PROCEEDINGS OF

ATRANS YOUNG RESEARCHER'S FORUM 2022

15TH ATRANS ANNUAL CONFERENCE

26 AUGUST 2022
CHATRIUM HOTEL RIVERSIDE BANGKOK, THAILAND

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 2022 Participants,

It is a pleasure to welcome you to the 15th ATRANS Annual Conference: Young Researcher's Forum (AYRF) 2022.

In this fifteenth year, ATRANS organized 2 days event in which AYRF 2022 Paper Presentation Session takes place on 25 August 2022 and the annual conference, our main event take place on 26 August 2022. 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 these 2 days virtual meeting event.

Every aspect of our lives has been affected by the pandemic of COVID-19. And it has been two years since the pandemic even though it is endemic now. Large parts of the world have emerged from lockdown and slowly restarted the economy. It is obvious that things are far from being back to normal. The experience of lockdown on the other hands, has brought us some lessons learnt and the opportunity to utilize digital technology to sustain our urban everyday life. These are among other reasons why this year conference's theme is upon "Transportation for a Better Life: Resiliency, Sustainability, and Safety in Transportation System."

On behalf of ATRANS, I wish to express my sincere gratitude to the Young Researcher's Forum Committee who worked relentlessly to make the Young Researcher's Forum 2022 possible. I earnest hope that you all, will enjoy listening to the presentations and have good times spending in our ATRANS Annual Conference and the Young Researcher's Forum 2022.

Tuenjai Fukuda, Dr. Eng.

ATRANS Secretary-General, and
Chair of ATRANS Conference & Activity Committee
August 2022

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

Dear ATRANS Young Researcher's Forum (AYRF) 2022 Participants,

I'm honored to have the opportunity to deliver a welcome message to new generation of researchers participating in the ATRANS Young Researcher's Forum (AYRF) 2022. Asian Transportation Research Society (ATRANS) plays an important role to encourage a new generation in creating and conducting research related to road safety, traffic, and transportation.

Hence, it is a great opportunity for young researchers, including bachelor's, master's, and doctoral students, as well as transportation scholars, to present their research results and make recommendations for policy makers and society.

Thank you to ATRANS and the students who participate in organizing the 15th ATRANS Annual conference tirelessly, and work together with a volunteer mind.

I sincerely hope that this event will benefit and make an impact on society and wish the conference to be accomplished and achieve all the goals.

Thank you,

Asst. Prof. Pol. Lt. Col. Waiphot Kulachai, Ph.D.

Vice-Chair of ATRANS Conference & Activity Committee
Suan Sunandha Rajabhat University
August 2022

Welcome Message from ATRANS Young Researcher's Forum Advisory Committee 2022

Dear ATRANS Young Researcher's Forum (AYRF) 2022 Participants,

Allow me to warmly thank the organizers of the ATRANS young researchers' forum (AYRF) session, as part of the 15th ATRANS annual conference, for giving me the privilege of welcoming and addressing you all. For me, it is a great honor and a pleasure. I would also like to thank them for having brought us together through this wonderful event. It is very fortunate that we could finally hold the event at the venue in Bangkok. It has been more than two years since the pandemic has kept us apart. I am sure that we are well and healthy. As the conference is also organized in a hybrid mode, we could also welcome colleagues from worldwide to participate during this time while traveling is still somewhat restricted in many areas.

The AYRF sessions are dedicatedly organized along with the main conference to be a platform for young colleagues to present their research works, either finished or on-going, to exchange ideas and have discussion, and also to meet with the highly experienced and recognized researchers and professionals. This year, the peer-reviewed 23 paper presentations divided in 6 sessions cover various challenging issues within the conference theme "Transportation for a Better Life: Resiliency, Sustainability, and Safety in Transportation System". I am sure that you will identify subjects of your interest and will benefit from many fruitful and enriching discussions.

I would like to take this opportunity to express my sincere thanks to the keynote speaker of the AYRF session: Professor Alexis Fillone, De la Salle University, The Philippines, and also to the reviewers for your time reading and giving your invaluable comments to the authors, and the organizing committee and staffs, without you we will not have this wonderful conference today.

I wish great success for the AYRF sessions and the main ATRANS conference.

Assoc. Prof. Dr. Varameth Vichiensan

Advisory Committee for ATRANS Young Researcher's Forum 2022
Kasetsart University Thailand
August 2022

Welcome Message from President of ATRANS Young Researcher's Forum Committee 2022

Dear ATRANS Young Researcher's Forum 2022 Participants,

It is a great pleasure that I welcome all of you, Every Honorable delegate to the 15th ATRANS Annual Conference: Young Researcher's Forum 2022

The conference's agenda of this year is about "Resiliency, Sustainability and safety in transportation system" It has been two years since the pandemic, our world is emerging from lockdown and slowly restarting the economy. Nevertheless, it seems as the COVID-19 Global pandemic still continues, according to the experience of lockdown, it is obvious that our living is far from being back to normal. The experience of lockdown has brought the limitations to urban mobility which has underlined a new important aspect of the issue of proximity applied to urban everyday life. the need to access a reliable digital infrastructure become increasingly important, regional cooperation on transport connectivity would be the key issue in helping to provide effective response in the subsequent recovery efforts for sustainable development, building resilience, and reimaging road traffic safety, energy, and environment to future pandemics and crises.

Finally, on behalf of ATRANS Young Researcher's Forum 2022 organizing committee, I am grateful to all the conference participants for your interesting and participation in ATRANS Annual Conference (Symposium). Last but not least I would like to thank you ATRANS member for give opportunity and support in the annual conference, and thank you to AYRF Committee 2022 who come from various university for your dedication to preparation this Annual conference. It is my great honor to be a part of working team. "Nobody perfect, But team perfect"

Thanapat T. Poolsawat

Burapha University (BUU)
President of ATRANS Young Researcher's Forum Committee 2022
August 2022

List of ATRANS Young Researcher's Forum 2022 Organizing and Scientific Committee

AYRF Organizing and Scientific Committee		
1	Mr. Thanapat Poolsawat	Burapha University
2	Mr. Sirawit Chinvanichai	Chulalongkorn University
3	Mrs. Suwaphich Chaiyakhan	Suan sunandha rajabhat university
4	Ms. Sandra Win	Chulalongkorn University
5	Mr. Aditya Mahatidanar Hidayat	Chulalongkorn University
6	Mr. Sakda Phakarsa	Suan sunandha rajabhat university
7	Ms. Suthida Sungkaew	Suan sunandha rajabhat university
8	Mr. Bundam Ro	Suranaree University of Technology
9	Mr. Tanapat Utansawat	Suranaree University of Technology
10	Mr. Tanapon Kluengklangdon	Suranaree University of Technology
11	Ms. Rika Kakishima	Nihon University
12	Mr. Shogo Saeki	Nihon University
13	Mr. Kota Iwanami	Nihon University

List of Mentors of ATRANS Young Researcher's Forum 2022 Committee

AYRF 2022 Mentors		
1	Dr. Rattanaporn Kaewkluengklom	Gifu University, Japan
2	Mr. Naruphol Niyom (AYRF Alumni and Mentor of ATRANS Young Researcher's Forum Committee 2017-2021)	PlanPro Corp., Ltd., (Transportation Consultant)
3	Ms. Suwishada Fukuda	ATRANS Secretariat for In-House Management
4	Ms. Narisara Pongpakdiboribarl	ATRANS Secretariat for Academic Affairs
5	Ms. Sutthikarn Weluwanarak	ATRANS Secretariat for Academic Affairs
6	Ms. Kanjana Saengkham	Rangsit University

List of Advisory Committee of ATRANS Young Researcher's Forum 2022 Committee

International Advisory Committee		
1	Dr. Tuenjai Fukuda	Chair of ATRANS Annual conference & Other Activity Committee Advisory Committee of AYRF 2022
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 2022 Suan Sunandha Rajabhat University
3	Assoc. Prof. Dr. Varameth Vichiensan	Advisory Committee of AYRF 2022 Kasetsart University

List of the Paper Reviewers of ATRANS Young Researcher's Forum 2022

NO.	Reviewer Name	Organization
1	Prof. Dr. Atsushi Fukuda	Nihon University, Japan
2	Prof. Dr. Hironori Suzuki	Nippon Institute of Technology, Japan
3	Prof. Dr. Alexis M. Fillone	De La Salle University, the philippines
4	Prof. Dr. Pongrid Klungboonkrong	Khon Kaen University
5	Prof. Dr. Thaned Sathiennam	Khon Kaen University
6	Dr. Passakon Prathombutr	Senior Executive Vice President, Digital Economy Promotion Agency (DEPA), MODES
7	Dr. Suwat Wanisubut	Former, Deputy Permanent Secretary, National Economic and Social Development Council (NESDC)
8	Dr. Rungsun Udomsri	Asian Transportation Research Society (ATRANS)
9	Dr. Pattarathep Sillapacharn	Department of Highways, Thailand
10	Dr. Tuenjai Fukuda	Nihon University, Japan
11	Dr. Sumet Ongkittikul	Thailand Development Research Institute (TDRI)
12	Assoc. Prof. Dr. Chumnong Sorapipatana	Asian Transportation Research Society (ATRANS)
13	Assoc. Prof. Dr. Sorawit Narupiti	Chulalongkorn University, Thailand
14	Assoc. Prof. Dr. Varameth Vichiensan	Kasetsart University, Thailand
15	Assoc. Prof. Dr. Viroat Srisurapanon	King Mongkut's University of Technology Thonburi
16	Assoc. Prof. Dr. Apiwat Ratanawaraha	Chulalongkorn University, Thailand
17	Assoc. Prof. Dr. Yossapong Laoonual	King Mongkut University of Technology, Thonburi
18	Assoc. Prof. Dr. Saroch Boonsiripant	Kasetsart University
19	Assoc. Prof. Dr. Paramet Luathep	Prince of Songkla University
20	Asst. Prof. Dr. Sittha Jaensirisak	Ubonratchathani University, Thailand
21	Asst. Prof. Dr. PhongPhan Tankasem	Mahasarakham University
22	Asst. Prof. Dr. Rattanaporn Kasemsri	Suranaree University of Technology
23	Dr. Puthipong Jaragasigorn	Thammasart University

Program of ATRANS Yong Researcher's Forum (AYRF) 2022 Paper Presentations

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PROGRAM OF ATRANS YOUNG RESEARCHER'S FORUM 2022

15TH ATRANS ANNUAL CONFERENCE

TRANSPORTATION FOR A BETTER LIFE: "RESILIENCY, SUSTAINABILITY, AND SAFETY IN TRANSPORTATION SYSTEM"

25 – 26 AUGUST 2022, AT CHATRIUM HOTEL RIVERSIDE BANGKOK

Day 1: 25 Aug 2022, 13:30 – 18:00 at the River Meeting Room on Ground Floor

13:30 – 18:00 ATRANS Young Researcher's Forum Paper Presentation Session at the River Meeting Room, Ground Floor

13:30-13:40 Special Lecture: "Sustainable Local Public Transport Planning through Academe-Industry-Government Collaboration in the Visayas Region, Philippines"
By Prof. Dr. Alexis Fillone, De La Salle University, The Philippines

13:40 – 14:20 Session 1.1: AYRF 2022 Paper Presentation Session Chaired by Prof. Dr. Alexis M. Fillone, De La Salle University, The Philippines

13:40 – 13:50 Presenter 1 AYRF 2022-002 "Redesign the tourism routes after COVID'19 pandemic: case study in Wang Nam khiao Sub-distinct Nakhon Ratchasima province, Thailand" Presents by **Asst.Prof.Dr.Narucha TANAIUTCHAWOOT,** Suranaree University of Technology, Thailand	13:50 – 14:00 Presenter 2 AYRF 2022-003 "Development of the Depth-first Search Algorithm for Solving the Link-nested Logit Model in Traffic Assignment problem" Presents by **Dr.Thiem Tien Bui,** University of Transport and Communications, Hanoi, Vietnam	zoom 14:00 – 14:10 Presenter 3 AYRF 2022-004 "Development of Collision Avoidance System for Vehicles using 5G C-V2I" Presents by **Mr. Warit Ditsayakarin,** Chulalongkorn University, Thailand	14:10 – 14:20 Presenter 4 AYRF 2022-006 "Effectiveness of policy incentives on electric motorcycle acceptance in Hanoi, Vietnam" Presents by **Dr. Truong Thi My Thanh,** University of Transport Technology, Hanoi, Vietnam

14:20 – 15:00 Session 1.2: AYRF 2022 Paper presentations Chaired by Assoc.Prof.Dr.Varameth Vichiensan, Kasetsart University

14:20 – 14:30 Presenter 5 AYRF 2022-001 "Assessment of Inter-municipal PUV services in Southern Iloilo, Philippines" Presents by **Ms.Elearina Dolores Tabbu Agustin,** De La Salle University, Philippines	zoom 14:30 – 14:40 Presenter 6 AYRF 2022-005 "Barrier-Free Mobility Assessment of General Luna Street, Intramuros, Manila" Presents by **Engr. Maria Emilia P. Sevilla,** University of the City of Manila, Philippines	14:40 – 14:50 Presenter 7 AYRF 2022-007 "Comparative analysis between Net cost method and Gross cost method - Case Study in Bangkok Blue line and Purple line -" Presents by **Mr.Kota Iwanami,** Nihon University, Japan	14:50 – 15:00 Presenter 8 AYRF 2022-023 "Research on the applicability of the shared parking model in the downtown area of Hanoi" Presents by **Dr. Nam Hoai Tran,** Hanoi University of Civil Engineering, Vietnam

15:00 – 15:10 Special Lecture "Utilization of Drones for Accident Data Collection In Thailand"
By Asst.Prof.Dr. Rattanaporn Kasemsri, Suranaree University of Technology, Thailand

15:10 – 15:50 Session 2.1: AYRF 2022 Paper presentations Chaired by Asst.Prof.Dr. Rattanaporn Kasemsri, Suranaree University of Technology, Thailand

15:10 – 15:20 Presenter 9 AYRF 2022-010 "Analysis of Impact of Spreading COVID-19 Infections on Usage Behavior of E-Commerce for Food" Presents by **Ms.Rika KAKISHIMA,** Nihon University, Japan	15:20 – 15:30 Presenter 10 AYRF 2022-011 "Solving static bike rebalancing problem by using Lagrangian Relaxation as stop searching criteria" Presents by **Mr.Theethad Prohmpradith,** Chulalongkorn University, Thailand	15:30 – 15:40 Presenter 11 AYRF 2022-012 "Analysis of Actual Condition of Walking Environment around Urban Railway Stations in Bangkok" Presents by **Mr.Shogo SAEKI,** Nihon University, Japan	15:40 – 15:50 Presenter 12 AYRF 2022-021 "An Equitable Transit-Friendly System: A Literature Review" Presents by **Engr. Orlean G. dela Cruz,** De La Salle University, Philippines

15:50 – 16:00 Coffee Break

Remarks: Please be noted that some AYRF 2022 Paper Presentation sessions will be conducted in English & some will be conducted in Thai. Each presenter will have 7-minute for presentation and 3-minute for questions and answers.

Important notes: In compliance with ATRANS Policy on Infectious Prevention Measures, all registered on-site participants must wear a mask, clean your hands, practice Cough Etiquette, refrain from wearing a mask excessively to prevent heat stroke and keep a safe distance while attending the conference event.

Program of ATRANS Yong Researcher's Forum (AYRF) 2022 Paper Presentations (continued)

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PROGRAM OF
15TH ATRANS ANNUAL CONFERENCE
TRANSPORTATION FOR A BETTER LIFE: "RESILIENCY, SUSTAINABILITY, AND SAFETY IN TRANSPORTATION SYSTEM"
25 – 26 AUGUST 2022, AT CHATRIUM HOTEL RIVERSIDE BANGKOK

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Day 1: 25 Aug 2022, 13:30 – 18:00 at the River Meeting Room on Ground Floor (continued)

16:00 – 16:40 Session 2.2: AYRF 2022 Paper presentations Chaired by Assoc.Prof.Dr. Paramet Luathep, Prince of Songkla University, Thailand

16:00 – 16:10 Presenter 13 AYRF 2022-013 "Effects of Alternative Mobility Modes and Health Awareness on Mode Choice in Vietnamese cities" Presents by **PhD Student VU THI HUONG,** **University of Transport and Communications, Vietnam**	**16:10 – 16:20 Presenter 14** AYRF 2022-014 "Development of Autonomous Delivery Service Prototype in Chulalongkorn University" Presents by **Mr.Sedtawud Larbwisuthisaroj,** **Chulalongkorn University, Thailand**	**16:20 – 16:30 Presenter 15** AYRF 2022-015 "Transportation Noise Investigation and Modelling Using Multiple Linear Regression" Presents by **Mr. Renold Anos,** **De La Salle University, Philippines**	**16:30 – 16:40 Presenter 16** AYRF 2022-016 "Real-world Autonomous Vehicle and Environment Simulation in Chulalongkorn University" Presents by **Mr.Sirapop Bovornrabporn,** **Chulalongkorn University, Thailand**

16:40 – 17:20 Session 3.1: AYRF 2022 Paper presentations Chaired by Dr.Puthipong Julagasigorn, Thammasat University, Thailand

16:40 – 16:50 Presenter 17 AYRF 2022-017 "Proposal on Indicators and Methods to Assess Sustainable Development of Urban Public Transport in Vietnam" Presents by **Mr.NGUYEN QUANG THANH,** **University of Transport and Communications, Vietnam**	**16:50 – 17:00 Presenter 18** AYRF 2022-018 "Management of Public Transport in Hai Phong city, Vietnam: A Serious Improvement to Success" Presents by **Ms.VU KHANH LINH,** **Binh An Construction Company, Ho Chi Minh City, Vietnam**	**17:00 – 17:10 Presenter 19** AYRF 2022-019 "Low-Carbon Urban Transport: Policy Context in Vietnam and Development Orientation in Hai Phong City" Presents by **Mr.NGUYEN HUU HA** **University of Transport and Communications, Vietnam**	**17:10 – 17:20 Presenter 20** AYRF 2022-020 "Analysis of Efficiency of Urban Public Bus Transport: A Case Study in Hai Phong City, Vietnam" Presents by **Mrs.VU THI PHUONG HOA** **Department of Natural Resources and Environment, Hai Phong People's Committee, Vietnam**

17:20 – 17:50 Session 3.2: AYRF 2022 Paper presentations Chaired by Asst.Prof.Dr.Phongphan Tankasem, Mahasarakam University, Thailand

17:20 – 17:30 Presenter 21 AYRF 2022-008 **TH** "ความต้องการทำงานที่บ้านหลังโควิด-19" "Preference of Teleworking from Home Post COVID -19" Presents by ศรุดา จันทร์ประสงค์ **Ms.Saruta Janprasong,** **Kasetsart University, Thailand**	**17:30 – 17:40 Presenter 22** AYRF 2022-009 "Gap acceptance for a U-turn median opening on intercity highways" Presents by **Mr.Anuwat Chetcharatphong,** **Suranaree University of Technology, Thailand**	**17:40 – 17:50 Presenter 23** AYRF 2022-022 **TH** "การวิเคราะห์ผลกระทบของการกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกันบนทางหลวงด้วยแบบจำลองการจราจรระดับจุลภาค" Impact Analysis of Differentiated Per-Lane Speed Limits on Multilane Highways Using Microscopic Traffic Simulation Models" Presents by ศุภศวัส สายงาม **Mr.Supasawat sanigam,** **Chiang Mai University, Thailand**

Session ends and return to hotel

Remarks: Please be noted that some AYRF 2022 Paper Presentation sessions will be conducted in English & some will be conducted in Thai. Each presenter will have 7-minute for presentation and 3-minute for questions and answers.

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Program of ATRANS Yong Researcher's Forum (AYRF) 2022 Paper Presentations (continued)

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TENTATIVE PROGRAM
15TH ATRANS ANNUAL CONFERENCE
TRANSPORTATION FOR A BETTER LIFE: "RESILIENCY, SUSTAINABILITY, AND SAFETY IN TRANSPORTATION SYSTEM"

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Day 2, 26 Aug 2022: Main Conference Program at Grand Ballroom, 4th Floor

9:00 – 9:30 Opening Session at the Grand Ballroom on 4th Floor		
9:00 – 9:10 Introducing and welcoming Message **By Dr. Chula SUKMANOP,** Inspector-General of MOT and Chairperson of ATRANS	**9:10 – 9:20 Welcome Message** **By Mr. Satoshi KAMADA,** Executive Director, IATSS	**9:20 – 9:40 Opening Remark** **By H. E. Arkhom TERMPITTAYAPAISITH** Minister of Finance, Thailand
9:40 - 10:00 Coffee break		

10:00 – 12:00 Morning Session at the Grand Ballroom on 4th Floor				
10:00 – 10:20 Special Lecture: "Resiliency, Sustainability, and Safety in Transportation System in Thailand" by Dr. Punya CHUPANIT, Director-General, Office of Transport and Traffic Policy and Planning, Ministry of Transport				
10:20 – 12:00 Session 1: moderated by Prof. Dr. Atsushi FUKUDA, ATRANS Honorable Advisor, Nihon University, Japan				
10:20 – 10:40	10:40 – 11:00	11:00 – 11:20	11:20 – 11:40	11:40 – 12:00
Speaker 1: "Resiliency, Sustainability, inclusion and Safety in Transportation System: Global and Regional Perspective" **By** Dr. Madan B. REGMI, Chief of Transport Research and Policy Section, UNESCAP	**Speaker 2:** "Resilience, Sustainability, and Safety in Transportation System: Japan Perspectives towards "4aaS" Meta Innovation" **By Prof.Dr. Kenji DOI** Osaka University, Japan	**Speaker 3:** "Safety and Accessibility in Public Transport System in ASEAN Countries and India" **By Mr. Yukio YAMASHITA** Senior Director, Japan Transport and Tourism Research Institute-ASEAN & India Regional Office (JTTRI-AIRO)	**Speaker 4:** "National Strategy on Economy, Resiliency, and Sustainability in Transport Infrastructure: Thailand Perspective" **By Mr. Punnaluk SURASWADI** Head of Land Transport Infrastructure Project, Infrastructure Strategy Department (ISD), Office of National Economic and Social Development Council (NESDC)	**Discussion, Q&A**
12:00 – 13:00 Luncheon provided				

Main Conference Program – 1st Afternoon Session

13:00 – 14:30, 1st Afternoon Session at the Grand Ballroom on 4th Floor				
13:00 – 13:15 Special Lecture: "City and Mobility in a Digital Age Transportation Technology for Better Bangkok" by Dr. Chadchart SITTIPANT, Bangkok Governor				
13:15 – 14:30 Session 2: "City and Mobility in a Digital Age Transportation Technology" Moderated by Assoc.Prof.Dr. Sorawit Narupiti, Chulalongkorn University				
13:15 – 13:30	13:30 – 13:45	13:45 – 14:00	14:00 – 14:15	14:15 – 14:30
Speaker 1: "City and Mobility Development in a Digital Age Transportation Technology: Japan experiences" **By Mr. Yasuhiro AIBA** JICA Urban Development Expert, Japan International Cooperation Agency, Bangkok Office	**Speaker 2:** "ADAS Map-Based Unmanned Driving: Alternative Driving Solution for Future City Movement" **By Dr. Jeong Hyop LEE, Senior Advisor** and **Mr. Dongho KIM, CEO** Program Management Unit for Competitiveness (PMUC), and FATOS Co., Ltd.	**Speaker 3:** "City Data Platform for smart mobility" **By Dr. Passakon PRATHOMBUTR** Senior Executive Vice President of the Digital Economy Promotion Agency (DEPA), Thailand	**Speaker 4:** "Traffy Fondue: A Smart Platform for people's engagement and empowerment for Smart City" **By Dr. Wasan PATTARA-ATIKOM,** Team Leader Intelligent Transportation Systems Research, Communication and Networks Research Group National Electronics and Computer Technology Center (NECTEC)	**Discussion, Q&A**

Continued on next page.

