

3. Recommendations to Enhance the Food Security of The Pork Supply Chain

From analyzing the current situation of food security in Hanoi pork supply chain, as well as the interview results in factors affecting the food security in the supply chain, it is recommended to develop the solutions in every stakeholder in the chain, from the farm to the distribution channel:

(i) Farm

- Ensuring good food security throughout the supply chain to minimize the risk of introducing new pathogens onto the farm.
- Developing any food security program covering all procedures of cleaning, sanitizing, and disinfecting.
- Establishing a routine of reacting to risk on occasion as part of a herd health plan.
- Reducing the spread of infectious diseases among pigs and their effects, including any negative economic effects.

(ii) Traders

- Traders should use labels or tags to identify their products and preserve records of the origin, destination, and quality of the pigs they handle.
- It is required the collaboration and coordination in the whole chain: Market participants in the pork value chain, such as farmers, slaughterhouses, retailers, consumers, veterinary professionals, operators of agriculture extension ministries, and the government, should collaborate and coordinate with each other. Join groups or cooperatives that may offer them advocacy, support, and direction; share information, comments, and best practices; and report any suspicious or strange events or situations.

(iii) Slaughter/ Processors

- It is necessary to gather carcasses and offal in a way that minimizes and/or avoids contamination by viscera, hides, the environment, or people.
- Every business should set up a food safety team to assess their specific business and create protocols for preventing viruses during harvest. This must to cover protocols, guidelines, instruction, evaluation techniques, and remedial measures for any deviations.
- A multi-barrier strategy should be used when designing a food safety system. This includes Before One, Plant Design and Environment, Intervention, Process Monitoring and Control, Training, Verification and Validation, among other components of the complete process.

(iv) Transporters

- It is required to determine the usage purpose for a specific truck. It is not advisable to convey circumstances where there is a food security concern in trucks carrying "safe" animals. Making a list of "permitted vehicles and permitted actions" for every truck in the process.
- It is necessary to clean and disinfect trucks in a methodical and organized way. The removal of organic debris, cleaning with water—preferably hot water and soap or descaling-cleaning, drying, and then disinfecting with proper materials are all necessary for this cleaning and disinfecting to be effective [20][21].
- Create a traceability system that enables the supply chain to track the origin, movement, and health of pigs and pork products.

(v) Distribution channels

- Improving hygiene and sanitation practices at all butcher stalls. This includes ensuring adequate water supply, waste management, disinfection, pest control, personal hygiene and protective equipment.
- Improving the monitoring and testing of pigs, pig products, and pollutants.
- Improving processes for all parties involved in the pork business, including producers, traders, processors, retailers, consumers, and policymakers, by increasing knowledge and educating them.

4. Conclusion

In order to guarantee the safety and quality of pork products, as well as the health and wellbeing of pigs, food security is a crucial component of the pig production chain. All chain participants' cooperation and coordination are also necessary for this. However, there is still a significant chance that food security will be compromised at any point in the supply chain, and most people are still unaware of the need to ensure food security in accordance with the law. The pig logistics chain may assist compliance with national and international norms and requirements, support the health and safety of pigs and people, and promote access to new and existing markets by applying food security measures.

5. Acknowledgement

This study is based on research supported by Vietnam Ministry of Science and Technology and German Federal Ministry of Education and Research (Project No. NDT/DE/21/300).

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