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Program of ATRANS Yong Researcher's Forum (AYRF) 2022 Paper Presentations (continued)

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Day 2, 26 Aug 2022: Main Conference Program – 2nd and 3rd Afternoon Sessions (continued) at the Grand Ballroom, 4th Floor

14:35 – 16:10, 2nd Afternoon Sessions at the Grand Ballroom on 4th Floor					
14:35 – 16:10 Session 3: Environmental-related Transportation and Technology (i.e., climate change, disaster, energy, EV, autonomous vehicles, etc.) **Moderated by Prof.Dr.Pongrid KLUNGBOONKRONG**, Khon Kaen University					
14:35 – 14:50	14:50 – 15:05	15:05 – 15:20	15:20 – 15:35	15:35 – 15:50	15:50 – 16:10
Speaker 1: "Adapting transportation engineering practice to climate change" **By Emeritus Prof.Dr. Michael TAYLOR** Transport Planning, University of South Australia, Adelaide, SA, Australia zoom	**Speaker 2:** "Climate Change and Disaster Management in Transportation in Thailand" **By Asst. Prof. Dr. Poon THIENGBURANATHUM** Deputy Director for Corporate Planning and Strategy Program Management Unit, The Office of National Higher Education Science Research and Innovation Policy Council (NXPO)	**Speaker 3:** **"Satellite Remote Sensing data for Disaster Management"** **By Dr. Manzul Kumar HAZARIKA** Director, the Geoinformatics Center (GIC), Asian Institute of Technology, Thailand zoom	**Speaker 4:** "Environmental Economic and Emission Reduction in Electric Vehicles" **By Assoc.Prof.Dr. Yossapong LAOONUAL** KMUTT, Board Member, Thailand National Electric Vehicle Policy Committee, Office of the Prime Minister of Thailand	**Speaker 5:** "Connected autonomous vehicles for environmentally-friendly mobility" **By Asst.Prof.Dr. Nuksit NOOMWONGS** Smart Mobility Research Center, Chulalongkorn University, Thailand	**Discussion, Q&A**
16:10 – 16:20 Coffee break					
16:20 – 18:00, 3rd Afternoon Sessions at the Grand Ballroom on 4th Floor					
16:20 – 18:00 Session 4: "Reimagining Road Safety" Moderated by **Dr.Witaya CHADBUNCHACHAI**, MD. Head of WHO Collaborating Centre on Trauma and Critical Care, Thailand					
16:20 – 16:35	16:35 – 16:50	16:50 – 17:05	17:05 – 17:20	17:20 – 17:35	17:35 – 18:00
Speaker 1: "Developing the Road Safety Audit System at Local Government in Japan" **By Prof. Dr. Satoru KOBAYAKAWA** IATSS member, Nihon U, Japan	**Speaker 2:** "Policy Implication on Road Accident Prevention in Children and Youth in Thailand" **By MP. Nikorn CHAMNONG** Chair of the Asia Pacific Regional Network for Road Safety, Thailand	**Speaker 3:** "Road Safety Master Plan Development" **By Dr. Sumet ONGKITTIKUL** Research Director, Transportation and Logistics Policy, TDRI	**Speaker 4:** "Utilization of Technology for Safety Management on Thai Rural Roads" **By Dr. Chakree BUMRUNGWONG** Executive Director for Information Technology and Communication Center, Department of Rural Roads, MOT	**Speaker 5:** "Reimaging Road Safety: Essential Role of NGOs in Pursuits of Making Roads Safer in Thailand and Beyond" **By Mr. Michael WOODFORD** Executive Chairman of Safer Road Foundation, UK	**Discussion, Q&A**
Closing Session at the Grand Ballroom on 4th Floor					
18:00 – 18:20 Certification and Closing Remark by Dr. Chula SUKMANOP, ATRANS Chairperson					
Present Certification to AYRF 2022 Presenters and Best Paper&Presentation Awards		Present Certification to AYRF 2022 Student Committee Members		Closing Remark	
19:00 – 22:00 Reception Dinner (by invitation only)					

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SESSION 1.1: AYRF 2022 RESEARCH PAPER PRESENTATION

From Paper ID: 002-2022, 003-2022, 004-2022, 006-2022

PAPER ID/ Page No.	Paper entitled	Presented by
002-2022 **p.2-18**	"Redesign the tourism routes after COVID'19 pandemic: case study in Wang Nam khiao Sub-distinct Nakhon Ratchasima province, Thailand"	**Asst. Prof. Dr. Atthaphon Ariyarit** Suranaree University of Technology, Thailand
003-2022 **p.9-17**	"Development of the Depth-first Search Algorithm for Solving the Link-nested Logit Model in Traffic Assignment problem"	**Dr. Thiem Tien Bui** University of Transport and Communications, Hanoi, Vietnam
004-2022 **p.18-25**	"Development of Collision Avoidance System for Vehicles using 5G C-V2I"	**Mr. Warit Ditsayakarin**, Chulalongkorn University, Thailand
006-2022 **p.26-36**	"Effectiveness of policy incentives on electric motorcycle acceptance in Hanoi, Vietnam"	**Dr. Truong Thi My Thanh** University of Transport Technology, Hanoi, Vietnam

Redesign the Tourism Routes After COVID'19 Pandemic: A Case Study in Wang Nam Khiao Sub-distinct Nakhon Ratchasima Province, Thailand

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Abstract

Wang Nam Khiao in Nakhon Ratchasima Province is known as the world's 7th largest source of ozone and is known as Eastern Switzerland. However, Wang Nam Khiao's tourist attractions information is hard to find when searching for tourist attractions in Nakhon Ratchasima. Therefore, this research aims to (1) support communities and natural resources in the province that have the potential to become tourist attractions; (2) design a route for community-based tourism and natural resources to suit the factors in travelers' diverse decisions and logistics systems; and (3) develop methods or tools for accessing tourist attraction information and presenting community-based tourism routes and natural resources to suit the diverse behavioral patterns. This study combines a survey to gather preliminary tourist attraction data and an experimental study to examine the travel route using a computer program system. The case study for this study is Wang Nam Khiao in Nakhon Ratchasima Province. The result from 107 tourists suggests that 46.7 percent prefer to travel for two days and one night. Nature tourism, sightseeing, and camping are preferred by more than half of those polled. The travel routes are designed using the traveling salesman and time window. The QGIS program displays the findings of each route, which include attraction locations, main and subsidiary highways, and the area's topography. These QGIS data, along with supplementary information, are then changed for presentation on the two-sided brochure, which is the main tourism media.

Keywords: Tourism routes, COVID'19 pandemic, Traveling salesman, QGIS program

1. General Introduction

The world's largest and most diverse industry is travel and tourism. Many countries rely on this thriving business to generate revenue, jobs, private sector expansion, and infrastructure development. Tourism development is supported, particularly in all developing countries, when other types of economic development, such as manufacturing or the exports of natural resources, are not economically feasible [1].

Wang Nam Khiao in Nakhon Ratchasima Province is known as the world's 7th largest source of ozone and is known as Eastern Switzerland. The topography of Wang Nam Khiao District is mostly high mountains, steep slopes rich in natural attractions, and rare wildlife such as the last herd of bulls at Khao Phaeng Ma. Due to the aforementioned climate and terrain, Wang Nam Khiao has cool weather almost all year round, with abundant rainfall and fog. Wang Nam Khiao was registered as a World Heritage Site on July 14, 2005. It is the 5th world heritage site in the country and the 2nd ranked natural heritage under the group name "Dong Phaya Yen - Khao Yai". Wang Nam Khiao District has areas in 2 national parks, namely Khao Yai National Park and Thap Lan National Park. In addition, most of the local people are engaged in agriculture, making Wang Nam Khiao district rich in natural resources and the environment Therefore, it stimulates and attracts many tourists to travel to the Wang Nam Khiao area and business people come. Invest in the tourism business to support tourists who come to the area continuously [2].

However, Wang Nam Khiao's tourist attractions information is hard to find when searching for tourist attractions in Nakhon Ratchasima. Most of the information appears as tourist attractions only in the Pak Chong-Khao Yai area, which is another sub- district of Nakhon Ratchasima province. Therefore, tourists have little information from both online and onsite platforms to design tourism routes based on their traveling behaviors and the conditions of tourist attractions. Researchers then aim to support tourism in the Wang Nam Khiao area especially tourism after the COVID 19 epidemic and allow tourists to have more information about tourist attractions in the Wang Nam Khiao sub- district. This research aims to increase the value in the local area and stimulate the economy of the Wang Nam Khiao sub-district. It also allows tourists to design travel itineraries according to their needs or individual travel behaviors by applying programs for route planning, designing, and logistical principles to route organization.

2. Algorithm and Factors of Route Planning Algorithm for the Traveling

The route planning problem is commonly modeled as an optimization problem to determine a feasible path to meet specific requirements [3]. The Dijkastra algorithm [4] was regarded as a good solution in the single criterion period (the shortest path issue). It is used to determine the shortest path based on the smallest weight from one node to another using the Cartesian diagram. Dijkstra's algorithm may not be applicable if there are edges of negative length. Genetic algorithms (GA) can deal with complex problems and search for multiple solutions in parallel within one process [5]. These algorithms are effective when dealing with multi-criteria optimization problems. The Traveling Salesman Problem (TSP) was defined as a classic problem of determining the shortest path by which a salesman can transit through multiple locations without returning to the same location more than once. TSP requires that all computations of feasible routes be acquired for this investigation. Then, prioritizing the factors evaluated, such as distance and priority, choose one of the shortest routes [6]. When dealing with timetables, Vehicle Routing Problem with Time Windows and Time-Dependent Travel-Times (VRP-TDTT) can be applied to find the solution. This problem involves servicing several customers, at different geographic locations, with various demands, and within specific time windows. The planner aims to find routes for the vehicles to service all the customers at a minimal cost in terms of travel distance without violating the capacity and travel time constraints of the vehicles and the time window constraints set by the customers. However, this problem is not solved by mathematical programming, but by using heuristic methods to find the near-optimal [7].

3. Route Planning Program

Route planning requires a program for calculating mathematic equations and for collecting and presenting the information. General Algebraic Modeling System (GAMS) is the development of mathematical programming tools [8]. It is a general algebraic modeling system, which is a high-level modeling system for mathematical optimization. GAMS is designed for modeling and linear solving. Nonlinear solving an integer combination optimization allows users to use a type of hybrid algorithm that combines different solvers. The model is described in a concise, human-readable algebraic text. This program is applied in many applications to optimize a vehicle routing problem [9, 10, 11]. Geographic Information System (GIS) is another program that helps with route planning. This program allows people to solve many geographic problems quickly, effectively, and easily with the ability to make analyses, especially location analysis in combination with traditional database systems [12]. GIS makes use of a variety of coordinate referencing systems to locate features on the earth relative to others, which make use of a variety of map projections to transform earth references onto a two-dimensional surface or the map. The information pertains to the various spatial features such as ownership, soil type, and vegetation for a land parcel. This program is applied to search geographic information systems in tourism management and also nature-based tourism resources assessment [13].

4. Research Methodology and Result

This research is a combination of a survey to collect preliminary tourist attraction data and experimental research by using a computer program system to analyze routes. From the preliminary survey, it was found that there are few tourist route designs and tourist attractions in Thailand, especially in the provincial areas where more community-based tourism should be supported. Therefore, the researcher needs to apply engineering knowledge to support local tourism to make it more accessible to tourists, starting from the Wang Nam Khiao area. This research is conducted in 4 steps as presented in Fig 1.

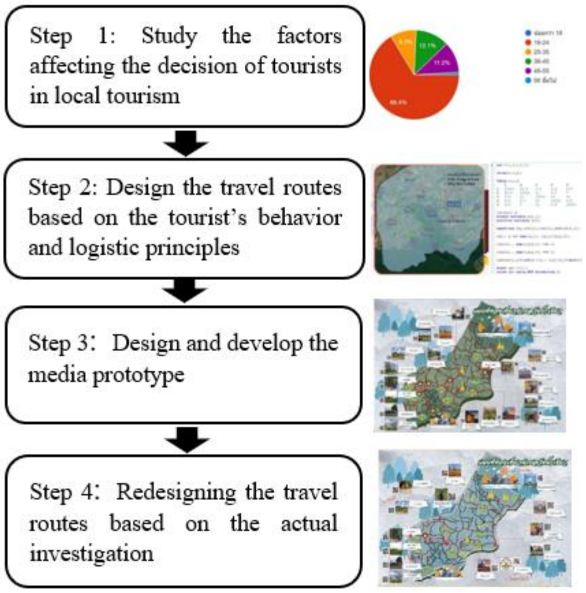

Fig. 1 Four Steps for conducting the research

4.1 Step 1: Study the Factors Affecting the Decision of Tourists in Local Tourism

After the covid 19 pandemic, human behaviors and lifestyles are changing. This can also affect traveling behaviors that should be initially investigated. The survey was designed and conducted to gather information including demographic, behaviors, and goals. The survey was launched on the Thai traveling webpage for 1 week. 107 respondents participated in the survey. The results of the survey are presented in Table 1.

Table 1 Results of factors affecting the decision-making of tourists from 107 participants.

Part no.	Topic	Alternative	%
1	Gender	Male	41.1
		Female	58.9
	Age	18-24	66.4
		25-35	9.3
		36-45	12.1
		46-55	11.2
		>56	0.9
2	Budget per time	< 1000	15
		1000-2000	28
		2000-3000	19.6
		3000-4000	11.2
		4000-5000	9.3
		>5000	1.8
	Time	Weekend	38.3
		Weekday	25.2
		Holiday	25.2
		Others	11.3
	Duration time	1 day	27.1
		2 days one night	46.7
		3 days one night	26.2
	Companion	0	8.4
		1-4	68.2
		5-9	20.6
		>9	2.8
3	Objective	sightseeing	59.8
		cultural tourism	49.5
		natural tourism	89.7
		local tourism	32.7
		camping	57.9

According to the survey's findings, males and females travel in the same manner on average. Most of the participants are young travelers 18-24 years old. They opted for a one-night stay on the weekend. Most of them prefer to have some companion around 1-4 people on the trip with a low budget (1000-2000 per time). Sightseeing, camping, and cultural tourism are also appealing to them. They are not very interested in local tourism. Local tourism, on the other hand, is encouraged to help the local community generate cash and create jobs. The results from this survey imply that a tourist route should have a variety of tourist attractions that can also promote a new tourist lifestyle.

4.2 Step 2: Design the Travel Routes Based on the Tourist's Behavior and Logistic Principles

Researchers start with gathering information about 60 tourist places in Wang Nam Khiao from the database in the U2T-University to Tambon project and the internet. Regarding a limited budget from the survey in Step 1, hotels and resorts are excluded from this initiative. These tourist places are then classified and filtered. Some small places are discarded. As a result, 20 tourist places are left to plan travel itineraries around. These tourist attractions are then grouped into five categories: camping, cultural tourism, natural tourism, farms, and cafés. Farms and cafés are popular with tourists visiting Wang Nam Khiao because travelers can learn many things about farming and different sorts of flowers. Travelers can also have a good experience of interacting with real animals such as goats and sheep. Cafes are popular places for travelers to check in and take photos. Some farms also have cafés to sell their products from the farm such as milk and cake. Regarding a beautiful environment and good atmosphere, travelers usually come to these provinces for camping. Camping areas are then seen as an important tourist places.

Twenty tourist places consist of four camping areas, three cultural tourism sites, three natural tourism sites, four farms, and six cafés among these tourist attractions. These tourist attractions' locations are compiled to create travel itineraries. Based on the interpretation of the results from the survey, tourist's behavior can be identified as the following

1) Tourists prefer camping for the night to staying at a hotel.
2) Tourists prefer to visit tourist attractions with different categories.

These behaviors are applied in designing travel routes. To simplify this problem as an initial step for designing the travel routes, the start and stop points of the journey are the same place, which is the camping areas. The travel routes are arranged by implementing all five categories of tourist attractions in one route. As a result, they should travel to at least 5 different destinations.

At the beginning of the route design, these four routes are identified using an idea of number of camping areas. The camping areas are the main travel place, which will be a starting point and an ending point of traveling. The other four tourism sites for each route are then chosen depending on the pathway distance. Finally, each route includes five tourist sites from various groupings but has the shortest path of traveling. The traveling salesman issue is used to assess a series of travel between these five locations, beginning and finishing at the same camping area. The GAMs program is used to determine the distance between each location based on the traveling salesman dilemma. The program calculates all routes to find the shortest path of traveling. An example of programming in the GAMS program is shown in Fig. 2.

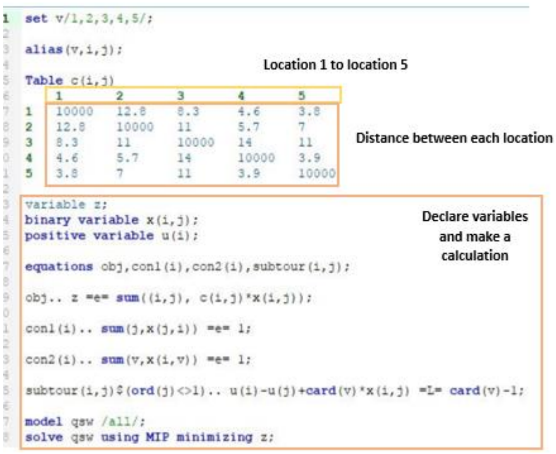

Fig. 2 An example of calculation based on the traveling salesman dilemma in GAMs application

4.3 Step 3: Design and Develop the Media Prototype

The researchers began the media prototype with a brochure as a simple resource for providing tourism information. Digital media will be expanded further if the information in the brochure is successful. Four travel routes from step 2 are applied in the brochure using the QGIS tool, which may depict the main roads, secondary roads, and geography of the locations. An example of one travel path in the media is shown in Fig 3.

Information in the media contains the names of tourist destinations, a suggestion of travel sequences based on the route's number, the main road and the secondary road, and other interesting places along the route, in kilometers, and duration time for traveling. Tourists might choose to follow this advice or visit other locations suggested by the media. On one side of the media, four different travel routes are depicted.

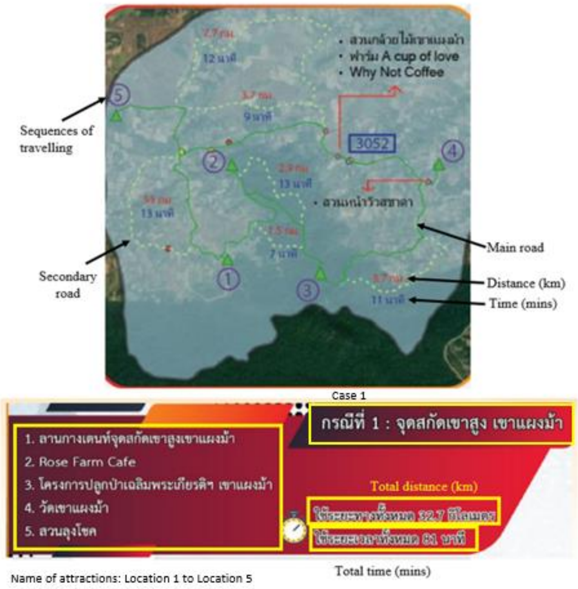

Fig. 3 The example of one travel route at Wang Nam Khiao with five attractive places.

On the other side of the media, all 20 tourist attractions are listed. This information is aimed to support tourist planning. Not only following our suggestion, but travelers can also plan their journeys. Furthermore, travelers can find more information about each tourist site by scanning QR codes placed in the media, as seen in Fig. 4.

Fig. 4 The overall travel route and locations of 20 tourist attractions

4.4 Step 4: Evaluate the Route Design by Surveying the Actual Route and Redesigning It

After identifying travel places and routes, researches make an onsite survey to evaluate the concept of route planning. However, several tourist places, including two camping places, are closed because of the COVID-19 pandemic. Another camping area is only open during the winter season, from the 25th to the 31st of December and from the 1st to the 2nd of January. As a result, there is just one camping location that is ideal for all seasons.

Flora Park is a tourist attraction that should be visited during the winter season because the majority of the blooms are winter blossoms. On the other hand, the Phaeng Khao Ma Orchid Garden is best explored during the summer. However, both are open throughout the year. Some tourist sites have limited operating hours. For example, the Saeng Tham Wang Khao Khiao temple is open from 5.30 a.m. until 10 a.m. Two tourism sites uncovered during the survey are included in the database to develop travel routes. These locations are part of the local tourist organization and are open all year. As a result, there are just 12 tourist attractions left. Subdistrict Administrative Organization Service Center Wang Nam Khiao has been included in the brochure to give travelers information about locations that can assist them. The front page of the brochure is then constructed using these 13 locations, as shown in Fig. 5.

Fig. 5 the front page of the final brochure with 12 tourist attractions and 1 service center

According to the findings of this study, researchers redesign travel routes by taking into account time and seasons. The time window idea is then used to build the new travel routes. Three distinct travel routes have been devised. As shown in Fig. 6, the time window is utilized to build the first and second travel routes for the winter and summer seasons.

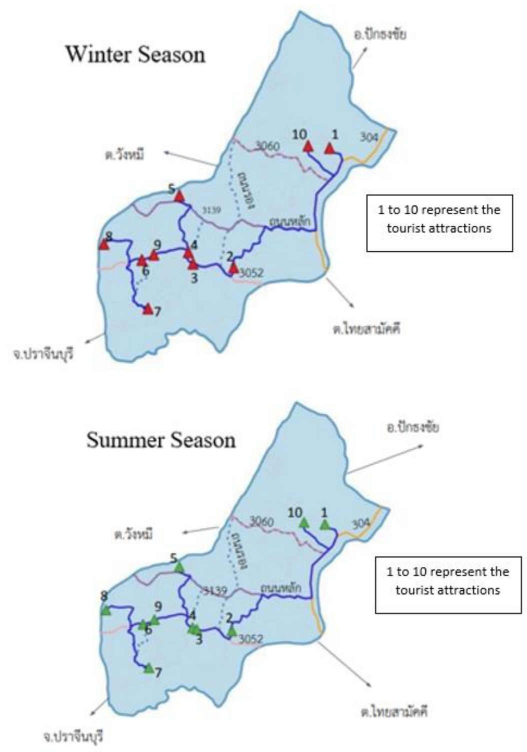

Fig. 6 Two travel routes based on the concept of the time window (Season, and opening period)

Most tourist attractions are identical in all seasons, except for tourist attraction number four, which is the Flora Park in winter and the Phaeng Khao Ma Orchid garden in summer. However, because the two sites are so close together, the travel patterns during the two seasons are practically identical. The Bird's Nest Camping is not included in these two routes due to time constraints, thus it is classified as an extra option for visitors.

The last brochure has 2 pages. The front page presents the overall locations of tourist attractions, roads, and surroundings. Tourists can use this information to plan their travels. The back page presents 3 travel routes using the concept of the time window and salesman traveling problem. Supplementary information such as the main and secondary roads, the number of roads, and the names of restaurants are added to the brochure. An example of information in the brochure is presented in Fig. 7.

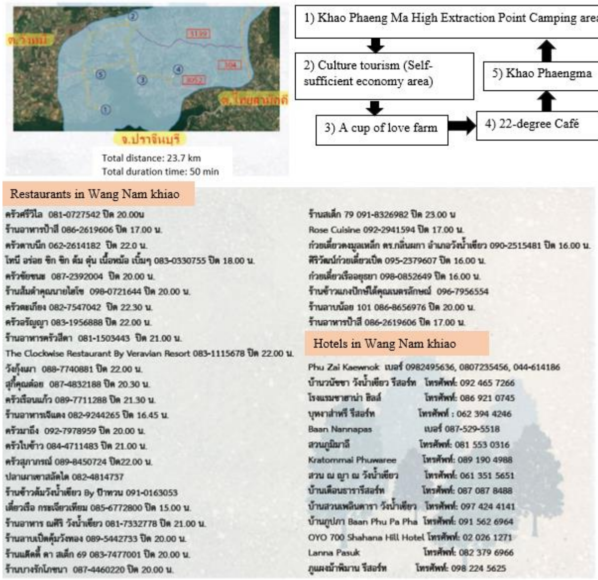

Fig. 7 The travel route based on the concept of the traveling salesman problem

5. Discussion and Conclusion

This research proposes the concept idea for designing the travel routes using the case study at Wang Nam Khiao Sub-distinct Nakhon Ratchasima Province. The travel routes are designed based on logistics principles and tourists' behavior. Tourists nowadays pay attention to nature tourism, especially after the COVID-19 epidemic. Therefore, designing the travel routes by integrating culture tourism and nature tourism is one strategy to support community tourism and increase opportunities to promote a better local economy. The priority strategy for designing travel routes is the time window. The GAMs program then calculates the shortest path based on the traveling salesman problem to save tourists money and time. However, the route types should be more diverse in terms of entrance place, length time, and conveyance.

Information on some locations is rarely available on a website or online platform, making it difficult for travelers to identify certain locations. This research assists travelers in learning more about the tourist attractions in this area. The QGIs program is used to represent area geographies, such as road types and surrounding areas. According to the results of the survey, several routes are unsuitable for transportation. Many areas lack road signage, making it risky and cumbersome for first-time visitors to reach these tourist attractions. If Wang

Nam Khiao wants to become a major tourist destination in the province, the government should prioritize the creation of better transportation routes. Based on these findings, the researchers discovered a weakness in outdated internet tourist information. Some locations are listed on the website even if they are closed. This problem may have an impact on travelers' plans and may damage expectations or attitudes toward that tourist sector. As a result, there should be a mechanism in place to assist in filtering tourist information, such as linking information from the internet system with the tax system to monitor the status of attractions.

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Development of the Depth-first Search Algorithm for Solving the Link-nested Logit Model in Traffic Assignment problem

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Abstract

In the four-step urban transportation planning procedure, the traffic assignment study's purpose is to estimate the network performance and predict the volume of traffic flows on links of the traffic network. The results of the traffic assignment suggest future traffic planning scenarios and directions to handle traffic congestion. In the wide range of traffic assignment models, the Stochastic User Equilibrium principle and the multinomial logit-based model have been fundamental. Although widely used, the assumption of the multinomial logit-based model consisting of independent distribution has also been criticized. To overcome this problem, the proposed link-nested logit model with a flexible correlation structure keeping the closed-form structure of the multinomial logit-based model has been extremely valuable in representing the Stochastic User Equilibrium traffic assignment problem. In general, the choice-set generation has been considered as a preferred solution. However, the route-set needs to be stored to compute the probability of choosing each route, causing a memory-occupancy problem. Also, the method of successive averages algorithm with predetermined step-size requires a very large number of iterations to converge. This paper will solve these problems with the use of the Depth-first Search loading procedure based on the STOCH3-efficient-route definition and the self-regulated averaging method. With these approaches, only link-based variables saving memory and the self-regulated averaging method saving computation time would improve the applicability of the link-nested logit model. A numerical experiment and an application to a real road network depict that the proposed method is effective for real network application.

Keywords: Link-nested logit model, Depth-first search algorithm, Traffic assignment

1. General Introduction

A key problem of traffic assignment is how to assign the Origin-Destination (OD) traffic demand onto the traffic network, in which the deterministic user equilibrium (DUE) and stochastic user equilibrium (SUE) are two major directions. While DUE assumes that each traveler has perfect information about actual travel conditions and seeks to minimize the cost associated with their path choice, the principle of stochastic user equilibrium presumes that no traveler can improve his or her stochastically "perceived" travel cost by unilaterally changing paths. The result of the SUE is more reasonable, realistic, and general than the DUE[1]. However, the well-known multinomial logit-based SUE traffic assignment with the overlapping problem, although widely used, has also been criticized. The overlapping problem in which many routes share links make the simple multinomial logit (MNL) model cannot correctly represent route choice. This problem is the IIA property (Independence of Irrelevant Alternative) that causes significant erroneous results on overlapping or correlated routes. The flow on the overlapping routes is overestimated because the network topology is not considered in the MNL model[1]. To overcome the route overlapping problem, many researchers modified the single-level tree structure of the original MNL model. For example, C-logit model[2] and path-size logit model[3]. Nevertheless, very similar patterns were shown in MNL and its modifications[4]. Since McFadden (1978)[5] presented the generalized-extreme-value (GEV) theory with the framework of random utility maximization, GEV-based route choice models have been widely applied including the link nested logit (LNL) model[6,7], the generalized nested logit (GNL) model[8], and the paired combinatorial logit (PCL) model. In this approach, a two-level tree structure using the marginal and conditional probabilities was considered, which allowed the route to belong to more than one nest. While a nest was a link in the LNL and GNL, it was a route pair in the PCL model. Because the number of nests in the PCL model will increase expeditiously with network size, it decreased the applicability of the PCL model. Some network GEV-based route choice models without explicit route enumeration were proposed in recent years[9]. When Fosgerau et al.[10] presented a recursive logit (RL) model for route choice without sampling any choice sets of paths, Mai et al.[11] proposed a nested RL model for route choice analysis that uses a system of non-linear equations to overcome the IIA property. However, because of the appearance of the cyclic route and the calculation of the inverse matrix made it very difficult to apply to the traffic equilibrium problem. All of the above, the link-nested logit model with flexible correlation structure keeping the closed form equation of MNL model is still valuable in representing route choice behavior and traffic assignment problem.

To solve the LNL model, in general, the choice-set generation has been considered as a preferred solution. Regarding route-set generation, there are two main methods including *k*-shortest routes and deterministic-based generation in the route-based approach[12]. However, the route-set needs to be stored to compute the probability of choosing each route, causing a memory-occupancy problem. Also, the method of successive averages (MSA) algorithm with a predetermined step-size requires a very large number of iterations to converge. Based on the definition of the "STOCH3-efficient route" [13] and the DFS algorithm[14], Bui et. al[15] and Bui[16] proposed the algorithm for solving the MNL SUE problem saving calculation time without using route-based variables. We also use these approaches for solving the LNL model. Furthermore, instead of depending on the MSA method, the self-regulated averaging (SRA) [17] method would be used to fasten the convergence rate of the SUE solution.

This paper is organized as follows. The next section will overview the link-nested logit model and the route-based MSA method problems. Section 3 shows how to solve these problems with the use of the DFS loading procedure based on the STOCH3-efficient-route definition and the SRA method. These approaches only use link-based variables to save memory and the SRA algorithm to save computation time. A numerical experiment and an application to the real road network in Section 4 depict that the proposed method is effective for real network applications. The final is some conclusions and remarks.

2. Overview of the Link-Nested Logit Model

The overlapping problem of the MNL model caused mistaken results on overlapping or correlated routes. For example, we use the simple network with an OD pair and four-link shown in Fig. 1 to illustrate this problem. There are three possible routes, two of them having a common link. Assuming the travel time on each of these routes is 10 minutes gives the flow on all the routes would be equal by using the MNL model. There is no problem with this result if the amount of overlap between the two bottom routes is relatively small (Fig. 1a) in which most travelers perceive the three routes as three distinct alternatives. However, if the amount of overlap is large, as shown in Fig. 1b, travelers may perceive the two bottom routes as a single alternative. As a consequence, the flows on heavily overlapping routes are overestimated.

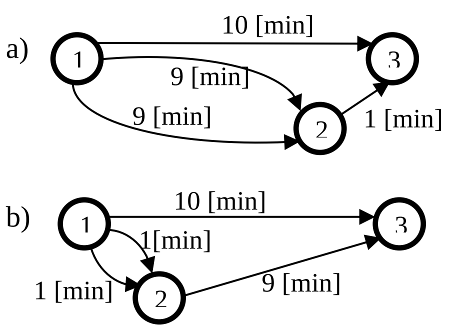

Fig. 1 A virtual network representing the problem of MNL model

To overcome the route overlapping problem, the LNL[6] based model with a flexible correlation structure has received the attention of numerous researchers. Consider the following function

$$G(y_1, y_2, \dots, y_k) = \sum_m \left[\sum_{k\in K_m} (\alpha_{km} y_k)^{\frac{1}{\mu}}\right]^{\mu} \quad (1)$$

where, $G(\dots)$ is the generator function of k nonnegative variables, y_k is the value of each discrete choice alternative, K_m is the set of all alternatives included in nest m, α_{km} is the inclusion coefficient of alternative k in nest m, $0 \le \alpha_{km} \le 1$ and $\sum_m \alpha_{km} = 1 \; \forall \, k \in K_m$, and μ is the degree of nesting, $0 < \mu \le 1$.

In the route choice context that is a case of discrete choice the terminology of the LNL model, k is considered as a route, m is considered as a link ij (between node i and node j) and y_k is assumed as $exp(V_k)$ in which V_k is the utility of alternative k. Considering a traffic network with $N = \{i, j, \ldots\}$ nodes, $A = \{ij, gh, \ldots\}$ links and $W = \{rs, \ldots\}$ OD pairs, the similarity between routes of each OD pair rs can be measured only on the network topology. It is assumed that the inclusion coefficient $(\alpha_{ij,k}^{rs})$ expresses a ratio of each link physical length (or free-flow time) on each route in which this coefficient is considered in each OD pair and not dependent on congestion:

$$\alpha_{ij,k}^{rs} = \frac{L_{ij}}{L_k^{rs}} \delta_{ij,k}^{rs} \qquad (2)$$

where L_{ij} is the link physical length (or free-flow time), L_k is the path physical length (or free-flow time), $\delta_{ij,k}^{rs}$ is the link-route incidence variable. $\delta_{ij,k}^{rs} = 1$ if nest m (link ij) in on route k and $\delta_{ij,k}^{rs} = 0$ otherwise.

If the GEV theory is applied and the utility of route k is assumed as $-\theta c_k^{rs}$, the probability of choosing route k is as following equation:

$$p_k^{rs} = \sum_{ij \in A} p_{(k/ij)}^{rs} pm_{ij}^{rs} = \frac{\sum_{ij \in A} \left(\left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}) \right\}^{\frac{1}{\mu}} \left[\sum_{k \in K_{ij}^{rs}} \left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}) \right\}^{\frac{1}{\mu}} \right]^{\mu - 1} \right)}{\sum_{ij \in A} \left[\sum_{k \in K_{ij}^{rs}} \left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}) \right\}^{\frac{1}{\mu}} \right]^{\mu}} \qquad (3)$$

where pm_{ij}^{rs} is the marginal probability of choosing nest m (link ij), $p_{(k/ij)}^{rs}$ is the conditional probability of choosing route k if nest m (link ij) is selected, θ is positive parameter, c_k is the travel time on route k, K_{ij}^{rs} is the set of routes included in nest m, i.e., the set of routes have the common link ij. pm_{ij}^{rs} and $p_{(k/ij)}^{rs}$ are given by the following equations:

$$pm_{ij}^{rs} = \frac{\left[\sum_{k \in K_{ij}^{rs}} \left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}) \right\}^{\frac{1}{\mu}} \right]^{\mu}}{\sum_{ij \in A} \left[\sum_{k \in K_{ij}^{rs}} \left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}) \right\}^{\frac{1}{\mu}} \right]^{\mu}} \qquad (4)$$

$$p_{(k/ij)}^{rs} = \frac{\left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}) \right\}^{\frac{1}{\mu}}}{\left[\sum_{k \in K_{ij}^{rs}} \left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}) \right\}^{\frac{1}{\mu}} \right]^{\mu}} \qquad (5)$$

Let q^{rs} and f_k^{rs} be the traffic demand and route traffic flow of an OD pair. In the logit-based traffic assignment model, it is assumed that

$$f_k^{rs} = q^{rs} p_k^{rs} \qquad (6)$$

It is clear that flow conservation is automatically satisfied

$$q^{rs} = \sum_{k \in K^{rs}} f_k^{rs} \qquad (7)$$

where K^{rs} is the set of routes connecting OD pair rs.

And, the relationship between the link flow (x_{ij}) and route flow (f_k^{rs}); the route travel cost (c_k^{rs}) and link travel cost (t_{ij}) are respectively represented by:

$$x_{ij} = \sum_{rs \in W} x_{ij}^{rs} = \sum_{rs \in W} \sum_{k \in K^{rs}} f_k^{rs} \delta_{ij,k}^{rs} \qquad (8)$$

$$c_k^{rs} = \sum_{ij \in A} t_{ij} \delta_{ij,k}^{rs} \qquad (9)$$

here, t_{ij} is the travel time of link ij, but since it changes depending on the traffic passing through the link, it can be regarded as a function of link traffic x_{ij}, so it is expressed as follows:

$$t_{ij} = t_{ij}(x_{ij}), \forall \, ij \in A \qquad (10)$$

From Equations (3)-(10), a fixed-point problem with route flow of the SUE LNL model traffic assignment is considered as follows:

$$f_k^{rs} = q^{rs} \frac{\sum_{ij \in A} \left(\left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}(\mathbf{f})) \right\}^{\frac{1}{\mu}} \left[\sum_{k \in K_{ij}^{rs}} \left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}(\mathbf{f})) \right\}^{\frac{1}{\mu}} \right]^{\mu - 1} \right)}{\sum_{ij \in A} \left[\sum_{k \in K_{ij}^{rs}} \left\{ \alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs}(\mathbf{f})) \right\}^{\frac{1}{\mu}} \right]^{\mu}} \qquad (11)$$

The well-known MSA method could be utilized to achieve equilibrium[18].

To illustrate the LNL model in the route choice context and show how this model can solve the overlapping problem, we consider the small network shown in Fig. 1b. Denoting link 1 is from node 1 to node 2, link 4 is from node 2 to node 3. Because there are 2 links from node 1 to node 2, to distinguish these links we will use the symbol link 2 for the link above and link 3 for the link below. There are 3 possible routes from origin node 1 to destination node 3: route 1 includes link 1, route 2 includes link 2 and link 4, and route 3 includes link 3 and link 4. The link-nested structure of the LNL model is different with 4 nests in concordance with 4 links as following figure:

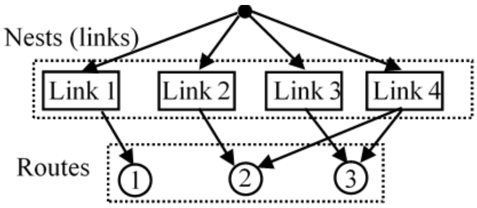

Fig. 2 The nest structure of the LNL model in the small network.

For further comparison, the route choice probabilities will be calculated. Some parameters are set for the computation reason in which $\mu = 0.1$ and $\theta = 1$. The results are shown in the following table:

Table 1 Route probabilities comparison

Route	Probability of choosing the route in different models	
	MNL	LNL
1	0.333	0.462
2	0.333	0.269
3	0.333	0.269

As can be seen, while the MNL cannot consider the overlapping problem, the LNL can treat this problem. In detail, the probability of choosing route 1 in the nested-logit model and LNL is greater than that in the MNL model because of the overlap between routes 2 and 3.

The overview of the LNL model for route choice context is shown in this Section. The problem of fixed-point with route traffic flow is also considered in Equation (11). Generally, the choice-set generation is the first step to solve this problem. However, the route-set storing cause a memory-occupancy problem. Besides, the MSA algorithm with predetermined step-size requires a very large number of iterations to achieve SUE solution. The next section will solve these problems by using the DFS loading procedure based on the STOCH3-efficient-route definition and the SRA method.

3. Link-Nested Logit Model with Depth-First Search Algorithm

Applying the LNL model with the route-based approach in section 2 is very difficult because the real transport network has many OD pairs and many routes connecting each OD pair. To increase the applicability of this model, our starting point is how to calculate the model without using route variables. In a transport network, while the node and link are constant, the number of routes depending on the number of OD pairs is huge. Thus, link-based and node-based variables should be used to model the LNL approach.

Instead of calculating the probability of selecting a route, the probability of selecting a link is considered because after all, the purpose of traffic assignment is to know the flow and travel time on the links. By the SUE condition, the probability of choosing link ij is the total of the probability of choosing route k containing link ij and is given by the following expression:

$$p_{ij}^{rs} = \sum_{k \in K^{rs}} p_k^{rs} \, \delta_{ij,k}^{rs} \tag{12}$$

where p_{ij}^{rs} is the probability of choosing link ij between OD pair rs. Denoting K_{ij}^{rs} is the set of routes connecting OD pair rs that consist of link ij, we do not need to consider $\delta_{ij,k}^{rs}$, Equation (12) becomes:

$$p_{ij}^{rs} = \sum_{k \in K_{ij}^{rs}} p_k^{rs} = \frac{\sum_{k \in K_{ij}^{rs}} \sum_{mn \in A} \left(\left\{ \alpha_{mn,k}^{rs} \exp(-\theta c_k^{rs}) \right\}^{\frac{1}{\mu}} \left[\sum_{p \in K_{mn}^{rs}} \left\{ \alpha_{mn,p}^{rs} \exp(-\theta c_p^{rs}) \right\}^{\frac{1}{\mu}} \right]^{\mu - 1} \right)}{\sum_{mn \in A} \left[\sum_{k \in K_{mn}^{rs}} \left\{ \alpha_{mn,k}^{rs} \exp(-\theta c_k^{rs}) \right\}^{\frac{1}{\mu}} \right]^{\mu}} \tag{13}$$

The link flow is represented as a function of p_{ij}^{rs}:

$$x_{ij} = \sum_{rs \in W} q^{rs} p_{ij}^{rs} \tag{14}$$

If the link travel time is the function of link flow, the route travel time is also the function of link flow. Thus, p_{ij}^{rs} is also the function of the link flow from Equation (13). Thus, we need to solve the fixed-point problem with link flow as follows:

$$x_{ij} = \sum_{rs \in W} q^{rs} p_{ij}^{rs}(\mathbf{x}) \tag{15}$$

Bui[16] used the "STOCH3-efficient routes" definition and confirmed that if the route choice set includes routes defined as "STOCH3-efficient routes", the DFS algorithm could be used to explicit all these routes. From there, we think about the use of DFS algorithm to calculate Equation (13) without considering route-based variables.

The difficulty, here, in the calculating p_{ij}^{rs} without route-based variables that can be decomposed into two parts:

$$u_{1,ij,k}^{rs} = \{\alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs})\}^{\frac{1}{\mu}}, \qquad (16)$$

$$u_{2,ij}^{rs} = \sum_{k\in K_{ij}^{rs}} u_{1,ij,k}^{rs} = \sum_{k\in K_{ij}^{rs}} \{\alpha_{ij,k}^{rs} \exp(-\theta c_k^{rs})\}^{\frac{1}{\mu}}. \qquad (17)$$

If we use the two above denotations, p_{ij}^{rs} becomes

$$p_{ij}^{rs} = \frac{\sum_{k\in K_{ij}^{rs}} \sum_{mn\in A} \left[u_{1,mn,k}^{rs} \left(\left[u_{2,mn}^{rs}\right]^{\mu-1}\right)\right]}{\sum_{ij\in A}\left[u_{2,ij}^{rs}\right]^{\mu}} \qquad (18)$$

Let we denote $numc_{ij}^{rs}$ and $dnmc^{rs}$ as the numerator and the denominator of Equation (18). The calculation of Equation (18) could be solved by calculating $numc_{ij}^{rs}$ and $dnmc^{rs}$ that are calculated through $u_{1,ij,k}^{rs}$ and $u_{2,ij}^{rs}$ variables. To calculate $u_{2,ij}^{rs}$, a prerequisite is $u_{1,ij,k}^{rs}$ that has been calculated. $u_{2,ij}^{rs}$ is calculated if we know all the routes passing through link ij, K_{ij}^{rs}, which requires running the DFS algorithm. If we save $u_{1,ij,k}^{rs}$ variable, it requires a huge amount of memory. So, the DFS algorithm is used for each OD pair without saving $\alpha_{ij,k}^{rs}$, $u_{1,ij,k}^{rs}$ and c_k^{rs} variables. For example, if the following network consists of efficient links in Fig. 3 and a network is saved as adjacent links instead of matrices, the DFS algorithm will traverse nodes in the following order: *r*, 1, 2, 3, 4, *s*, 5, 4, *s*.

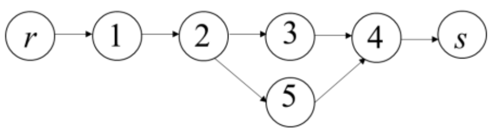

Fig. 3 A virtual network with an OD pair

We can use a one-dimensional array to mark the route from origin r to destination s that can be reused for saving memory. After first reaching destination s, the mark array consists of the links *r*1, 12, 23, 34, 4*s* that represent a route. Then, the algorithm comes back to node 2 because no adjacent links need to be visited from node 3 to node *s*. It then continues to chase links 25, 54, and 4*s* to reach destination s for the second time. The mark array is reused by removing the backtracked elements (links 4*s*, 34, 23) and updated by adding the new visited links (links 25, 54, and 4*s*), and now consists of links *r*1, 12, 25, 54, 4*s*, which represent another route. With a recursive technique, we can reach the destination node s by $|K^{rs}|$ times that represent the number of efficient routes in route-set and we know all the routes passing through link ij.

Some variables will be used: Ω_{ij}^{rs} denotes indicator variable ($\Omega_{ij}^{rs} \coloneqq 1$ if link ij is efficient from r to s and $\Omega_{ij}^{rs} := 0$ otherwise) that can be defined by STOCH3-efficient-route; a_{ij} is the likelihood of link ij $a_{ij} = \exp(-\theta t_{ij})$; $mark_{ij}$ array to mark the efficient route in the DFS algorithm and node-based variable, vn_n^{rs}. The process of calculating $numc_{ij}^{rs}$ and $dnmc^{rs}$ as follows:

- For each link ij, set $a_{ij} \coloneqq \exp(-\theta t_{ij})$, $u_{2,ij}^{rs} = 0$. We can run the DFS algorithm from origin node r to destination node s with the recursive technique as follows: Set all vn_n^{rs} to 0 and vn_r^{rs}:=1. After each link and node with the nonzero value of Ω_{ij}^{rs} (efficient link) is visited[16], we update $vn_j^{rs} = a_{ij} vn_i^{rs}$. When reaching destination node s, we know all the links visited from node r to node s that is exactly information of an efficient route k and $vn_s^{rs} = \exp(-\theta c_k^{rs})$[16]. Each time we reach the destination node, we have information about links that belong to an efficient route through the mark array, $mark_{ij}$, we can calculate $\alpha_{ij,k}^{rs}$ each time s is reached and use this to calculate $u_{1,ij,k}^{rs}$ without saving $\alpha_{ij,k}^{rs}$ variable. $u_{2,ij}^{rs}$ is also calculated at each time reaching s, if link ij is a member of mark array, we add $u_{1,ij,k}^{rs}$ to $u_{2,ij}^{rs}$ without saving $u_{1,ij,k}^{rs}$ variable. When s is reach $|K^{rs}|$ time (total efficient routes), $u_{2,ij}^{rs}$ is completely calculated. When the DFS algorithm stops, $dnmc^{rs}$ is computed by summing $u_{2,ij}^{rs}$ for all links ij in the network.
- To calculate $numc_{ij}^{rs}$, we must have the result of $u_{2,ij}^{rs}$ that is only completely computed when the DFS algorithm stops, i.e., all efficient routes are considered. Thus, we must run the DFS algorithm again to calculate $numc_{ij}^{rs}$. We set $numc_{ij}^{rs} = 0$ and continue running the DFS algorithm for the second time. vn_s^{rs} is calculated by using the same procedure as the first time. Note that $u_{1,mn,k}^{rs} = 0$ if route k does not consist of link mn. Thus, we only need to calculate $u_{1,mn,k}^{rs}$ for all links mn belonging to mark

array, $mark_{ij}$. At each time reaching destination node s, we calculate $u^{rs}_{1,gh,k}\left(\left[u^{rs}_{2,gh}\right]^{\mu-1}\right)$ that is summed up all the links gh in the mark array and added to $numc^{rs}_{ij}$ if link ij is a member of mark array. When s is reach $|K^{rs}|$ time, $numc^{rs}_{ij}$ is completely calculated.

From the above techniques, we do not need to use route variables to calculate Equation (18) and because it is calculated for each OD pair, we can reuse variables for each calculation loop to save memory. In a large-scale network, while the number of links is fixed, the number of routes will increase rapidly when the number of OD pairs increases. Therefore, using link-based variables and calculating link flows will save memory.

The DFS loading procedure using STOCH3-efficient-route definition with the SRA method for the LNL traffic assignment is shown as follows:

Step 0: Preliminaries.

(a) Set current iteration counter $l := 1$, $\eta \in [1.5,2]$, $\gamma \in [0.01,0.5]$, $\vartheta^{(l-1)} = 0$, and convergence test value σ.

(b) Define reasonable links by setting the value of Ω^{rs}_{ij}.

(c) Find an initial feasible flow pattern based on free flow link times (t^0_{ij}):

- For each link ij, set $t_{ij} = t^0_{ij}$, $a_{ij} \coloneqq \exp(-\theta t_{ij})$ and, $x^{(l)}_{ij}$=0.
- Performing the DFS algorithm from origin node r to destination node s with recursive technique twice to calculate p^{rs}_{ij}.
- Contribution to total link-flows as follows:

$$x^{(l)}_{ij} \coloneqq x^{(l)}_{ij} + q^{rs} p^{rs}_{ij}. \qquad (19)$$

Step 1: Link travel time and link impedance update.

(a) Set $l := l + 1$.

(b) Update $t^{(l)}_{ij} \coloneqq t_{ij}\left(x^{(l)}_{ij}\right)$ and $a_{ij} \coloneqq \exp(-\theta\, t^{(l)}_{ij})$.

Step 2: Direction finding.

Based on the link travel time $\{t^{(l)}_{ij}\}$ and a_{ij}, running DFS algorithm from origin node r to destination node s twice to update p^{rs}_{ij}. When the DFS algorithm stop, the auxiliary link flow is yielded as the following equation:

$$yx^{(l)}_{ij} \coloneqq yx^{(l)}_{ij} + q^{rs} p^{rs}_{ij} \qquad (20)$$

Step 3: Link flow update

(a) Calculate $\vartheta^{(l)}$ as follows:

$$\vartheta^{(l)} = \begin{cases} \vartheta^{(l-1)} + \eta, \text{if } \left\|\mathbf{x}^{(l)} - \mathbf{yx}^{(l)}\right\| \geq \left\|\mathbf{x}^{(l-1)} - \mathbf{yx}^{(l-1)}\right\| \\ \vartheta^{(l-1)} + \gamma, \text{if } \left\|\mathbf{x}^{(l)} - \mathbf{yx}^{(l)}\right\| < \left\|\mathbf{x}^{(l-1)} - \mathbf{yx}^{(l-1)}\right\|. \end{cases} \qquad (21)$$

(b) Let $rg^{(l)}_{ij} = yx^{(l)}_{ij} - x^{(l)}_{ij}$.

(c) Set $x^{(l+1)}_{ij} = x^{(l)}_{ij} + \frac{1}{\vartheta^{(l)}} rg^{(l)}_{ij}$.

Step 4: Stopping the test

If $max_{ij}\left\{\left|rg^{(l)}_{ij}\right|\right\} \leq \sigma$, stop. The solution is $\{x^{(l)}_{ij}\}$. Otherwise, go to step 2.

In the proposed method, we do not need to save the route choice set to reduce computational storage. Also, the DFS algorithm with recursive solving tree data structures and the SRA method help reduce computational time.

4. Applications

4.1 Applications to a Virtual Road Network

The small network with 5 nodes, 7 links, and an OD pair shown in Fig. 4 would be considered. The link parameters are depicted in Table 2. There are 4 possible routes from node 1 to node 5: route 1 (1→2→3→5), route 2 (1→3→5), route 3 (1→4→3→5), and route 4 (1→5). Travel demand is 900 [pcu]. The nest structure is shown in Fig. 5

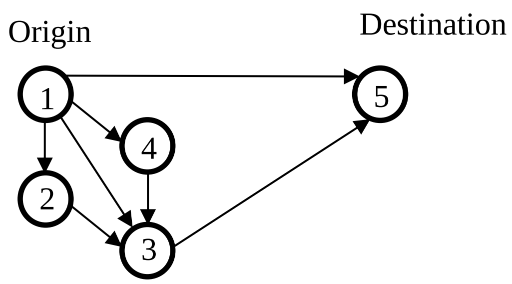

Fig. 4 A small virtual road network

Table 2 The link parameters of the small network

No.	Link	Free-flow travel time (min)	Capacity (pcu)
1	12	10	150
2	13	5	100
3	14	5	150
4	15	30	500
5	23	10	125
6	35	20	500
7	43	5	125

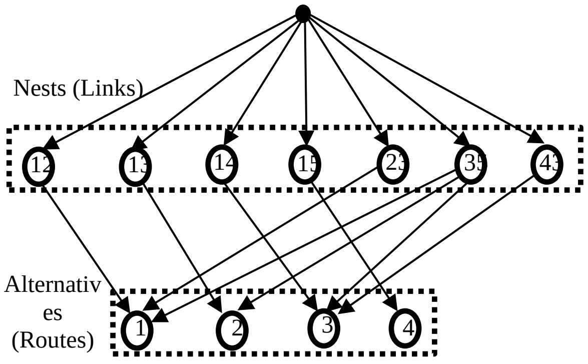

Fig. 5 Link-nested structure of the small network

To illustrate the calculational effect of the proposed method, the link-nested logit model will be calculated by using two methods: the route-based approach[18] and the DFS algorithm approach proposed in this study. To assess the accuracy of the proposed method, the *RMSE* indicator indicates the error of comparing between two approaches is calculated as follows:

$$RMSE = \sqrt{\frac{1}{|A|}\sum_{ij\in A}\left(\ddot{x}_{ij} - x_{ij}\right)^2} \quad (22)$$

where, $\ddot{x}_{ij}$ and x_{ij} are the link flows at the SUE solution calculated by using the route-based approach[18] and the DFS algorithm approach, respectively. The parameters of the BPR function are assumed: $\alpha = 1$, $\beta = 2$. The parameter θ is 0.5 We also assume that parameter μ changes from 0.1 to 0.9. The programs were coded by Fortran.90 programming language and ran on a personal computer. The results of the calculation time and *RMSE* indicator are shown in Table 3. As can be seen, the results of link flows are the same between the two methods with the extremely small value *RMSE* indicator. Also, we will save computational time with the DFS algorithm approach. In this comparison, the saving time is at least 94%. Furthermore, we also do not need to explicit route choice set with the DFS algorithm. In a real road network with a huge amount of OD pairs and routes connecting each OD pair, the effectiveness of the DFS algorithm will exponentially increase.

Table 3 The comparison between two methods

μ	Calculation time of Route-based approach (sec)	Calculation time of DFS algorithm approach (sec)	*RMSE*
0.1	0.94	0.03	0.000561
0.2	0.91	0.03	0.000556
0.3	0.91	0.02	0.000556
0.4	0.91	0.03	0.000557
0.5	0.28	0.02	0.000556
0.6	0.92	0.02	0.000555
0.7	0.92	0.05	0.000549
0.8	0.92	0.03	0.000553
0.9	0.91	0.02	0.000552
Total calculation time (sec)	7.61	0.23	

4.2 Applications to a Real Urban Road Network

We also apply the proposed model in this paper to the Kanazawa road network in Japan[16]. The OD demand data from a previous personal-trip survey is used with 383 OD pairs of the morning peak from 6:00 to 7:00 AM. The BPR function of the travel time of the car uses $\alpha = 1.0$, $\beta = 2.0$, and the assumed parameter is $\theta = 0.2$, $\mu = 0.5$. The elongation ratio h_{ij}^{r} is set to 1.5 for every link of the network. While the route-based approach could not run in this application, the DFS algorithm approach gives the SUE solution in a short time of 2.33 seconds. The DFS-based model for MNL[16] is also calculated to compare with the proposed model in this paper. In the previous paper, the DFS algorithm was used to solve the MNL model with only one computation loop. However, in this paper, the DFS algorithm needs to be used twice to solve the LNL model (detailed in Section 3). The calculation process for the LNL problem is much more difficult than for the MNL problem. Nevertheless, the computational ability of the proposed model in this good is very good. The results show that the computation time in this LNL model (2.33 seconds), although larger than the MNL model (1.33 seconds), still ensures very good computational ability. Moreover, Fig. 6 shows the comparison between the calculated link flows of the MNL and LNL models. The result depicts that the LNL and MNL models have a close relationship and the LNL model could be used to replace the well-known MNL model. While the MNL model cannot solve the overlapping problem, the LNL model can solve this. The calculation results of these two models are quite similar in this calculation case study. Because the number of OD pairs is quite small (383 OD pairs). Moreover, Kanazawa city is a small city with relatively little traffic volume. Therefore, the problem of route overlapping is not very common in this case. In the future, application to bigger cities with high traffic volume will need to be carried out to detail the applicability of the LNL model.

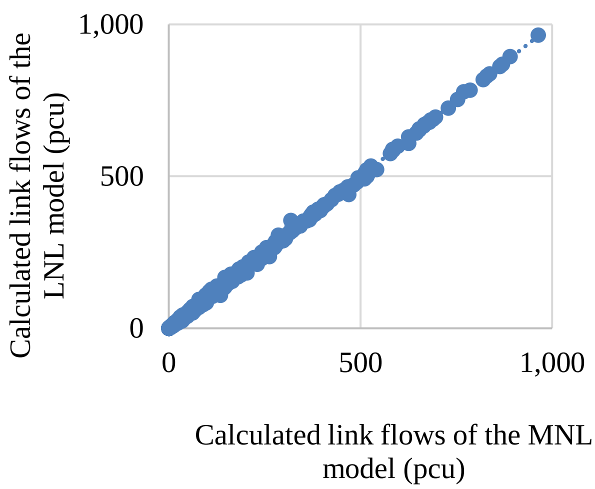

Fig. 6 The comparison between the calculated link flows of the models

5. Conclusions

An effective DFS algorithm for solving the LNL model in traffic assignment problem has been considered in this paper. Instead of using the route-based MSA method, the DFS algorithm with STOCH3-efficient-route definition and the SRA method is proposed. Because the proposed method does not use route-based variables, it helps to save memory by using only link-based and node-based variables. Also, the calculation time is reduced. The application to a simple road network has shown the ability to replace the old method of the proposed algorithm and the applicability of the model. The application to the actual model also shows that. In the future, we may work to further develop the combination of solving other problems of the MNL model and explore more of the structure of the model.

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Development of Collision Avoidance System for Vehicles using 5G C-V2I

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Abstract

The survey of the year 2003 by the national highway traffic safety administration (NHTSA) found that 19,000 accidents occurred on Merging Road, accounting for 3.5% of lane-change accidents. As the Smart Mobility Research Center's autonomous vehicle deployment has lane merging that has no signal and needs to be driven with vehicles on the road, it is necessary to install a warning system to reduce the risk of accidents. This research is to create a warning system based on C-V2I for detecting vehicles on the main road in a position that autonomous vehicles on the secondary road cannot detect and send notifications to the autonomous vehicle by designating the Merging Road in front of the Faculty of Engineering, Chulalongkorn University as a place for experiment. This is because the location is a junction with no signal and is in the autonomous route area. In this research, the warning system was divided into 3 subsystems: detection, processing, and communication. The system will have a working process. When a car moves into the notification area Camera and LiDAR (laser detection system) installed in a calibrated system will detect and send the data to the Nvidia Jetson TX2 (processing system) for processing the Image dataset: YOLO v4 and Point Cloud dataset: SFA3D. After that, the result data will be processed together and checked to increase the accuracy of the detected object by the Intersect of Union (IoU) method and send data via MQTT (Communication System) to display information to the safe driver inside the autonomous vehicle's display screen by showing the upcoming vehicle's position in the detected area along with an audible warning. The communication system between infrastructure and vehicle will work and operate through the 5G cellular network. From the test, the camera can be detected without the impact of the environment, such as the high dynamic range of lighting and shadow of the tree, and the detection distance can be achieved within 20 meters, which is enough for usage in low-speed conditions This is a consequence of the limitation of the device. In terms of processing and warning speeds is 340 milliseconds. When considering a maximum speed of 50 km/h, it was found that the processing time is equivalent to a car's running distance of about 5 meters, which is enough to allow the safe driver in an autonomous vehicle to respond to warnings on time. In The future, this research will be applied to autonomous vehicle control to be able to respond to notifications automatically in the next step.

Keywords: C-V2I, Merging Road, 5G, Autonomous Vehicle

1. Introduction

The survey of the year 2003 by the national highway traffic safety administration (NHTSA) found that 19,000 accidents occurred on Merging Road, accounting for 3.5% of lane-change accidents [1]. Based on data from the U.S. Fatality Analysis Reporting System (FARS) and General Estimates System (GES), surveyed that 82,609 police-reported crashes occurred at interchanges on the interstate in 2001, and found 24,996 crashes resulted in injuries and 544 fatal incidents. there reported that 18% of all interstate crashes, 17% of injury crashes, and 11% of fatal crashes occurred at interchanges [2]. The aforementioned accidents show that vehicles driving through the merging roads have a high risk of accidents and there is also a high risk of fatal accidents. Regarding the Smart Mobility Research

Center's autonomous vehicle deployment, A route must drive through the unsign merging road, therefore, to be driven with vehicles on the road. it is necessary to invent a warning system to reduce the risk of accidents by creating a system on the roadside that can detect vehicles moving in the area where the sensors of the autonomous car cannot detect and send the warning information to the autonomous vehicle.

Cooperative Vehicle Infrastructure System (CVIS) technology is one of the key technology that will improve the safety and efficiency of maneuvering through the merging zone [3]. In this research, the focus will be on the Cellular Vehicle to Infrastructure System (C-V2I) to develop a preliminary collision warning system. Because the previous work used a camera detection algorithm [4] and there were problems with the high dynamic range of the scene's lighting and the shadow of the tree. This research aims to improve the detection performance of the system by integrating cameras and lidar to detect vehicles. To increase the accuracy, the IoU (Intersection over Union) method is implemented for the integration of sensors together that output the type, and position of the vehicles [5]. Then, the data is processed and alerted to the safe drivers on an autonomous vehicle to prevent accidents on merging roads.

2. Literature Review

This section will begin with a review of recent research on vehicle detection from cameras and LiDAR and will also feature research reviews on data extraction from LiDAR. To train the dataset of an autonomous vehicle object detection, KITTI Dataset is used as a benchmark dataset.

2.1 LiDAR Based 3D Objection

2.1.1 "Super Fast and Accurate 3D Object Detection Based on 3D LiDAR Point Clouds" (Maudzubg.)

Super Fast and Accurate 3D Object Detection Based on 3D LiDAR Point Clouds, abbreviated as SFA3D, is a detection algorithm that uses Lidar to detect pure objects [6]. It uses deep learning processing and detection. It uses a ResNet-based Keypoint Feature Pyramid Network (KFPN) pre-trained model. Input is a lidar, Birds-Eye-View view [7] for consideration, and Output will be the Heat map, Center offset, Yaw angle, Dimension, and Z coordinate. For Output, we will consider x,y,z,l,w,h, and heading angle so that will consider it as a 2D Bounding Box and take it into consideration Combined detection with camera detection

2.1.2 "Velodyne LIDAR Method for Sensor Data Decoding" (M V Okunsky, N V Nesterova). [8]

Today, LIDAR is becoming one of the important devices used in robots and vehicles, so an understanding of the elements of LIDAR technology, its working principle, and how to implement the detection data of the LIDAR sensor output are all fundamental for navigation. LIDAR can be applied to a variety of situations such as creating a simulated map, and detecting the environment while creating the path of the robot. including the VLP-16 sensor, which is one of the most widely used models, so this document was written to develop Techniques for decoding raw data from LIDAR VLP-16 for use with other programs.

2.2 Camera-Based Object Detection

2.2.1 "Yolov for Darknet ROS" (Tossy0423) [9]

Yolov is an algorithm used in Object Detection. Object detection is computer technology. Computer-related principles of Vision and Image Processing are used in AI tasks to detect objects of a specific type such as humans, cars, and buildings that are in pictures or videos. It can penetrate deeply into many fields, such as making face detection and pedestrian detection. Detecting pedestrians can be applied in a variety of applications such as use in security and driverless cars, etc. [10], which in this work is used with ROS or Robot Operating System (ROS), a system created to allow flexibility in writing robot control software. Here, it is used to detect with a camera and to detect traffic in real-time.

3. Methodology

3.1 System Composition

In this research, various device as shown in Table 1 and Fig. 1 are used.

3.2 Experimental Method

3.2.1 Initial Design

In this research, the design process is divided into three sections.

1) Set the merging road in front of the Faculty of Engineering, Chulalongkorn University as a place to conduct experiments. This is because the location is a merging road with no signal and it is in the area of the autonomous shuttle route. The detector stand consists of a Camera, Lidar, and Data Processing Unit (Nvidia Jetson TX2) by camera

position and will be installed according to the KITTI Dataset [11].

Table 1 Overall System Device

	Device function	Device Model	Location
1	LIDAR (Detection Device)	Velodyne LiDAR PUCK	Roadside
2	Camera (Detection Device)	AVERMEDIA LIVE STREAMER CAM 313	Roadside
3	Processing Device	Nvidia Jetson TX2 Developer kit	Roadside
4	Collision Warning Device	Laptop HP Pavilion Gaming 15-ec1xxx	Onboard
5	Collision Warning Device	Arduino UNO R3 Board	Onboard
6	Collision Warning Device	GPS Ublox NEO-7M GPS Module	Onboard
7	WiFi connected device	HUAWEI AIS5G CPE	Roadside / Onboard

Fig. 1 Experimental device

2) Image detection and processing using a trained image processing model. The condition is to be able to deliver results quickly and accurately. This is because in the notification there is a delay in response from both the communication system and the human/machine reaction. To alert the time before the accident by the Nvidia Jetson TX2 that will be used as a processor model, SSD-Mobilenet and SSD-Inception can be used to detect real-time images (Real-time object detection) by detecting by type in the YOLO4 dataset [10], SFA 3D, which covers various objects found in the road, such as cars, motorcycles, people, and can distinguish object effectively overlapping as shown in Fig. 3 and the system will divide the alarm area into 3 levels as shown in Fig. 4, which the distance in each level is set at 14 m distance.

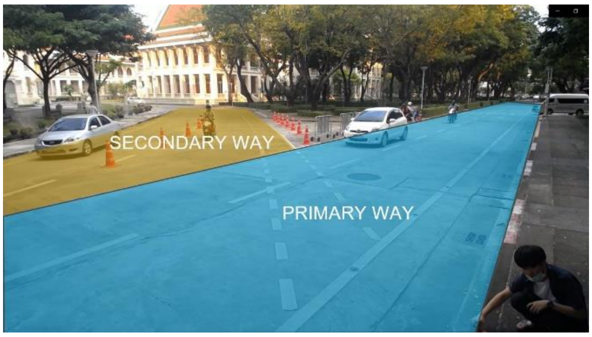

Fig. 2 Experimental site near Faculty of Engineering Chulalongkorn University

Fig. 3 Image from image detection and evaluation.

Fig. 4 Three-level notification area.

3) C-V2I is a system that communicates between the vehicle and the infrastructure the detection and communicating system is installed

at the docking station and sends the signal directly to the vehicle. In the test, a CPE will be used to connect 5G network signals for both the roadside docking station and the test vehicle. Inside the car, there is a screen to warn the safe driver. When the processor processes the image and finds the object that caused the risk of an accident while the car is moving through the Merging Zone, the system sends a signal through the MQTT Protocol to the computer on the car to display an interface for warning the safe driver according to various situations and stop alerting when the vehicle moves out of the test area.

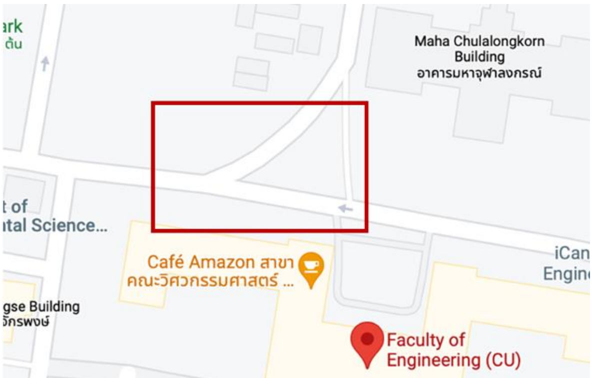

Fig. 5 Unsigned Merging Road area to set the warning system

The experimental location was determined using a GPS to determine the location of the vehicle by pre-specifying the receiving area. When the car moves into the notification area, it will subscribe to NETPIE's servers to receive information and notify if the system detects a car. And when the car moves out of the signal area, it will unsubscribe, as shown in Fig. 5.

3.2.2 Hardware Installation

Because the LiDAR and camera mounting layouts take a distance from the KITTI dataset and require processor space. Therefore, a docking station for installing LiDAR, Webcam Camera, and Processor (Nvidia Jetson) is prepared as shown in Fig. 6.

3.2.3 Integrated System Operation

3.2.3.1 Schematic Diagram of the System

The system diagram consists of 2 parts.

1) The detection system is performed using Nvidia Jetson machines, LiDAR, and Webcam cameras. As shown in Fig. 7a

2) The part of the communication and warning system displayed using a laptop and a geolocation device. As shown in Fig. 7b

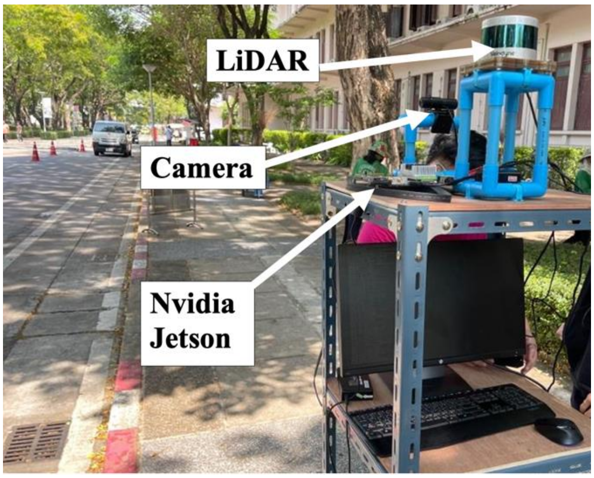

Fig. 6 Docking Station for placing LiDAR, Webcam cameras.

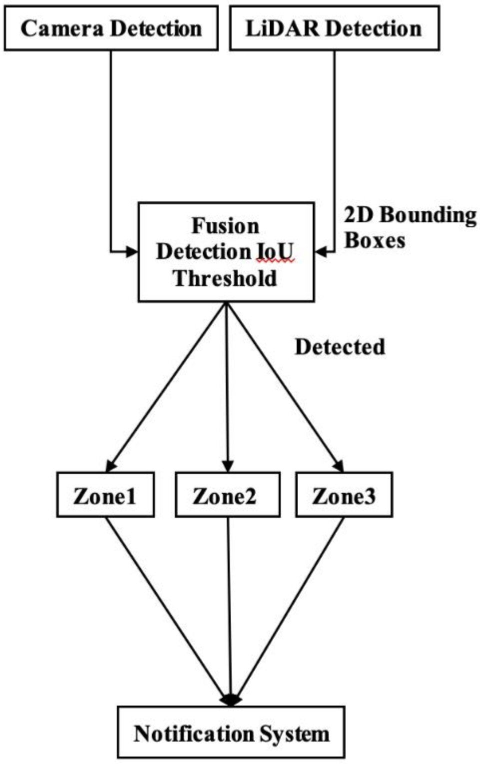

Fig. 7a Vehicles Detection System Diagram

3.2.3.2 Vehicle Positioning Device

GPS Module sends latitude and longitude coordinates to Arduino Uno board and transmits data via the serial port of the Laptop as shown in Fig. 8.

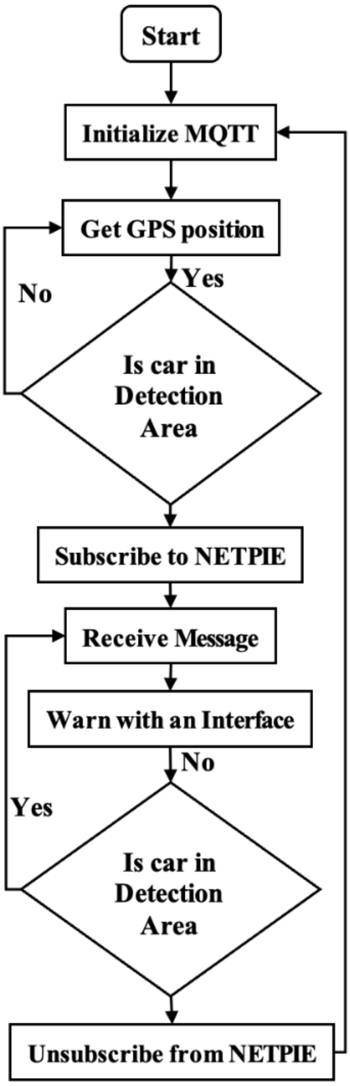

Fig. 7b The Communication System Diagram

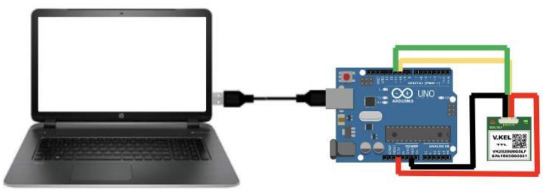

Fig. 8 Connection between Arduino Uno laptop and GPS module.

3.2.3.3 Warning System

The vehicle entering the notification area will subscribe to the specified topic of the MQTT server when the program receives a message indicating the detected area from the image processor. The program will display a visual warning of the detected area that looks like a parking camera or a side view camera of the car.

3.2.4 System Testing

3.2.4.1 Lidar Computing Test

The LiDAR computational test is performed by recording traffic data in the test area. The detection algorithm, SFA3 D, detects feature objects or vehicle characteristics in the Point-Cloud. BEV view (Bird-eye-view), where detection is used A deep-learning pre-trained model adopted by SFA3D when an object is detected in the Point-Cloud in BEV view, it creates a bounding box around the object. After that, the detectable Project Bounding Box will be inserted into the image obtained from the Webcam as shown in Fig. 9 to simplify ready for the collaboration of visual detection.

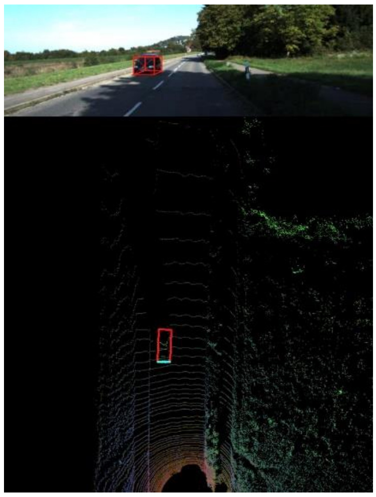

Fig. 9 Point-Cloud object detection, BEV view.

3.2.4.2 Image Processing System Test

The image processing system test uses a video recording of the traffic conditions of the test area. The detection algorithm is Yolov4 , which detects the object and determines the processing speed because the algorithm is used to detect it first. Page with SSD Mobilenet, which will consider the processing speed and compare the two results.

3.2.4.3 Camera and LiDAR Compatibility Test

Camera and LiDAR interoperability testing takes the detection results from camera detection and simplified LiDAR detection. A detectable frame, or bounding box, is overlapped and calculated with IoU (Intersection over Union) and is considered as shown in Fig. 10

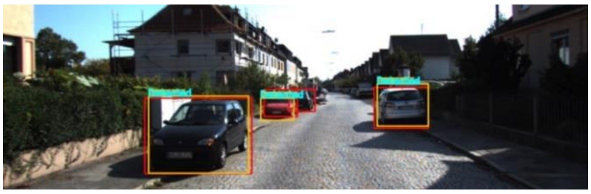

Fig. 10 shows the IoU consideration of the results detected from both the LiDAR and the camera.

3.2.4.4 MQTT System Testing

Verify the transmission time of the MQTT system is carried out to determine if it is suitable for adaptation. The message was sent from the Publisher to the Subscriber via NETPIE Broker and the total time was measured in milliseconds (ms). Six tests were performed and the average time was taken for comparison with the time using the MobileNet algorithm.

3.2.4.5 Overall system testing

For the overall system test, the vehicle will be driven from the main road with a speed test of not more than 50 kilometers per hour. (Considering the test location in Chulalongkorn University, there is a speed limit of not more than 50 kilometers per hour), which will determine if a car drives through Zone 1, Zone 2, and Zone 3, the system will be able to detect cars that pass through it or not. And the response time of the system is determined from the time the vehicle can be detected when entering the test position.

4. Results

4.1 Test Results of LiDAR Processing System

The results of testing the LiDAR processor using the SFA3D algorithm with Point-Cloud data recorded from LiDAR Velodyne VLP16 were conducted. Results showed that the detection capability is insufficient, based on actual detection experiments. It found that it has less detection range and stability than required. This is due to the low point density of VLP16 LiDAR. As a result, the recognition distance of the vehicle characteristics is shorter than those with higher point density LiDAR models such as the HDL64, as shown in the detection capability curve referenced with other LiDAR scanners as shown in Fig. 11.

4.2 Image Processing System Test Results

From the previous results, LiDAR alone cannot detect a vehicle in long distances as we expected. However, the Pain-Point of the previous detection algorithm of SSD Mobilenet is that it cannot detect vehicles in high dynamic range light due to the car's color being light and the sunlight being too bright, and the shadow of the tree. It could be corrected by the image processing engine using the Yolov4 Algorithm. The test with recorded traffic video even with lower exposure showed that the detection capability of Yolov4 compared to the SSD Mobilenet is more effective. While the previous detection work was not stable as shown in Fig. 12, Table 3. and Table 4. This efficiency gain may be due to the processing complexity of deep learning increasing, but the processing time is also increased. In the Mobilenet SSD Algorithm, the processing time is about 180 ms, but the processing time of Algorithm Yolov4 is about approx. 280 ms. The increased processing time of 100 ms will be considered for safety considerations in the Discussion.

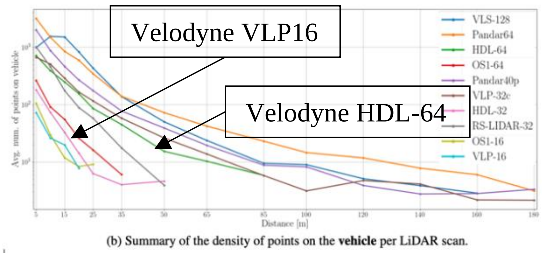

Fig. 11 Detection capability graph, referring to other LiDAR Scanners [12]

Fig. 12 Detection with Yolo (left). Detection with SSD mobile net (right).

4.2 MQTT System Test Results

In the MQTT test using NETPIE servers, the results shown in Table 2 that the average transmission time is approximately 36 ms.

4.3 Overall System Test Results

From the overall system test to determine whether the system can detect the car or not and how long it will take to process and notify the safe driver by starting a timer from the time which the system detects it in each zone, the results are illustrated in Table 4.

Table 2 Three Zone MQTT Transmission Time

MQTT Transmission Time			
	Zone 1	Zone 2	Zone 3
Experiment	T(ms)	T(ms)	T(ms)
1	42	34	29
2	32	43	37
3	28	35	37
4	34	39	39
5	35	42	41
6	40	33	29
Average	35.17	37.67	35.33

The results showed that the average time it took to process and alert the safe driver was in the range of 253 - 394 ms, with an average of 325 ms in each zone, which is considered sufficient response speed when considering that the maximum speed of a car is 50 kilometers per hour. The distance to be considered for the brake pedal is approximately 5 meters.

5. Conclusion/Discussion

From this research, it was found that C-V2I systems could be designed and developed. It can detect objects such as various types of vehicles and pedestrians on the road and send information to warn autonomous vehicles' safe drivers of the risk of accidents. And it can transmit data with 5G with an average time of approximately 350 ms, although it is slower at processing and alerting drivers than in conventional detection systems but it is sufficient to support the usage of a car driving at a speed of 50 km/h.

With the results of the research operations mentioned above, the researcher believes that this research can be used for further study and development. Therefore, the following guidelines are proposed for further study. Deployment in other locations or other situations, If considered to be applied in a real situation, it may be necessary to consider the speed of the incoming cars with a speed of more than 50 kilometers per hour. For this case, a shorter processing and data transfer time is needed. It can be achieved by using a faster detection algorithm and new hardware.

Table 3 SSD Mobile-net detection time and detection capability

	Zone 1		Zone 2		Zone 3		
Experiment	T(ms)	Detect or not	T(ms)	Detect or not	T(ms)	Detect or not	
1	189	Detect	209	Detect	246	Detect	
2	156	Detect	-	-	-	-	
3	240	Detect	251	Detect	245	Detect	
4	207	Detect	328	Detect	213	Detect	
5	211	Detect	148	Detect	-	-	
6	200	Detect	-	-	-	-	
Average	200.50		234		234.67		223.06

Table 4 Yolov detection time and detection capability

	Zone 1		Zone 2		Zone 3		
Experiment	T(ms)	Detect or not	T(ms)	Detect or not	T(ms)	Detect or not	
1	304	Detect	342	Detect	284	Detect	
2	281	Detect	329	Detect	308	Detect	
3	277	Detect	316	Detect	335	Detect	
4	394	Detect	253	Detect	350	Detect	
5	352	Detect	305	Detect	351	Detect	
6	369	Detect	341	Detect	361	Detect	
Average	329.50		314.33		331.50		325.11

6. Acknowledgment

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Effectiveness of Policy Incentives on Electric Motorcycle Acceptance in Hanoi, Vietnam

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Abstract

Electric vehicles are considered a possible alternative for the reduction of CO2 emissions produced by gasoline-powered vehicles. Hence, various incentive policies have been implemented internationally; however, the effectiveness of these incentives for Vietnamese transport users has not been investigated and recognized. This study conducted stated preference surveys of actual electric motorcycle (EM) users to evaluate their opinions regarding incentives for EMs. The survey results show that the recharge duration and driving range are the most inconvenient factors for EM users who presented dissimilar perceptions of different incentive policies. In particular, EM users showed a greater preference for operating subsidies, such as reduction in electricity purchase price and road-use tax over subsidies for purchasing or setting up of charger stations. The study results provide empirical evidence for transport planners and authorities to provide sufficient strategies for long-term EM development.

Keywords: Electric Motorcycle, Policy Incentives, Electric Motorcycle Adoption, Vietnam

1. Introduction

Each paper must be divided into two parts. The first part includes:

The transport sector is a significant source of air pollution, especially of particulate matter and nitrogen dioxide, and is the main source of environmental noise in many cities [1]. Therefore, the production of electric cars (ECs) and electric motorcycles (Ems) has expanded in the mobility market. Previous studies have revealed that an EM uses 72% less energy than a typical ICE motorcycle and produces 6.16 tons less CO2 equivalent than greenhouse gas (or 45% less) over its 8-year lifespan[2]. EMs can gradually replace gasoline-powered motorcycles in many Asian cities and can be considered a potential solution for air quality improvement and noise mitigation [3], [4]. Different incentive policies have been implemented in Asian cities to promote the adoption of electric vehicles (EVs) (Zhang et al., 2014). These incentives include purchasing and operating cost subsidies, free parking, low electricity rates, and access to bus lanes.

The transport sector is one of the main causes of air pollution in Hanoi, Vietnam, with nearly 3 million motorcycles in circulation in 2018 [6]. A study showed that approximately 46% of the dust nanoparticles in Hanoi came from the transport sector[7]. The Vietnamese government has announced a vision for developing green vehicles in Vietnam. Encouragement for green vehicle development was mentioned in Decree 57 in 2020 and has been in effect since July 10, 2020[8]. This decree attracted businesses to invest in the production of EVs, hybrid vehicles, and vehicles using biofuels and natural gas in Vietnam. Specifically, components imported for the production of 'green cars' were entitled to a 0% tax, and the zero tax applies to companies that manufacture components and spare parts and not solely automobile manufacturers as before. Although there was great support, only 283,000 EMs were sold in 2019, a decrease of 26.7% from the previous year's record.

Compared with the EM market in other cities in Vietnam, EM sales in Hanoi have declined in the past three years, particularly in 2020, because of the Covid-19 pandemic which resulted in a reduction in travel demand. However, the major reason for EM sales reduction is that the local government has not actively expanded the charging infrastructure, and there is a lack of incentives for Hanoi residents to purchase EMs. For subsidies, the government has primarily focused on four-wheel vehicles via import tax reductions and the production of automotive spare parts. In addition, there is no subsidy for operating costs such as road-use tax, electricity rate, and annual vehicle tax.

Although incentive policies have been applied internationally, the level of satisfaction with each policy differs. In particular, incentive policies for EM acceptance have not been fully captured. A prior EM adoption survey conducted in Vietnam showed that technological improvements and economic incentives, particularly sales tax, significantly affect the adoption of EVs[9]. However, this study focused only on subsidies at the time of an EM purchase. Therefore, this study aimed to examine EM users' satisfaction with incentives offered for the entire life cycle of EM ownership, which is important to better formulate policy measures. For this purpose, experienced EM users were selected for the survey to assess the influence of policy measures on EM purchases and operations. The next section examines previous studies on incentive policies to promote EVs. The experimental design and data collection are described in Section 3. Section 4 explains the data analysis and discussion, and the conclusions are presented in Section 5.

2. Literature Review

Various incentive policies have been implemented to promote electric cars (ECs). In many countries, incentives have been widely applied to EC ownership and usage, such as tax savings, insurance charges, highway tolls, and parking costs. Since 2016, ECs have been exempted from annual sales tax in Germany for 10 yrs. To counteract the upfront purchase price of an EC, Germany announced direct subsidies of €5,000 for private EC buyers and €3,000 for commercial EC buyers in 2016. Similarly, France designed a subsidy scheme in 2008 to encourage people to buy ECs[10]. In 2017, France proposed a bonus of €10,000 to encourage the removal of diesel cars greater than 10 yrs. old. The United States has offered tax credits between $2,500 and $7,500 based on the battery volume of an EC since 2008. In 2014, more than 37 states established incentives, and EC purchases were tax-free [11], [12]. Other benefits such as unrestricted parking and priority access to high-density lanes were also offered to EC owners. In addition, the US government has committed to funding EC technological development, new EC manufacturing facilities, and EC charging stations[13], [14]. The UK government issued a policy to increase the use of bicycles and ECs. These changes stemmed from the state of environmental pollution and sedentary habits that threaten health. Under the current scheme, EV buyers can receive a maximum of £4,500 through the government subsidy program[2].

Unlike the purchase costs of EMs, the high price of ECs is seen as one of the key barriers to their adoption[15]. Consequently, EC users have been offered many incentives to encourage EC market adoption[16]. Previous research has assessed the effectiveness of various incentives and can be divided into two groups. One group examined how the market share of ECs changed over time as incentive strategies were implemented, and the other group used survey data to assess consumer behavior towards ECs.

Many studies have shown that incentive policies encourage the adoption of ECs [12], [17]–[19] and EMs [9], [20], [21]. However, the effectiveness of such incentives varies depending on the measures applied. A policy was more effective when offered as a financial incentive (purchase price reduction, tax reduction) than when offered as a non-financial benefit (parking unrestricted, access to priority lanes). Furthermore, various studies (see Table 1) have examined EV adoption and the effects of incentive policies for both ECs and EMs. Stated preference surveys were widely utilized because the revealed preferences were hardly adopted because of the small EV market [2], [18], [22].

Compared with ECs, incentives for promoting EMs have rarely been examined. Recently, studies on EM adoption have focused on Taiwan, Indonesia, Vietnam, and Macau. In Taiwan, the environmental and energy concerns of motorcycle use in urban areas have fostered the rapid development of EMs and significantly contributed to their market acceptance [23]. Regarding incentive policies, a study indicated that emerging energy technologies have achieved competitive advantages via economies of scale owing to government subsidies [21].

Table 1 Summary of studies on EV adoption and incentive policies.

Author(s)	Country	Analysis model	Factors
Chiu and Tzeng, 1999 [23]	Taiwan	Multinomial logit	purchase price, maximum speed, emission level, operating cost, cruise distance
Jones et al., 2013 [9]	Vietnam	Mixed logit	price, range, refuel/recharge time, operating cost, maintenance cost, acceleration speed, license requirement, sales tax
Silvia and Krause, 2016 [24]	USA	Agent-based model	purchase price subsidy, development of charging installation, development of city EV fleet
Bjerkan et al., 2016 [25]	Norway	Logistic regression model	exemption from purchase tax, exemption from vat, vehicle license fee reduction, exemption from road tolling, free parking, bus lane access, free ferry tickets
Wang et al., 2017 [17]	China	Multinomial logit	purchase price, cruise range, purchase restriction rescission, driving restriction rescission, access to bus lane, public charging fee exemption, road toll exemption, parking fee exemption, purchase tax exemption, insurance charge exemption
Jenn et al., 2018 [12]	USA	Generalized model, knowledge model, lagged-dependent model	individual credit, fleet credit, HOV lane access, time of use rate, inspection exemption, registration fee reduction, EV charging subsidies
Guerra, 2019 [26]	Indonesia	Mixed logit	monthly payment, charge time, maximum speed, maximum range, socio demographic, fuel price
Zhu et al., 2019 [20]	Macau	Binary logit	sale price, charging fee, repair fee, battery life and cost, battery endurance, environmental benefits, charging convenience, fuel price, driving speed, load capacity, tax incentives
Gong et al., 2020 [19]	Australia	Nested logit	vehicle body type, price, set-up cost, operating cost, recharge time, range of a single recharge, access to bus lane, rebates on upfront costs, rebates on parking fees, energy bill discount, stamp duty discount
Liu and Lai, 2020 [27]	Macau	Partial least squares structural equation modeling	perceptions of environmental policy, pollution reduction, saving of energy, driving performance

Taiwanese government subsidy policies have gradually phased out the market and transferred finite budgets to other emerging energy technologies that need to achieve economies of scale. The key motivation of transport users in Macau to purchase EMs was their perception of environmental policy, pollution reduction, and energy savings[27]. Consumers in Macau often pay more attention to an EM's actual cost, such as sale price, charging fee, repair fee, and tax reduction incentives, while the driving speed and load capacity of EMs attract very little attention[20]. Similar findings have been reported on users' willingness to adopt EMs in Indonesia. The driving speed, range, charge time, and purchase price were of significance to Indonesian transport users[26]. Furthermore, charge time was particularly important, suggesting that improvements in battery-charging technology and charging infrastructures could substantially impact consumers' willingness to adopt EMs.

In previous research, incentives have been combined as a single variable. As a result, the impact of a single incentive has hardly been examined. Moreover, the majority of people interviewed lacked experience with EMs or ECs and incentives because they did not own one[12], [19], [28]. People who have experience with an EV have a better level of awareness and understanding of EVs than that of the general public. Therefore, it is recommended to recruit survey respondents with EV experience [29].

3. Data and Methodology

3.1 Experimental Design

The implementation of incentive policies has been rather limited in Vietnam; therefore, investigating the preference of transport users for different levels of incentive measures was not possible. Thus, a stated preference survey was conducted to examine EM users' perceptions of possible incentive policies.

To investigate consumer adoption of EMs, an EM was described as a product including three attributes: purchase price, cruise distance, and recharge duration. The study also focused on the possible impact of incentive policies on EM adoption. Therefore, incentives for EMs are described by five attributes: purchase subsidy, battery guarantee, charger equipment subsidy, electricity cost, and road maintenance subsidy. While purchase subsidy and charger equipment subsidy are provided once during EM purchasing, subsidies for electricity rates and road maintenance fees are provided during the entire operating cycle of an EM. Finally, eight attributes were selected and designed for the choice sets. We designed different levels of each attribute that were close to real values for the sake of the survey respondents' understanding. Each attribute had three or four levels. Table 2 lists these attributes, levels and experiment set they are included.

A long list of attributes makes it difficult for respondents to select their choice. An earlier study recommended that no more than five attributes should be included in a survey questionnaire to allow participants to make choices more easily[30], [31]. Therefore, the eight attributes listed in Table 2 were separated into two groups. We made two distinct estimations using two datasets and then combined them into an equation in the post-estimation process. Then, in each group, two common attributes were selected, which were later utilized to aggregate the estimated findings from the two datasets. Purchase price and subsidy are two typical features. Finally, two sets of attributes were obtained: Set 1 contained cruise distance, charger equipment subsidy, and battery guarantee, and Set 2 included electricity cost subsidy, recharge duration, and subsidy for road maintenance fee in addition to two common attributes.

Different alternatives were created based on the two sets of attributes allowing interviewees to make decisions. A full factorial design was used to account for all possible combinations of attributes and levels. However, this combination generated a large number of choice scenarios for survey respondents, including 576 choice scenarios for Set 1 and 768 choice scenarios for Set 2. Consequently, an orthogonal array was used to reduce the correlation between attributes as indicated in[32]. Finally, the number of choice scenarios was reduced to 50, with 20 from Set 1 and 30 from Set 2. The questionnaires were designed based on three randomly chosen choice scenarios from a pool of 50 possibilities. Figure 1 shows an example of the decision scenario.

3.2 Data Description

The survey participants were recruited from June 6 to 21, 2020, when the Covid-19 pandemic was well controlled in Vietnam. This new normal status was applied to shopping malls, office buildings, schools, universities, and public areas. All survey participants were EM owners with prior driving experience and access to a home charging utility. Furthermore, we gathered responses via face-to-face interview surveys so that the questions can be explained properly. This sample approach improved the survey's quality, resulting in greater completion rates and replies from participants with better comprehension of the subjects. At the completion of the survey, 581 respondents had been selected, of which 557 responses were utilized for the analysis because 24 responses were incomplete or inconsistent. Table 3 summarizes the attributes of the respondents.

There was an equal distribution of male and female respondents, and their ages were primarily 18–39 (above 60%). Educational status and household income were also assessed. EM ownership and usage are correlated with a medium-income young age group[10], [12].

Table 2 Attribute descriptions and levels

Attribute (unit of measurement)	Description	Level	Experiment
Purchase price (0.1 M VND)	Total EM consumer cost	200/400/600	Both
Purchase subsidy (0.1 M VND)	Tax reduction of EM purchase	40/60/80/100	Both
Cruise distance (km)	Total riding distance with fully charged battery	60/80/100/120	Set 1
Battery guarantee (1000 km)	EM battery-life performance guarantee	100/120/140/160	Set 1
Charger equipment subsidy (0.1 M VND)	Total government cost to install an EM charger	20/30/40	Set 1
Electricity cost (0.1 M VND/yr)	Cost of charging an EM battery over 1 year of use	4/6/8/10	Set 2
Recharge duration (min)	Time required to recharge EM battery from empty to full	10/20/30/40	Set 2
Subsidy for road maintenance (0.1 M VND/yr)	Amount of reduction in road maintenance fee for 1 year of EM ownership	1/2/3/4	Set 2

* VND: Vietnam Dong

Table 3 Respondent description

Respondent attribute	Description	Percentage of total respondents
557 respondents		
Gender	Male	49.1%
	Female	50.9%
Age	18–29	28.3%
	30–39	32.6%
	40–49	18.5%
	50–59	19.4%
	60 and over	1.2%
Education	College/associates	26.2%
	Undergraduate	59.2%
	Graduate	14.6%
Monthly household income	<3 M VND/mo	7.2%
	3–6 M VND/mo	16.5%
	6–10 M VND/mo	29.6%
	10–20 M VND/mo	29.8%
	20–40 M VND/mo	12.6%
	>40 M VND/mo	4.3%

3.3 Multinomial Logit Model

A multinomial logit model was used to analyze the data collected from the stated preference survey. For this purpose, a utility function was constructed containing EM characteristics and subsidies. The utility of the ith customer selecting the jth option from J options is $U_{ij} = \beta \cdot x_{ij} + \varepsilon_{ij}$, where β is a coefficient vector, x_{ij} is an input vector, and ε_{ij} is the error term. For the logit model, the error term was assumed to be an independent identically distributed extreme value. The selection probability was given as the logit probability because the selection was made for the option with more utility than for the other options, P(Uij > Uik for ∀ i ≠ k) = $\frac{e^{\beta' . x_{ij}}}{\sum_{k=1}^{J} e^{\beta' . x_{ik}}}$. The maximum likelihood technique was utilized to estimate the coefficient vector β to determine the values that maximized the likelihood of the choice probability (Train, 2003).

Scenario 1: Set 1

Choice	Purchase price	Purchase subsidy	Cruise distance	Battery guarantee	Charger equipment subsidy
	40 million VND	4 million VND	100 km	100 thousand km	2 million VND
	60 million VND	6 million VND	80 km	120 thousand km	3 million VND

Scenario 2: Set 2

Choice	Purchase price	Purchase subsidy	Recharge duration	Electricity cost	Subsidy for road maintenance fee
	40 million VND	6 million VND	20 minutes	0.4 million VND/year	0.6 million VND/year
	20 million VND	4 million VND	40 minutes	0.6 million VND/year	0.8 million VND/year

Fig. 1 Selection examples

As indicated in Section 3.1, the survey used two independent datasets that differed from surveys using standard logit probability. Consequently, the coefficients for each dataset were estimated separately and subsequently aggregated using a post-analysis process. VSet1 and VSet2 are the utilities analyzed using the standard logit probability composed of Set 1 and Set 2, respectively. The functions are

$$\hat{V}_{set1} = \hat{\beta}_1 . x_{1ij} + \hat{\beta}_2 . x_{2ij} + \hat{\beta}_3 . x_{3ij} + \hat{\beta}_4 . x_{4ij} + \hat{\beta}_5 . x_{5ij}, \tag{1}$$
$$\hat{V}_{set2} = \hat{\beta}_1 . x_{1ij} + \hat{\beta}_2 . x_{2ij} + \hat{\beta}_6 . x_{6ij} + \hat{\beta}_7 . x_{7ij} + \hat{\beta}_8 . x_{8ij}, \tag{2}$$

where x1 to x8 are survey attributes, including purchase price, purchase subsidy, cruise distance, battery guarantee, charger equipment subsidy, electricity cost, recharge duration, and subsidy for road maintenance, respectively, and β1 to β8 are the coefficients for the corresponding factors. Coefficient β1 had an inverse of cost value unit because the purchase price, x1, had a cost unit that was inserted into both equations, and the utility was unitless. Consequently, VSet1 and VSet2 were converted into cost units by dividing the two sides by β1. Each coefficient had participants' units of willingness to pay. These equations are expressed as

$$\hat{M}_{Set1} = x_{1ij} + \hat{\beta}_2/\hat{\beta}_1 . x_{2ij} + \hat{\beta}_3/\hat{\beta}_1 . x_{3ij} + \hat{\beta}_4/\hat{\beta}_1 . x_{4ij} + \hat{\beta}_5/\hat{\beta}_1 . x_{5ij}, \tag{3}$$
$$\hat{M}_{Set2} = x_{1ij} + \hat{\beta}_2/\hat{\beta}_1 . x_{2ij} + \hat{\beta}_6/\hat{\beta}_1 . x_{6ij} + \hat{\beta}_7/\hat{\beta}_1 . x_{7ij} + \hat{\beta}_8/\hat{\beta}_1 . x_{8ij}. \tag{4}$$

By combining Eqs. (3) and (4), a supplementary equation can be expressed, and the selection probability was P(Uij > Uik for ∀ i ≠ k) = $\frac{e^{(M_{Set\,1} + M_{Set\,2})}}{\sum_{k=1}^{J} e^{(M_{Set\,1} + M_{Set\,2})}}$. Because neither Set 1 nor Set 2 contained all factors, the coefficients were analyzed according to the factors contained in the dataset while keeping the other factors unchanged. The coefficients were considered to be mathematical values of the βs from Sets 1 and 2 in this combined equation. The coefficient for the purchase price is $\frac{\hat{\beta}_1^{Set\,1}+\hat{\beta}_1^{Set\,2}}{2}$, where the superscripts denote the collected data. The coefficient for purchase subsidy appearing in both datasets is $\frac{\hat{\beta}_1^{Set\,2}\hat{\beta}_2^{Set\,1}+\hat{\beta}_1^{Set\,1}\hat{\beta}_2^{Set\,2}}{2\hat{\beta}_1^{Set\,1}\hat{\beta}_1^{Set\,2}}$, and the other coefficients are $\hat{\beta}_3/\hat{\beta}_1^{Set\,1}$, $\hat{\beta}_4/\hat{\beta}_1^{Set\,1}$, $\hat{\beta}_5/\hat{\beta}_1^{Set\,1}$, $\hat{\beta}_6/\hat{\beta}_1^{Set\,2}$, $\hat{\beta}_7/\hat{\beta}_1^{Set\,2}$, and $\hat{\beta}_8/\hat{\beta}_1^{Set\,2}$. Eq. (5) represents the combined utility.

$$\hat{V} = \frac{\hat{\beta}_1^{Set\,1}+\hat{\beta}_1^{Set\,2}}{2}.x_{1ij} + \frac{\hat{\beta}_1^{Set\,2}\hat{\beta}_2^{Set\,1}+\hat{\beta}_1^{Set\,1}\hat{\beta}_2^{Set\,2}}{2\hat{\beta}_1^{Set\,1}\hat{\beta}_1^{Set\,2}}.x_{2ij} + \frac{\hat{\beta}_3}{\hat{\beta}_1^{Set\,1}}.x_{3ij} + \frac{\hat{\beta}_4}{\hat{\beta}_1^{Set\,1}}.x_{4ij} + \frac{\hat{\beta}_5}{\hat{\beta}_1^{Set\,1}}.x_{5ij} + \frac{\hat{\beta}_6}{\hat{\beta}_1^{Set\,2}}.x_{6ij} + \frac{\hat{\beta}_7}{\hat{\beta}_1^{Set\,2}}.x_{7ij} + \frac{\hat{\beta}_8}{\hat{\beta}_1^{Set\,2}}.x_{8ij} \quad (5)$$

4. Results and Discussion

The surveys collected three choice scenarios from each respondent. Finally, 1671 acceptable responses were obtained from the 557 participants. Table 4 presents the analysis results for the separate (Set 1, Set 2) and combined (Set 1+2) set models.

The results showed that all the analyzed coefficients had a significant level at the 95% confidence level (Table 4). Importantly, the observed signs of the coefficients were in accordance with the expected outputs. Specifically, cost- and time-related variables had negative (-) coefficients, indicating a utility reduction when customers consumed more. By contrast, the coefficient for the variables linked to incentives and subsidies was positive (+), and consumers generally desired greater incentives and subsidies.

Table 4 Analysis results for Set 1, Set 2, and Set 1+2

Attribute	Separate models		Combined model
	Set 1	Set 2	Set 1+Set 2
Purchase price	−0.02128***	−0.01623**	−0.01876***
Purchase subsidy	0.00752*	0.01892**	0.01322**
Cruise distance	0.00816***		0.00824***
Battery guarantee	0.00855***		0.00863***
Charger equipment subsidy	0.04384*		0.04378*
Electricity cost		−0.32597***	−0.32604***
Recharge duration		−0.00367***	−0.00374***
Subsidy for road maintenance		0.28696***	0.28704***
Sample size	1002	669	1671
Log-likelihood	−524.120	−351.160	−875.280
Rho-SQ	0.1540	0.1918	0.1729

* $p < 0.05$, ** p. < 0.01, *** $p < 0.001$

Table 4 shows the estimated coefficients for the association between the factors and utility of the participants. Nevertheless, because utility is a unitless measurement of customer satisfaction, the marginal willingness to pay (MWTP) was obtained by dividing the utility coefficient by the purchase price coefficient. The MWTP is simple to explain because it reflects the amount that buyers are likely to pay for a unit increase in the conforming factor. For each MWTP, the 95% confidence level was determined using the method described in[33]. Table 5 shows the results of the MWTP analysis and confidence levels for each attribute.

According to the estimates, EM users were likely to pay 19700 VND to shorten the recharge duration time by one minute and 27700 VND to extend the driving range by one kilometer. The MWTP for both recharge duration and cruise distance were higher than the values in the range 9000–18000 VND to reduce the one-minute recharge duration and the range 6000–22000 VND to increase cruise distance resulting from previous studies according to potential customer interviews in Vietnam and Indonesia[9], [26]. This result is in accordance with previous studies in that driving EMs increased people's anxieties about charges and cruise distance, which were the primary causes of inconvenience[34]. EM users were likely to spend 46000 VND for each 1000 km extension of battery guarantee.

The investigation considered two forms of EM procurement subsidies: purchase and charger equipment subsidies. EM owners considered charger financial subsidies to be higher than they perceived. The charger equipment subsidy was 3.3 times more than the purchasing subsidy for the same amount of money according to EM owners. This suggests that, for the same money, a charger equipment subsidy would be more effective in motivating the purchase of an EM. The high MWTP for the charger equipment subsidy is owing to the increased charging considerations among EM owners as revealed in a similar study[9], [26], [35].

When a subsidy is applied to the operating costs of EMs, the effect on a possible EM adoption is amplified. When EM owners received an electricity cost discount and a subsidy for road maintenance fees, they thought the amounts were 17.3 and 15.3 times greater, respectively, than they actually were. A study reported that Indonesians were willing to pay 250,000 rupiah more (50% of the average purchase price) to reduce fuel prices by 1000 rupiah[26]. Similar findings were obtained by other researchers in Macau [20] and Taiwan[23]. We adjusted the unit of MWTPs for subsidies during the operating duration to reflect the life period of EMs to examine consumer preferences for subsidies during operation and at purchase. If a normal EM operates for 10 yrs., the volume of subsidies for operation will accumulate over that time. As a result, the MWTPs for electricity cost and subsidy for road maintenance fee can be translated to 1.738 and 1.530 (1 M VND/10 yrs.), respectively (Table 5). When these values were compared to the MWTPs for purchase subsidies, customers preferred subsidies during operation 2.2 to 2.5 times more.

There are several reasons for this phenomenon. First, EM owners perceive that their benefits increase during the EM ownership period because the operation subsidies are provided cumulatively. Second, EM users recognize that the operating cost of EMs is much higher than the purchase price. Finally, respondents might appreciate the non-monetary benefits, such as CO2 emissions and noise reduction, which were not included in the survey. This finding reveals that customers are more willing to buy EMs when subsidies are offered to support operating costs rather than purchase prices.

Table 5 Analysis results for MWTP

Attribute (units)	MWTP (0.1 M VND)	2.5%	97.5%
Recharge duration (1 min)	−0.197	−0.305	−0.126
Cruise distance (1 km)	0.277	0.202	0.409
Purchase subsidy (0.1 M VND)	0.704	0.315	1.230
Charger equipment subsidy (0.1 M VND)	2.336	0.603	4.278
Battery guarantee (1000 km)	0.459	0.235	0.797
Electricity cost (0.1 M VND/yr)	−17.387	−26.966	−10.973
Subsidy for road maintenance (0.1 M VND/yr)	15.307	9.095	24.796

VND: Vietnam Dong

5. Conclusion

Incentive policies have been implemented in many cities to encourage the adoption of ECs. However, such subsidies are rarely applied in motorcycle-dominated countries with a geographical focus on Asia. The results facilitate a better understanding of customer perceptions of incentives for EMs to recommend relevant policies to promote EM expansion. Stated preference surveys were designed for actual EM users to examine their possible selection of EMs with more realistic responses.

Subsequently, the predicted coefficients were transformed into the MWTP, allowing for more understandable interpretations. The MWTP values for increased driving range and reduced recharge duration were significantly higher than those reported in previous studies. This means that the recharge duration and driving range of EMs are the most inconvenient factors for regular EM users.

The study also reveals that purchasing subsidies (purchase and charger equipment subsidies) and those that occurred during the EM ownership period have a positive impact on EM purchasing. The MWTP of EM users for their received subsidies was much higher than they actually had. When MWTPs for operational and purchase subsidies were compared, operational subsidies had higher MWTPs. It is clear that incentive policies that allocate more funding to operational support, rather than purchasing, are more effective. The results of this study will be useful for transport authorities in developing incentive policies to encourage EM adoption.

We acknowledge that our study had some limitations. First, survey information was collected from Hanoi, Vietnam, a metropolitan agglomeration whose features may differ significantly from those of other cities. This is an issue for all vehicle adoption research because geographical location clearly has an impact on travel behavior and mode choice. As a result, other investigations for different locations and nations are required for comparison with the findings of this study. Second, many participants were young. We do not know if this is typical of EM adoption, though it appears to be the case, and further research is needed. Despite the fact that there is a growing body of research on EV adoption in general, the demographic profile of users is likely to be very diverse, and each type of EV may logically attract a different relative advantage, reflecting the differing perceived incentives and adoption barriers. EM adoption research is still in its early stages, and more research on battery technology and charging systems is needed to ensure the long-term viability of the industry.

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SESSION 1.2: AYRF 2022 RESEARCH PAPER PRESENTATION

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001-2022 **p.38-48**	"Assessment of Inter-municipal PUV services in Southern Iloilo, Philippines"	**Ms.Elearina Dolores Tabbu Agustin** De La Salle University, Philippines
005-2022 **p.49-58**	"Barrier-Free Mobility Assessment of General Luna Street, Intramuros, Manila"	**Engr. Maria Emilia P. Sevilla** University of the City of Manila, Philippines
007-2021 **p.59-64**	"Comparative analysis between Net cost method and Gross cost method - Case Study in Bangkok Blue line and Purple line -"	**Mr.Kota Iwanami** Nihon University, Japan
023-2021 **p.65-75**	"Research on the applicability of the shared parking model in the downtown area of Hanoi"	**Dr. Nam Hoai Tran** Hanoi University of Civil Engineering, Vietnam

Assessment of Inter-municipal PUV Services in Southern Iloilo, Philippines

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Abstract

The improvement of the transportation services is important in the economic growth of developing countries like the Philippines. In the pursuit of comprehensively improving the transportation in the country, the government launched the Public Utility Vehicle Modernization Program (PUVMP). One of its components is the Local Public Transport Route Plan (LPTRP). This gives jurisdiction to local government units to determine the appropriate public transport routes and corresponding public transport services based on the passenger demand of their locals. In the study, the area of interest where LPTRP was implemented is Southern Iloilo. From LPTRP, new transport operation services and route modification were implemented. This is to improve the transport operation in Southern Iloilo where tricycles traverse National Road, and Public Utility Vehicles load-unload anywhere along the road without any restrictions. Data collection include Household Interview Survey (HIS) and vehicular traffic counts which were conducted by individual LGUs in their respective towns and city, while other secondary data collected from government agency, Department of Public Works and Highways (DPWH) were also used. Trip generation models using category analysis were then developed to estimate the trips generated by households. The base and proposed scenarios were modelled using EMME/4 software. In the study, the proposed scenario recommends the following services: feeder, local, and limited stops services. This scenario also introduced Filcab/multicab modes to replace tricycles along National Highways. The recommended scenario was then evaluated using performance indicators such as frequency, reliability, and utilization from LPTRP standards. Policies proposed include the addition of loading-unloading zones and terminals and restricting public transportation modes to serve only the route they franchised and to not go beyond what is stipulated.

Keywords: Category analysis, Local Public Transport Route Plan, Route modification, Transport operation services, EMME/4

1. Introduction

1.1 Background of the Study

The economic growth of developing countries like the Philippines depends on different factors and one of which is the country's transportation system. In a study conducted by Asian Development Bank (ADB), it was found that 77% of the country's population is expected to use road-based transportation to do their daily activities by 2030. Therefore, improvement of the existing transportation in the country is important in making cities livable in the future years.

In the Philippines, the existing public transportation system are being provided by competing operators and drivers. This competition leads to irrational supply of Public Utility Vehicle (PUV) services, and unorganized transportation services. This consequently leads to unrestricted loading and unloading of passengers which can be perceived by commuters as unsafe. In addition to this, absence of waiting areas and proper sidewalks, and unorganized transfers of passengers from one mode to another discourages passengers to use public transportation. These inconveniences lead to commuters to use their own private vehicles and other door-to-door, non-fixed route services such as tricycles and trisikads (e.g., rickshaws). These add to the volume of vehicles traversing the roads, resulting to congestion.

To address these problems, the government launched the PUV Modernization Program (PUVMP) in 2017. This is to comprehensively change policies, models, and practices, among others, to improve the transportation system of the Philippines. One of its components is the Local Public Transport Route Plan (LPTRP). The LPTRP aims to give jurisdiction to the Local Government Unit (LGU) in planning and implementing the transport route plans and policies of local areas. This is so since the LGU knows more the needs or demands of commuters in the area. In this study, LPTRP was used to modify the transport operation services and restrict tricycles from traversing National Road in Southern Iloilo.

1.2 Study Area

The district of interest is the 1st district of Iloilo or Southern Iloilo. The district is composed of 7 municipalities namely Guimbal, Igbaras, Miagao, Oton, San Joaquin, Tigbauan, and Tubungan. The average annual growth rate in population of every municipality is at least 0.42% and the distance of each municipality from each other is at least 10 km.

Fig. 1 shows the existing transport operation services in Southern Iloilo that operate as described in Table 1. Tricycles in the area are classified as non-fixed fare transportation operation service where drivers can drop and pick up passengers anywhere along the road upon passenger request. Capacity of tricycles is 4. Fare is also dependent on the agreement between passenger and drivers. As shown in the Fig. 1, tricycles pass all the municipalities in Southern Iloilo without restrictions. This means that they travel even along national roads. Jeepneys and some UV (Utility Vehicle) Expresses operate as collector/distributor service. Capacity of jeepneys is at 18 while UV Expresses' capacity is 22. These modes board and alight passengers at local stops or anywhere along Southern Iloilo. Lastly, interprovincial buses and some UV express board passengers at terminals and sometimes even along the national highway if they are not yet at full capacity.

1.3 Statement of the Problem

In 2019, MMDA investigated the existing transportation in Southern Iloilo. Based on their investigation, the roads in Southern Iloilo can cater to the vehicle volumes, but with the absence of the permanent loading-unloading zones, obstructions, and faulty traffic signals are causing slower traffic.

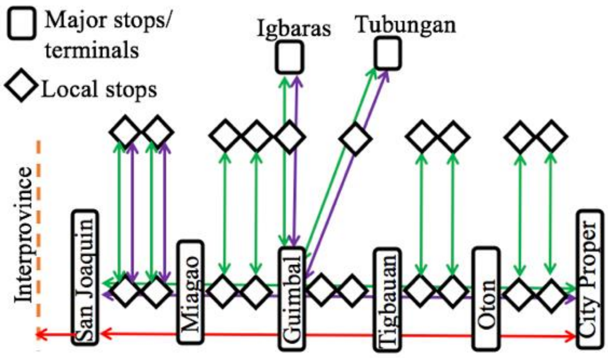

Fig. 1 Existing services in Southern Iloilo

Table 1 Specifications of the existing services in Southern Iloilo

Legend	Type of Service	Modes
↔ (purple)	Collector/ Distributor	 **Fig. 2** Jeepneys  **Fig. 3** UV Express
↔ (green)	Non-fixed fare transportation operation service	 **Fig. 4** Tricycles
↔ (red)	Regular service	 **Fig. 5** Interprovincial buses • UV Express

In addition to this, the dominant competition among operators and drivers result to oversupply of units, and temporary loading-unloading zones. These add to the existing vehicle volume and slowing down of traffic. Volume of vehicles along National Road traversing Southern Iloilo increases with tricycles allowed to traverse the National Road. This is in contrary to the Joint memorandum Circular

No. 1, Series of 2008 of DILG and DOTC which states that "*Tricycle operation should only be confined along city or municipal roads, not along national roads, and is limited only to routes not traversed by higher modes of public transport*."

1.4 Objectives of the Study

To be able to address the problems in Southern Iloilo, the study aims to assess the current public transport service operation in Southern Iloilo. This can be done by: (1) estimating the current and potential public transport demand; (2) proposing improvements in the service operation of public transport operation service and assessing its impact; and (3) providing recommendations on the improvement of the public transport operation service in Southern Iloilo according to LPTRP standards.

2. Literature Review

2.1 Different Transportation Modes in the Country

In a study by the Department of Transportation and Communications (2016), the supply of PUV in the Philippines is sufficient but are not found attractive by commuters. Some of these PUV's are jeepneys, tricycles, and buses. Based on previous studies that investigated the improvement of these modes, transportation service operation can be improved through industry consolidation, restricting tricycle service along national road; and rationalization of supply of the different modes (Guillen, M. et al., 2003; Boquet, 2012). In the study, improvement in operation services was done by modifying the existing services and routes of the transportation modes in Southern Iloilo.

2.2 Supply and Demand in Public Transportation

In previous studies, the transport supply is determined by the availability of public transportation, service frequency and route diversity, and service accessibility; while the demand depends on the socio-demographic factors such as age, status, employment, and income (Ariyoshi et al., 2019; Haghshenas et al., 2019). In the research, the relationship between the trips made by respondents based on their income and vehicle ownership quantifies the demand while the existing services, and transport networks show the supply side.

2.3 Category Analysis and Models in Transportation Research

In transportation studies, statistical analysis is important in showing the relationship among different factors that could influence the result of the research. In the study, the statistical analysis used was simple category analysis (SCA) showed the different factors that affect the trips generated. In previous studies, category analysis was used in previous studies to determine the relationship of different household characteristics to generate trips (Yang, Y., 2015; Chiou, Y. et al., 2015; Konečhy, V. et al, 2021; Al-Taei, A. et al., 2006; Chang, J. et al., 2014).

2.4 Network Modelling in Transportation Studies

Previous transportation studies use software to do their analyses. These different software (GIS-based software such as EMME/4 etc.) use OD matrix calculator to create and compare the different scenarios, optimize supply, and demand, and propose situation (Alam Q. et al., 2020; Deloukas, A. et al., 1997; Kanaroglou, P. et al., 2009). In the study, EMME/4 was used to model existing transport operation services and proposed scenario for improvement.

3. Methodology

In the research, descriptive method was used to analyze data from the Household Interview Survey (HIS) and secondary data. From the HIS, the trip characteristics, household (HH) characteristics, personal characteristics, and traffic counts were collected while Average Annual Daily Traffic (AADT) was from secondary data (DPWH GIS 2020). These were used for simple category analysis (SCA). This analysis was used to generate passenger demand model. SCA was used to calculate the number of trips per household or the Mean Trip Rate (MTR). The MTR was used to calculate expanded trips per municipality. The expanded trips was used to populate Origin-Destination (OD) matrix. The OD matrix and the traffic counts from the secondary data were modelled using EMME/4. The network modelled from EMME/4 is then calibrated to produce models with minimal error. The calibrated model was then used to model proposed scenario which was evaluated using performance indicators from the LPTRP standards.

4. Results

4.1 Simple Category Analysis

In the study, different household (HH) characteristics from the conducted HIS was used to represent the trips generated by the respondents. The collected data was analyzed using Simple Category Analysis (SCA). SCA was used to show how the trips generated are related to Household Income and vehicle ownership. The relationship between variables is quantified through Mean Trip Rates (MTR) where MTR is calculated as number of trips/HH. Table 2 shows the MTR results for every municipality in Southern Iloilo. MTR for every municipality shows how the vehicle ownership and household income affect the trips produced. MTR was also used to expand trips based on the existing and future population.

Table 2 Mean trip rate from SCA of every municipality based on their Household Income and vehicle ownership

Munici-palities	Vehicle Ownership	Household Income (Php)		
		<9520	9520-19040	> 19040
Guimbal	No Vehicles	1.34	1.82	2.6
	With Vehicles	2.6	5	5
Grand MTR		1.65		
Igbaras	No Vehicles	1.49	1.83	4
	With Vehicles	3.13	3	3.82
Grand MTR		1.97		
Miagao	No Vehicles	1.82	2.68	2.63
	With Vehicles	3.29	3.25	3
Grand MTR		2.08		
Oton	No Vehicles	1.89	1.68	2.2
	With Vehicles	2.19	2.96	3.31
Grand MTR		2.04		
San Joaquin	No Vehicles	2.28	1.72	2.97
	With Vehicles	3.36	2.43	2.31
Grand MTR		2.48		
Tigbauan	No Vehicles	1.33	2.11	2.54
	With Vehicles	1.73	1.64	2
Grand MTR		1.55		
Tubungan	No Vehicles	1.92	2.95	2
	With Vehicles	1.7	1.63	1.75
Grand MTR		1.95		

4.2 Generated Trips from SCA

The generated model from SCA was used to calculate trips for year 2020 to represent the population per municipality. MTR per municipality was used to calculate expanded existing trips for every municipality based on their population. Table 3 shows the number of HH per municipality, and the corresponding calculated grand MTR, and estimated trips.

Table 3 Estimated trips (2020) calculated from the Grand MTR

Municipality	Number of HH (2020)	Grand MTR	Estimated Trips (2020)
Guimbal	7,839	1.65	12,934
Igbaras	7,322	1.97	14,425
Miag-ao	15,001	2.08	27,827
Oton	22,367	2.04	29,566
San Joaquin	11,335	2.48	28,110
Tigbauan	14,225	1.55	21,517
Tubungan	4,906	1.95	9,760
TOTAL	82,995	14	144,139

4.3 EMME/4 Modelling

4.3.1 Calibration Process

To be able to model the data closely to the actual, the collected data was calibrated. The calibration process was used to get the least error/difference between model and AADT to provide model closest to the actual. The value for R^2 was used to evaluate calibration. Fig. 6 shows the selected points that represented the volume for comparison of AADT and expanded trip models. For the variables to be considered as closely related to each other, the value should be close to 1. In the study, we considered R^2 value of at least 0.8 for the model to be accepted and used in the scenarios proposed.

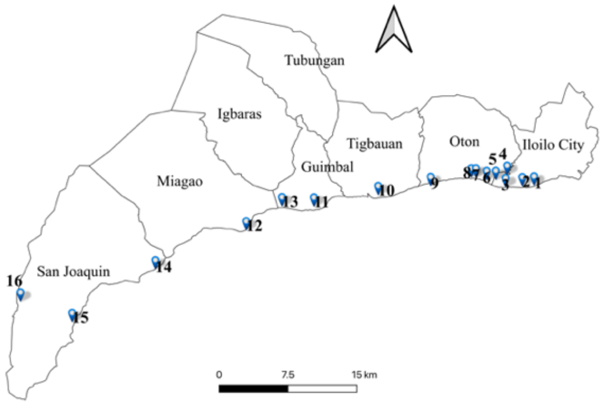

Fig. 6 Calibration points for EMME/4 modelling of the scenarios in Southern Iloilo

4.3.1.1 Transit Calibration

Table 5 shows the trips from the estimated peak hour and the model. 10% peak hour is based on the hourly commuter flow estimates from LPTRP of Southern Iloilo. From the graph of model vs estimated peak hour (Fig. 7), R^2 is 0.8871.

Table 5 Corresponding trips from AADT and base model for every road segment

Point No.	Name of Road Segment	Estimated Peak Hour ('10% of Daily)	Model
1	Iloilo-Antique Rd	1902	1758
2	Arevalo By-Pass Rd	1894	1665
3	Iloilo-Antique Rd	4823	4399
4	Oton-Pakiad-Mandurriao Rd	4823	4419
5	Iloilo-Antique Rd	3220	4230
6	Iloilo-Antique Rd	5501	4378
7	Iloilo-Antique Rd	3203	3282
8	Oton-Buray-Sta Monica-Sn Antonio-Sn Miguel Rd	770	446
9	Iloilo-Antique Rd	2363	2465
10	Tigbauan-Cordova-Leon Jct Rd	2423	2282
11	Iloilo-Antique Rd	2087	1964
12	Iloilo-Antique Rd	2841	1994
13	Iloilo-Antique Rd	1432	556
14	Iloilo-Antique Rd	395	749
15	Miagao Cadre Rd	613	56
16	Iloilo-Antique Road	2363	1758
17	Tiolas-Sinugbuhan Rd	2423	1665
18	Iloilo-Antique Rd	2087	4399

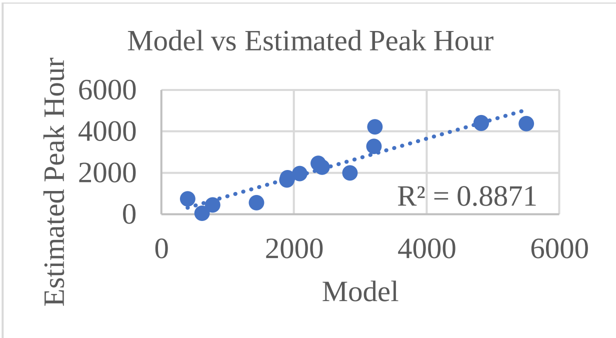

Fig. 7 Model vs Estimated Peak hour graph, base model year 2020

4.3.2 Base Scenario

Fig. 8 shows the existing transport operation service demand or the calibrated base model of the study area. As shown in the Fig. 8, the boarding-alighting of the respondents is concentrated in Iloilo City or the City Proper.

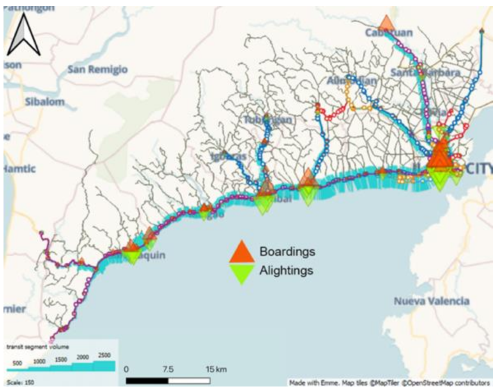

Fig. 8 Base scenario in Southern Iloilo

Fig. 9 shows the number of units and travel time of the respondents as modelled in EMME/4. The Fig. 9 shows the routes traversed by jeepneys or existing modes in Southern Iloilo. Among these routes, Lawigan-Iloilo City has the longest travel time and length of route.

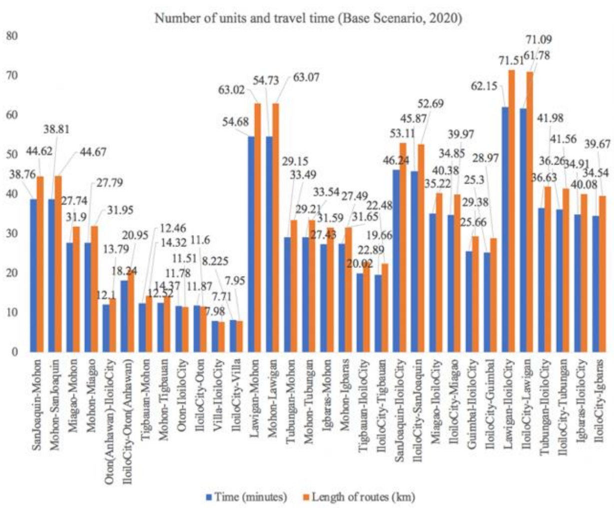

Fig. 9 Summary of length of routes and travel time of each route in Southern Iloilo

The number of units is usually dependent on the passenger demand. Fig. 10 shows the number of units from EMME/4 modelling and the passenger demand based on the OD matrix from HIS. As shown in the Fig. 10, Tubungan-Iloilo City route segment requires the most number of units according to EMME/4 results. Although this is the case, Iloilo City to San Joaquin segment has the highest passenger demand.

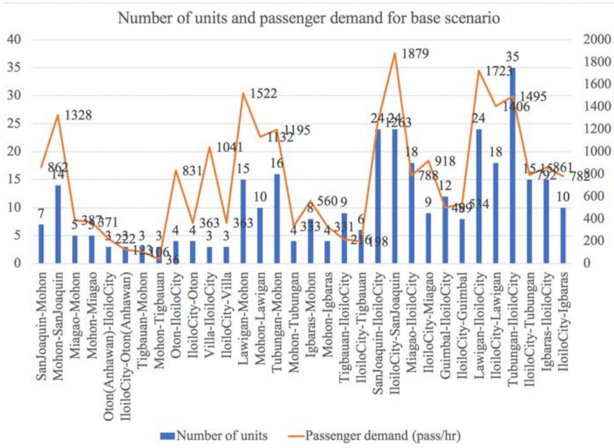

Fig. 10 Number of units and passenger demand for base scenario

4.3.3 Proposed Scenario

For the proposed scenario, the types of services proposed are feeder, local, and limited stops services (Fig. 11). The feeder service in this scenario exclusively serves the local/tertiary roads and traversed by tricycles (Table 6). These modes can stop anywhere along their route upon passenger's request. The Filcab and modernized jeepneys operate as local service where passengers board and alight at loading unloading zones and terminals. The capacity of Filcabs and modernized jeepneys is 18 for both modes. Lastly, the limited stops service only stop at municipalities and served by modernized jeepneys with a capacity of 22.

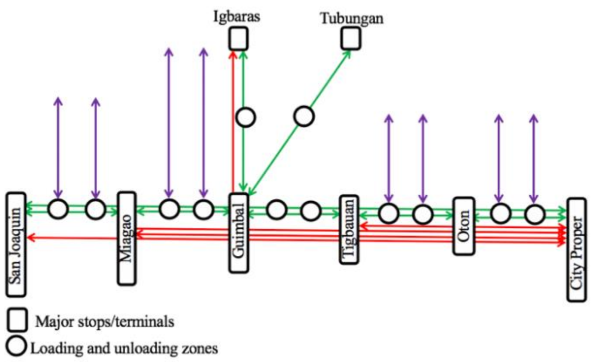

Fig. 11 Proposed services in Southern Iloilo

Table 6 Description of the types of services from the proposed scenario

Legend	Type of Service	Modes
	Feeder	Tricycles
	Local service	 **Fig. 12** Filcab  **Fig. 13** Modernized Jeepneys

Legend	Type of Service	Modes
↔	Limited stops service	 **Fig. 14** Modernized Jeepneys (limited stops)

4.3.3.1 Modelled Proposed Scenario

Fig. 14 shows the modelled proposed scenario. The lessened demand at the City Proper is shown in this scenario as well as the increased demand at the neighboring municipality and intersections of Guimbal and Igbaras.

4.3.3.2 Proposed Routes and Number of Units of Local Filcab Services

Fig. 15 shows the length of each route and the travel time of the proposed limited stops service. San Joaquin to Lawigan and vice versa routes are the longest routes in terms of kilometers and travel time as shown in the Fig. 15.

Fig. 15 Boarding-Alighting of passengers when proposed scenario is implemented

For the proposed scenario, RMC formula was used to calculate the number of units. RMC formula accounts for average seating capacity (ASC) and number of round trips/hr. In preparing guidelines for LPTRP use, RMC formula (1) from LPTRP is more recommended since it accounts for ASC.

$$\text{RMC formula: Number of Units (NU)} = \frac{PD \times SF \times PHF \times DF}{UR \times VLF \times ASC \times NRT} \quad (1)$$

Where:
PD = Passenger demand per route
SF = Seasonal Factor
PHF = % of peak hour volume to daily volume (negligible since PD from EMME/4 is already at peak hour)
DF = directional factor (value is 1 since analysis is per direction)
UR = Utilization Rate (85%)
PCF (VLF) = Passenger comfort factor (85%)
ASC = Average Seating Capacity
NRT = Number of round trips/hr

As shown in Fig. 16, the Lawigan to San Joaquin segment requires the highest number of units while Tubungan to Guimbal route segment has the highest passenger demand. Since the RMC formula also considers the travel time in NRT, this affects the calculation of the number of units required per segment. As shown in Fig. 15, the travel time for Lawigan to San Joaquin segment is longer compared to Tubungan to Guimbal segment. This yields a lower NRT, hence the higher number of units required.

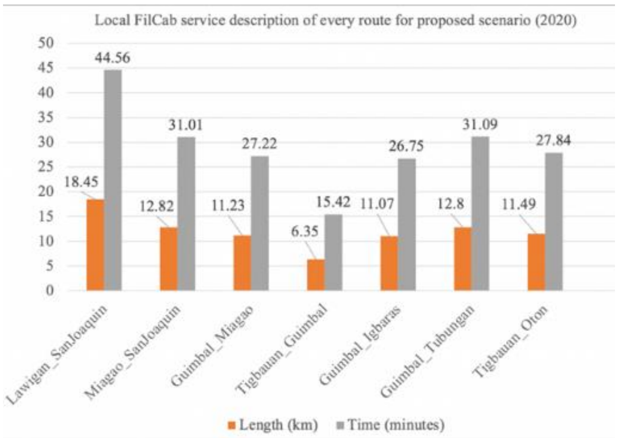

Fig. 16 Length of routes and travel time for proposed local Filcab services

4.3.3.3 Proposed Routes and Number of Units of Local Jeepney Service

Fig. 17 shows the length of each route and the travel time of the proposed local jeepney service. Oton to Iloilo City and vice versa routes are the longest routes in terms of kilometers and travel time as shown in the Fig. 17.

Fig. 18 shows the number of units using RMC formula and passenger demand for modernized jeepney services. Among the routes, Iloilo City to Oton route has the highest demand, requiring most number of units.

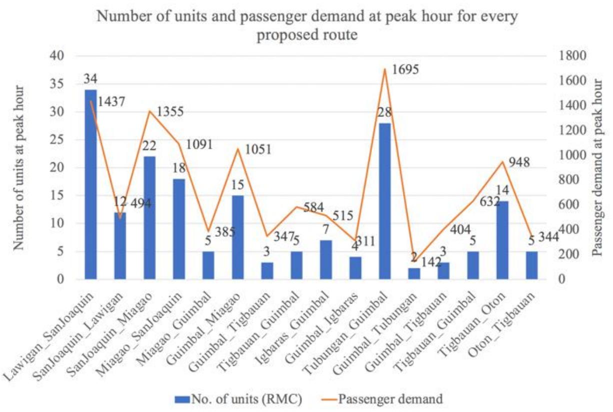

Fig. 17 Number of units and passenger demand for local Filcab services, proposed scenario

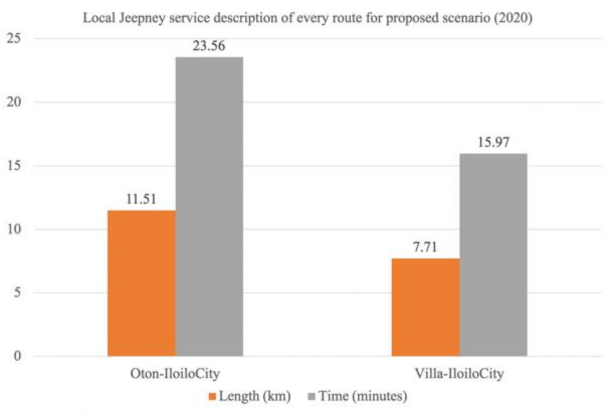

Fig. 18 Length of routes and travel time for proposed modernized jeepney services

4.3.3.4 Proposed Routes and Number of Units of Limited Stops Services

Fig. 19 shows the length of each route and the travel time of the proposed limited stops service. Modernized jeepneys operate as limited stops services in the proposed scenario. San Joaquin to Iloilo City and vice versa routes are the longest routes in terms of kilometers and travel time as shown in Fig. 19.

Fig. 20 shows the number of units calculated using RMC formula and passenger demand for limited stops services. Iloilo City to San Joaquin produced the highest passenger demand, requiring the most number of units.

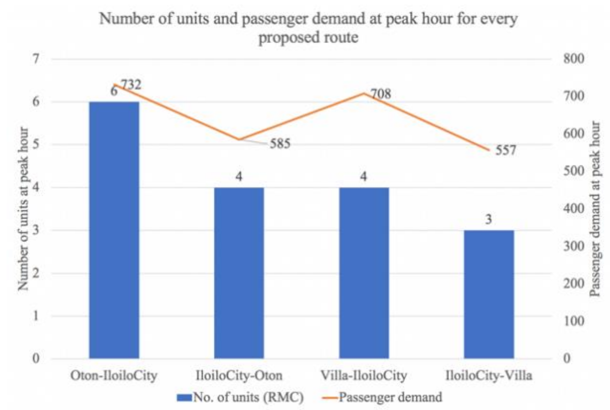

Fig. 19 Number of units and passenger demand for modernized jeepney services, proposed scenario

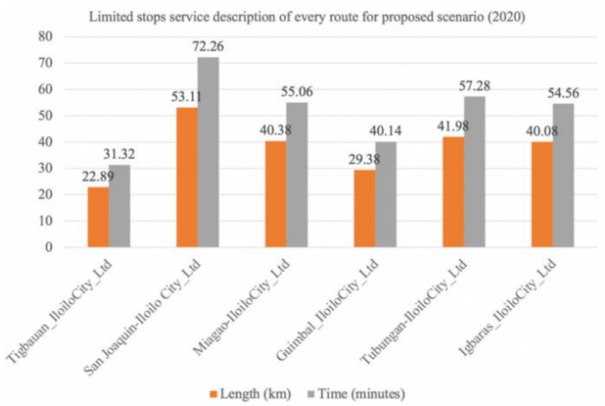

Fig. 20 Length of routes and travel time for proposed limited stops services

4.3.4 Comparison of Base Model to Proposed Scenario

Table 7 shows the proposed routes in comparison with the existing. As shown, all proposed routes were modified by replacing jeepneys with modernized ones that operate as local and limited stops services.

Comparing the number of units existing to the number of units from RMC formula as shown in Fig. 21, it can be observed that fewer units are required for most of the routes. This is because the modes have larger capacity.

Fig. 22 shows the travel time comparison between the existing to proposed scenarios. It can be observed that the travel time is longer for the proposed scenario compared to the base scenario. This is expected since the proposed scenario stops at terminals where travel time accounts for the mode transfers of commuters. Although this is the case, the study emphasizes the difference in number of units, average speed.

Table 7 Existing and proposed mode for every route segment

Route Description	Existing Mode	Proposed Mode
Lawigan_SanJoaquin	N/A	Filcab
SanJoaquin_Lawigan	N/A	Filcab
SanJoaquin_Miagao	N/A	Filcab
Miagao_SanJoaquin	N/A	Filcab
Miagao_Guimbal	N/A	Filcab
Guimbal_Miagao	N/A	Filcab
Guimbal_Tigbauan	N/A	Filcab
Tigbauan_Guimbal	N/A	Filcab
Igbaras_Guimbal	N/A	Filcab
Guimbal_Igbaras	N/A	Filcab
Tubungan_Guimbal	N/A	Filcab
Guimbal_Tubungan	N/A	Filcab
Guimbal_Tigbauan	N/A	Filcab
Tigbauan_Guimbal	N/A	Filcab
Tigbauan_Oton	N/A	Filcab
Oton_Tigbauan	N/A	Filcab
Oton-IloiloCity	Jeep	Modernized Jeep
IloiloCity-Oton	Jeep	Modernized Jeep
Villa-IloiloCity	Jeep	Modernized Jeep
IloiloCity-Villa	Jeep	Modernized Jeep
Tigbauan_IloiloCity_ Ltd	Jeep	Modernized Jeep (Limited stops)
IloiloCity-Tigbauan_Ltd	Jeep	Modernized Jeep (Limited stops)
San Joaquin-Iloilo City_Ltd	Jeep	Modernized Jeep (Limited stops)
Iloilo City-San Joaquin_Ltd	Jeep	Modernized Jeep (Limited stops)
Miagao-IloiloCity_Ltd	Jeep	Modernized Jeep (Limited stops)
IloiloCity_Miagao_Ltd	Jeep	Modernized Jeep (Limited stops)
Guimbal_IloiloCity_Ltd	Jeep	Modernized Jeep (Limited stops)
IloiloCity_Guimbal_Ltd	Jeep	Modernized Jeep (Limited stops)
Tubungan-IloiloCity_ Ltd	Jeep	Modernized Jeep (Limited stops)
IloiloCity-Tubungan_ Ltd	Jeep	Modernized Jeep (Limited stops)
Route Description	Existing Mode	Proposed Mode
Igbaras_IloiloCity_Ltd	Jeep	Modernized Jeep (Limited stops)
IloiloCity-Igbaras_Ltd	Jeep	Modernized Jeep (Limited stops)

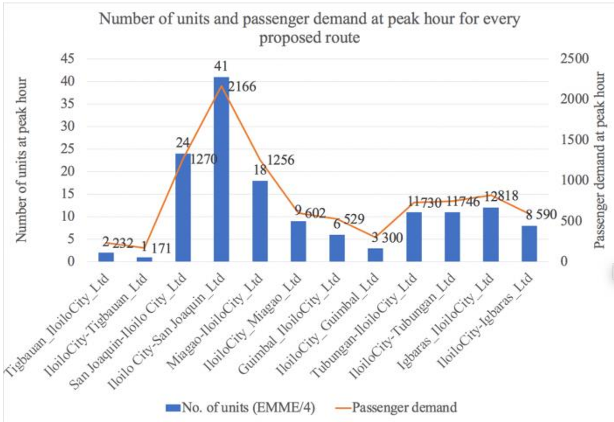

Fig. 21 Number of units and passenger demand for limited stops services, proposed scenario

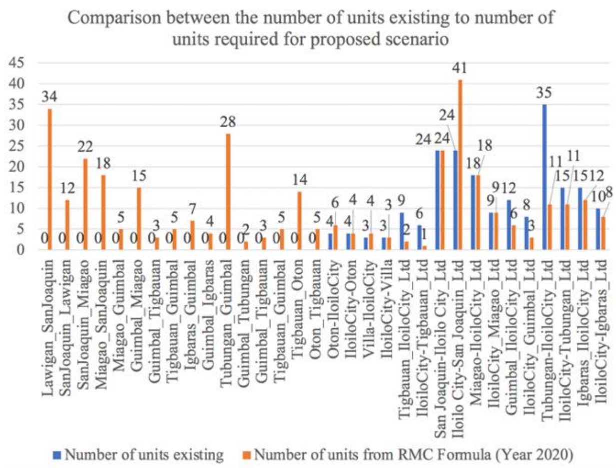

Fig. 22 Comparison of the existing number of units to proposed number of units from RMC formula

Introducing new service modes and modified service routes affects the passenger demands at specific areas. In the study, this increased the demands in other municipalities as shown in Fig. 23. This means that the new routes and service operations modified makes neighboring municipalities of City Proper attractive.

In addition to the comparisons mentioned, the proposal is evaluated through LPTRP standards. The LPTRP Manual mentions different performance indicators to determine how the different services affect the transportation operation in the study area. In this study, indicators such as frequency, reliability, and utilization were investigated.

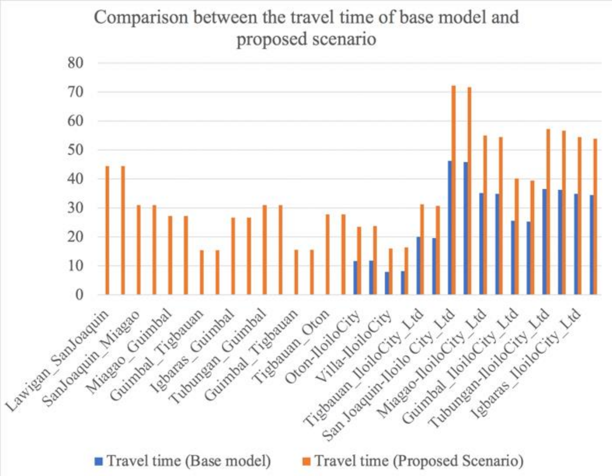

Fig. 23 Comparison between the travel time for every route in the base model and proposed scenario

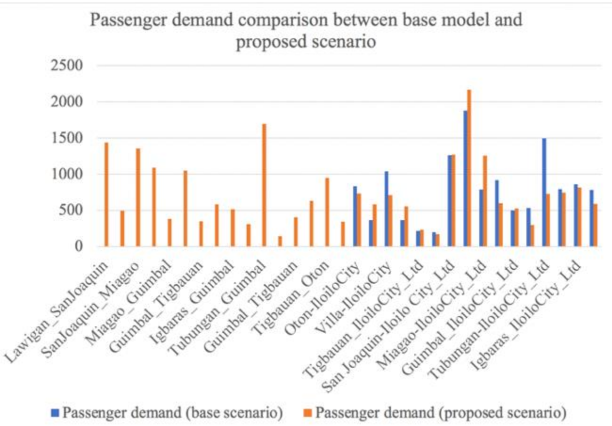

Fig. 24 Comparison between the passenger demands at every route for base model and proposed scenario model

For frequency, number of units, and headways were compared to show if there are any improvements once implemented, while reliability is dependent on the waiting time. As shown in Table 8, the number of units required was less than the existing units. Since the required number of units is less than the existing, it is expected that the headway is greater for the proposed scenario as shown in the table. The waiting time component of passengers is already incorporated in the travel time in the study. As observed in the table, the average speed in both scenarios also improved although it is almost the same at 21.30 kph for existing and 21.49 kph for proposed.

For utilization, the load factors for existing and proposed scenarios were compared. Higher load factor is more recommended since the load factor indicates the ratio of actual passenger occupancy to the distance capacity. As shown in Table 8, the load factor for the proposed is higher than the existing. This shows that the modes are occupied for most of the trips.

Table 8 Comparison of existing to proposed scenario through performance indicators

Factors	Existing scenario	Proposed scenario
Veh-Distance Traveled (VDT), km	774,231.9	753,214.63
Veh-Hours Traveled (VHT)	422,619.7	396,888.54
Total Veh Volume	1,623,748.0	1,576,613.62
Average travel speed (kph)	21.30	21.49
Average Load Factor	0.95	0.95
Headway	4	6

5. Conclusion

The SCA was used to estimate trips generated by households and used in developing proposed PUV routes in Southern Iloilo. To address the problems in public transportation in Southern Iloilo, different types of service were introduced. The proposed services are more efficient and will replace tricycles operating along the national roads. The new services will also be using new PUV modes to replace the traditional jeepneys. All of which addresses the problems in transportation of Southern Iloilo. Based on the models developed in EMME4, the introduction of local and limited stops services along national roads, and feeder service along local roads is recommended for Southern Iloilo. Proposed limited stops service routes require lesser units compared to the existing service since modernized jeepneys have higher capacities. Performance indicators from LPTRP was used to compare the resulting service frequency, travel time, and utilization of units to show improvements in the public transport service.

6. Recommendation

Future studies can investigate industry consolidation where the operators can form cooperatives that can coordinate scheduling of trips, lessening the competition among operators and drivers on the road, improving further the transport operation services, and providing connectivity among different modes and their routes.

Research can be further improved by considering the different establishments existing in Southern Iloilo in proposing new or adjusted routes. Further studies can show how the improvement in the existing services make a municipality more attractive to commuters and consequently improve the economic growth of the municipalities. Network model can be further improved by factoring in the travel cost and travel time.

In addition to this, personal characteristics and trip purpose of commuters can be further investigated by future researchers when considering route improvements. The acceptance of commuters to proposed routes can then be added in proposing new operations.

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Barrier-Free Mobility Assessment of General Luna Street, Intramuros, Manila

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Abstract

The rise in motorization in the Philippines has led to the fall of most of its walkability ratings, leaving pedestrian and accessibility facilities behind. Despite the existence of the prevailing laws like the Accessibility Law or locally known as the *Batas Pambansa* 344 (BP 344), structures that lack proper access and mobility for persons with disabilities (PWDs) such as roads, crosswalks, crossings, government establishments, educational institutions, and historical sites are evident. Thus, this paper evaluates the facilities for PWDs in General Luna Street, Intramuros, Manila, where prominent heritage, cultural, educational and government agencies are located. An evaluation index was created in conducting the assessment of the facilities for accessibility based on the requirements set by the law. Upon examination, General Luna Street has a compliance rate of 19.72%. Results of the study found out that roads are subjected to sudden level changes and uneven surfaces, facilities like dropped curbs and handrails were missing, there were few allotted curb-cut outs, and obstructions that lessen the purpose of walkways. Six out of nine buildings in the study area have ramps in their entrances and the crossings that lack both tactile blocks and stop lines. Moreover, maps of the facilities were created, and an inventory was established with the application of geographic information system (GIS). An accessibility enhancement plan was provided to open prioritization opportunities and recommendations that could serve as a basis for development plans and for the inclusiveness of the society to PWD.

Keywords: Barrier-free, Accessibility, Mobility, GIS

1. General Introduction

In the Philippines, the Philippine Statistic Authority (PSA) census has shown that of the 92.1 million documented household population, 1.57% (1.44 million) have disabilities [1]. Numerous laws and ordinances have been passed that protect and promote the rights of PWDs. However, PWDs are still often neglected and tied to negative stereotypes because of the poor implementation of such laws. Mobility of PWDs have even been more left behind due to the exponential rise in motorization, shifting the prioritization for development of pedestrian facilities to private vehicles and road expansions [2]. Walking has been man's primary means of mobility and the greatest social equalizer in the world, yet pedestrians still tend to avoid walking because of various obstructions and unclean or not properly maintained sidewalks [3].

The capital city of the Philippines, the city of Manila, is one of the cities that initiated development and rehabilitation projects for the betterment of pedestrian mobility [4]. Not only that Manila is a melting pot for various establishments, but also its heritage and culture has drawn it to be a famous tourist destination to which one of the best spots is Intramuros, the "walled city". As Intramuros becomes recognized as Asia's leading tourist attraction, the Intramuros Administration (IA) continues to extend its efforts to promote tourism by planning to implement pedestrian-only streets inside the walled city [5]. Thus, walking becomes an integral mode of mobility within the walls.

This study has evaluated the mobility of PWDs in General Luna Street, Intramuros, Manila, through the assessment concerning the accessibility and mobility features of roads, buildings, and crossings. An evaluation index formulated for this study was adapted from the provisions of the Accessibility Law (BP 344), and Department of Public Works and Highways Department Order No. 65 series of 2013 (DO 65), which was utilized to assess and to create an inventory of the facilities for accessibility. The data collected was evaluated and mapped using a geographic information system (GIS) to provide an inventory and various maps related to the facilities for accessibility which can be used by different parties, most importantly the PWDs, and the Intramuros Administration for urban planning purposes.

2. Literature Review

2.1 Philippine Urban Mobility

The Congressional Policy and Budget Research Department (CPBRD) of the Philippines noted from the assessment of the Asian Development Bank (ADB) that insufficient and ineffective transport planning is evident in most Philippine towns and cities [6, 7]. Traffic control devices often do not conform to official standards due to underinvestment and lack of attention to proper road maintenance.

Furthermore, a study that seeks to provide an action-oriented framework for urban mobility has pointed out that road safety has shown that it comprises an about 53% of total traffic deaths as mentioned by a report from World Health Organization (WHO) [8]. Thus, the problems concerning urbanization and mobility that is seen from that study shows that the assessment conducted by ADB from 2012 is still reflected up to this date and may pose a major risk of further deterioration in the mobility of urban populations.

In the same study it was shown that 30% of the total trips comprises walking trips in Metro, Manila and thus, highlights the significance of barrier-free facilities. Fig. 1 shows some of the non-motorized challenges and proposed solutions from the action-oriented framework presented in that study [8].

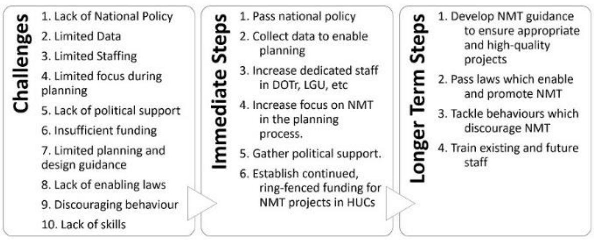

Fig. 1 Non-Motorized Transport Challenges and Proposed Solutions. Adapted from Mettke et al. (2020)

There are initiatives such as the Philippine Urban Mobility Programme (PUMP) which showcases an action-oriented framework to enhance the capabilities of each city to fulfill the pedestrians' mobility needs. Presently, the proposal of such study and laws that will enable and promote NMT are still on its way.

2.2 Laws, Guidelines and Papers Providing Standards for Accessibility of PWDs

The law in the Philippines that focuses on providing guidelines to enhance the mobility of disabled person and to create accessible designs is the Accessibility Law (BP 344). Minimum requirements for accessibility are provided as well as illustrated information on the dimensional requirements as required for the facilities. In addition, the Department of Public Works and Highways (DPWH), has provided Department Order No. 37 series of 2009 to enforce the law along national roads which ensures that the accessibility features conform to the minimum requirements of the law. DPWH Department Order No. 67 series of 2013 provides the revised guidelines on the installation of pedestrian crossing markings along national roads, aiming to improve road safety standards in the country.

Another tool utilized in this study is the Department of Public Works and Highways (DPWH) – Road and Bridge Information Application (RBIA). RBIA is a data repository for the road conditions under the National Road network in the Philippines. Through its GIS system, the map provides the classification of the roads located within Intramuros together with the parameters used to describe the road conditions and what are the expectations of those roads.

2.3 Analysis of GIS Data in Relation to Accessibility

A study on the application of Geographic Information System (GIS) on historical sites and its take on the visitors with disability and reduced mobility showed that the tool facilitated in providing personalized information on accessible and safe pathways, with the final goal of finding the best possible route to reach a target according to the tourist's specific needs [9].

Coincidentally, their study is related to Intramuros since it is also home to historical sites, and the significance of the location may affect how facilities for accessibility are provided for PWDs. Upon completion of the system, the records of individual elements can be integrated with GIS in identifying accessible routes in areas with consideration for the disability or reduced mobility of their visitors.

However, it is mentioned in that study that the improvements of physical access for tourists are a compromise, because historic sites have significance in terms of their design and may be conserved [9]. Thus, planning facilities of accessibility using GIS can be an effective tool in providing the adequate number of facilities without compromising the historic significance of the sites.

3. Methodology

3.1 Conceptual Framework

The assessment of facilities for accessibility used the input-process-output framework to establish clarity to the assessment. Furthermore, the facilities for accessibility consisted of the facilities presented in the Accessibility Law (BP 344) as the inputs for the assessment.

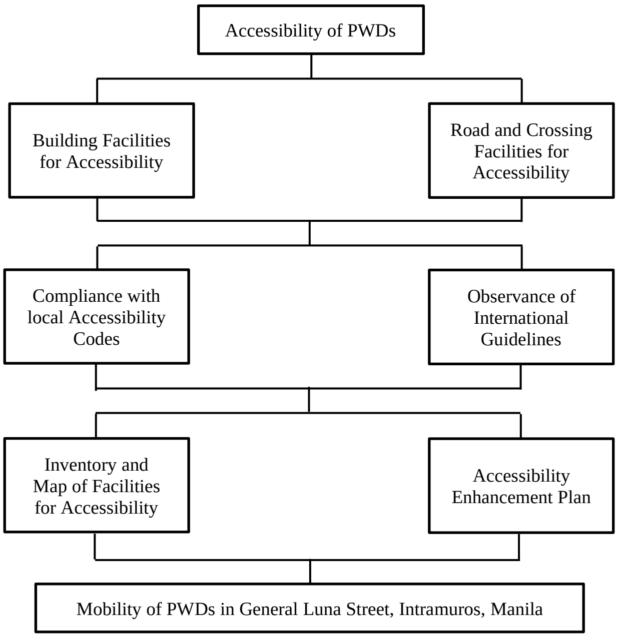

Fig. 2 Conceptual Framework

The process framework has showcased the analysis of data with their compliance with codes for accessibility in the Philippines, and the observance of international guidelines for accessibility. Lastly, the outputs of the study are consisted of the inventory and map of facilities for accessibility and the recommendations to enhance the mobility of PWDs or the Accessibility Enhancement Plan.

3.2 Development of an Evaluation Index

The study developed an evaluation index adapted from the Accessibility Law (BP 344) and some of the requirements in DPWH DO 65 s. 2013 to assess the compliance of certain structures for accessibility present in the roads, buildings, and crossings in the research locale.

The term "Evaluation Index" was used to describe the collection of assessment forms and the process of using them in creating a detailed and organized assessment of the road considered.

The elements included in the forms are as follows: Dropped curbs, curb cut-out, walkways, handrails, signages, crossings, building entrances, and building ramps. These were some of the basic elements required by the law, and essential in providing accessibility to PWDs which were aimed to be assessed in this study.

The forms used to assess a specific type of facility were used to record the observations, and the location of the facility being assessed. Each form included the specific provision of the code to be assessed, and the reference on what code it was lifted from. There are columns for the compliance which either passed or failed the standard. There are also columns for N/A, and remarks for other noteworthy observations within the evaluation.

Upon assessment primarily, the general compliance of the facility for accessibility itself were determined. It is compliant if it passed all the specifications required, partially compliant if it passed in at least one but failed in other aspects, and non-compliant if the facility did not pass any of the requirements of the law for a particular type of facility. Finally in the overall evaluation, partially compliant facilities are categorized as non-compliant, since the law requires full compliance and failing one requirement may compromise the overall function of the evaluated facilities for accessibility.

3.3 Assessment of Facilities for Accessibility in General Luna Street

The field survey of the location starts with the segmentation and designation of segments. The street which was assessed started from the intersection of General Luna Street and Muralla Street, and ended in the intersection of General Luna Street and Soriano Avenue.

Each segment of the street was classified based on the General Luna Street's intersection with perpendicular streets. Each segment was divided into two sides of the street to identify the east and west sides. The buildings whose façade is along or near the segment were also labelled and considered to be located in that segment. An example of this labelling of the parts of a segment is presented in Fig. 3.

The list of all road segments, and buildings assessed, considered for this study is shown in Table 1. There are a total of nine (9) road segments, with the code of R divided into two sides either a or b, and nine (9) buildings, denoted by the code B, along General Luna Street.

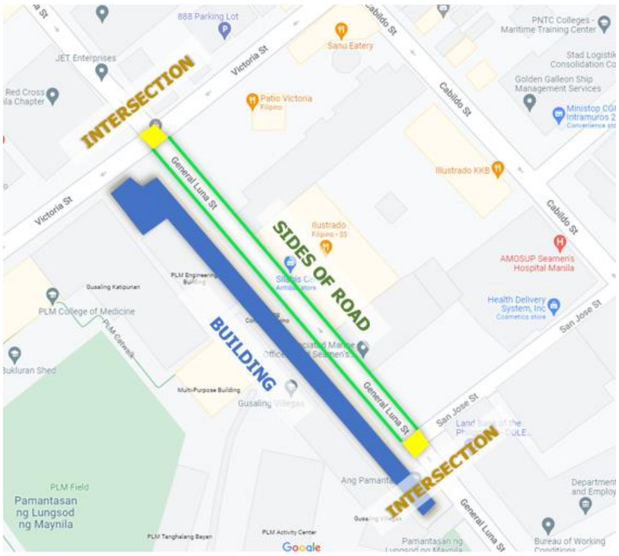

Fig. 3 Sample segment in consideration

Table 1 Road Segments, Buildings, and Intersections of General Luna Street

CODE	ROAD SEGMENTS
R1a – R1b	Muralla St. – San Jose St.
R2a – R2b	San Jose St. – Victoria St.
R3a – R3b	Victoria St. – Sta. Potenciana St.
R4a – R4b	Sta. Potenciana St. – Urdaneta St.
R5a – R5b	Urdaneta St. – Real St.
R6a – R6b	Real St. – Anda St.
R7a – R7b	Anda St. – Beaterio St.
R8a – R8b	Beaterio St. – Sto. Tomas St.
R9a – R9b	Sto. Tomas St. – Soriano Avenue
CODE	**BUILDINGS**
B1	University of the City of Manila
B2	DOLE Building
B3	AMOSUP Seamen's Hospital
B4	Philippine Red Cross
B5	NCCA Building
B6	San Agustin Church
B7	Plaza San Luiz Complex – Casa Manila
B8	The Manila Cathedral
B9	Palacio Del Gobernador

3.4 Mapping using GIS

Geographic Information System or GIS is a system used for entering, storing, manipulating, analyzing, and displaying geographic or spatial data

[10]. The study utilized a free and open-source mapping tool named Quantum Geographic Information System (QGIS), which allows the input of data collected onto a project file in creating an inventory for the facilities of accessibility in Intramuros.

The basemap used in conjunction with QGIS is OpenStreetMap (OSM). Further, recorded coordinates during the data collection were directly imported to QGIS using the add-on "Mergin" for QGIS, this is a cloud-based project editing tool which utilizes a free Android application for mobile phones, "Input: QGIS in your pocket" by Lutra Consulting, to record the coordinates and location on the map of the observed facilities. Photographs of the facility assessed were documented with an image with the coordinates for its location, also utilizing the GPS of smart phones.

For this study, the geographic coordinate reference system used is the World Geodetic System 1984 or WGS 84, while the coordinate system used is EPSG 4326. The consistency of the coordinate reference system used for the study, the tools and information collected were ensured to be under WGS 84.

QGIS allows the creation and editing of shapefiles which was done to make an inventory of the facilities for accessibility in General Luna Street.

The study utilized vector data which can either be point, line, or polygon data, together with their attribute tables. Each of the assessed facility for accessibility were recorded as point data with their GPS coordinates as their location. This study represented the segments of the road and the assessed walkways through line data, by digitizing the roads from the basemap. The study utilized polygon data to represent the location and the boundaries of the buildings assessed through digitizing the structure outlines on the basemap.

The methodological and detailed recording of the data allowed the creation of an inventory of the facilities for accessibility which can be used to view the information and make decisions based on actual conditions. The output maps of the process show the location of the facilities for accessibility, their compliance, and the accessibility of the roads and buildings.

3.5 Accessibility Enhancement Plan

The accessibility enhancement plan contains the systematic outline of conclusion and recommendations for the evaluated data. As part of the reports in the accessibility enhancement plan, it contains the compliance rate of the facilities for accessibility along General Luna Street, Intramuros, Manila.

Within the accessibility enhancement plan, this measure was able to provide conclusion from the interpretation of each of the assessed facilities. In turn, the recommendations outlined in the accessibility enhancement plan provided measures that are directed to the specific problem to enhance the mobility of PWDs in General Luna Street, Intramuros, Manila.

On account of the data from the evaluation index, it was stored through GIS for inventory and mapping of the recorded facilities for accessibility. The relevance of mapping served as the outcome of this research and it would also aid the urban planning and development sectors in providing a more accessible and barrier-free environment for all pedestrians.

4. Results

4.1 Assessment and Mapping of Facilities for Accessibility in General Luna Street

The general map of facilities for accessibility evaluated for this study was mapped out and shown in Fig. 4, the types of facilities that were assessed include: building ramps, building entrances, curb cut-out, signages, crossings, and walkways. The curb ramps along General Luna Street consist only of the curb cut-outs and the dropped curbs were not found, similarly, handrails along the walkways were also not present as noted by the lack of their data point in the map. Also, the span of General Luna Street included for the study is indicated in the map, and the outline of the buildings considered and evaluated were also visible as hatched shapes in the map.

4.1.1 Curb Cut-Out

The study paved way in evaluating the curbs present along General Luna Street in Intramuros, Manila but it was found out that dropped curbs are not present along General Luna St., and only curb cut-outs are present.

The field survey assessed a total of six (6) curb cut-outs and using the criteria indicated on the IRR of BP 344, it was found out that all six of the curb cut-outs are compliant with each of the following requirements:

- *Should only be allowed when it will not obstruct or lessen the width of the walkway.*
- *Minimum width of the cut-out should be 0.90m.*

- *Should have a gradient not more than 1:12.*

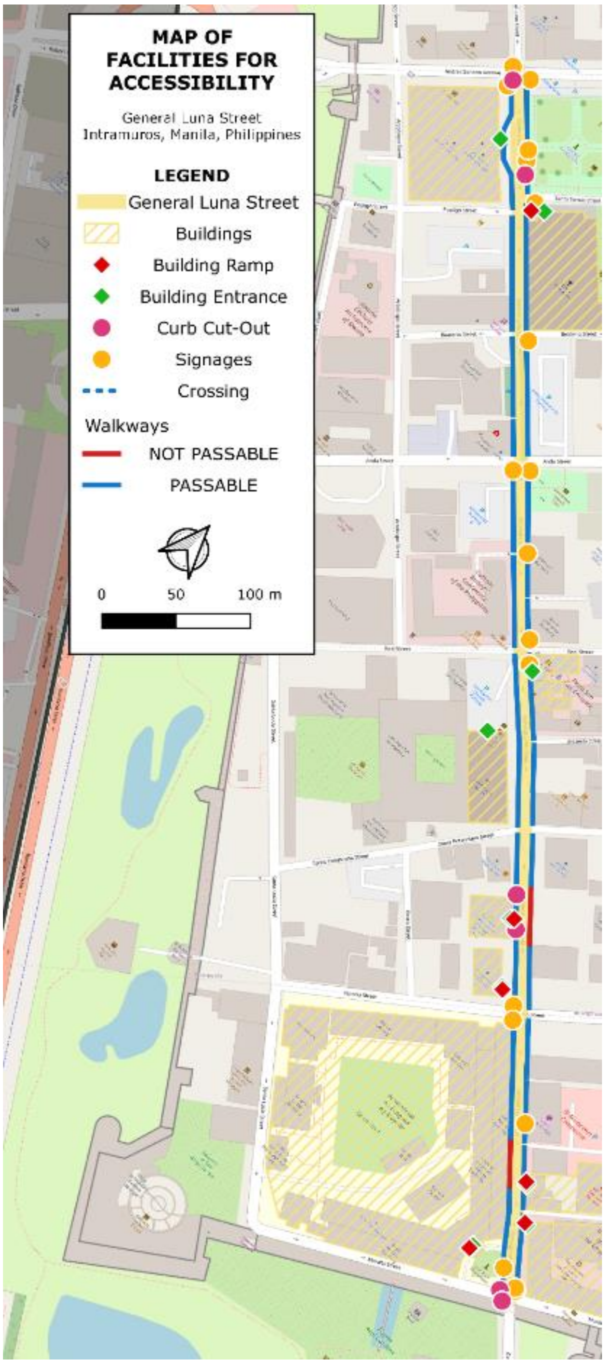

Fig. 4 Location of Facilities for Accessibility along General Luna Street

However, the amount of six (6) curb cut-outs for the whole length of around 800 meters in General Luna Street is relatively few to provide enough accessibility to all sidewalks, intersections, and buildings. Thus, more curb cut-outs should be installed across the sidewalks and intersections of General Luna Street to give PWDs a safe transition across elevation changes.

In addition, BP 344 does not state anything about the installation of detectable warnings on ramps as persons with visual impairments can obtain helpful navigational cues from curb ramps and the edges of the curb [11]. So, it is recommended to install detectable strips onto the curb ramps which can notify pedestrians with visual impairments about the placement, start, and end, of the ramps.

4.1.2 Walkways

The sidewalks were classified into individual walkways and were identified by changes in sidewalk characteristics such as elevation change, width change, material change, and other significant difference between parts of a sidewalk.

The study designated and assessed a total of 29 walkways. The evaluation showed that out of the 29 walkways, two (2) are fully compliant in the criteria, while the majority, 27 of the walkways are only partially compliant, and none are non-compliant.

- *Designed to be as level as possible and provided with slip-resistant material.*

For the criterion, 27 out of 29 walkways passed and there were two walkways which failed in this aspect, the walkway has floor tiles which could be slippery especially during rainfall, and the other walkway has the surface utilized as a parking lot and made the surface to have variations in level.

- *Required minimum width of 1.20 meters.*

Out of the 29 assessed walkways, only 19 or 65.52% had complied with the required width. The lengths of those walkways amount to approximately 447.35 meters or about 29.71% of the total walkway measured, and is a significant problem considering that General Luna Street is one of the primary roads located along Intramuros.

- *Should have a surface with no cracks or breaks creating edges above the surface by 6.5 mm.*

The criterion where the lowest percentage of walkways complied, with only 8 out of 29 complied at a 27.59% passing indicating that most of the walkways do not have a continuous surface.

- *Should follow straightforward routes and with right angle turns.*

All the walkways, 29 out of 29, had complied in this criterion, since the span of General Luna Street is a straight road, the sidewalks are also straightforward which can help in the ease of movement for all pedestrians.

- *Ensure that there are no overhanging branches of trees or shrubs in the walkways.*

Only 1 out of 29 walkways, a walkway had shrubs that overhang and obstruct the walkway. It is recommended that these shrubs be removed or trimmed out so that it would not cause issues with pedestrians or PWDs traversing the walkway.

- *Passageways should have no obstructions in the route*

Assessments showed that 10 out of 29 walkways, or a percentage of 34.48% passed the criterion that there should be no obstructions along the route, and the majority had various types of obstruction along the walkways which can be dangerous and should be removed.

4.1.3 Signages

The observations for all signages are uniform since the assessed signages in General Luna Street is also uniformly designed and installed. The evaluation identified and assessed a total of 18 signages found along the considered span of General Luna Street. despite the uniform design, the designs are only partially compliant with the requirements of the IRR of BP 344.

- *Directional and informational signs should be located where it can be conveniently seen even by a person on a wheelchair or those with visual impairments.*

All 18 of the signages passed this criterion because their designs are easily seen and placed in a convenient location.

- *Signs to be simple and easy to understand, made of contrasting colors and contrasting gray matter.*

In addition, all signages passed in the criterion that states the design requirements of the signage to make detection and reading easy.

- *Accessible routes and facilities should be indicated with international symbol for access.*

However, there were no observed signages with the stated purpose. There were present accessible facilities such as curb cut-outs, but it did not have an associated signage to indicate their presence. So, all the assessed signage is classified in N/A as they do not serve the said purpose, which the study recommends to provide signages for the accessible routes or facilities present.

- *Protruding signs should provide a minimum headroom of 2.0 meters.*

For the headroom requirement, all signages are classified under N/A because the signages assessed were all floor mounted, and none are overhanging, wall, or door mounted.

- *Signages indicating public rooms and places should have raised symbols, letters, or numbers with a minimum height of 1 mm, and should have braille symbols.*

Lastly, all the signages failed in this criterion because they did not have any extrusion and were smooth and flat, and was observed that they did not have any braille symbols. Despite being designed well, this is the deficiency of the design as it lacks braille symbols, so it is recommended that braille symbols be installed on the signages to accommodate the pedestrians with visual impairments.

4.1.4 Building Ramps

Based on the assessment, there were 6 identified building ramps out of the 9 buildings for public use along General Luna Street.

- *Ramps should have maximum gradient of 1:12.*

Significantly, it was observed that all building ramps were not compliant in their gradient and the presence of these steep-sloped ramps creates physical barriers for PWDs.

- *Handrails should be provided on both sides of the ramp at 0.70 m and 0.90 m.*

Only 2 out of 6 ramps within General Luna Street complied with this requirement, which is very concerning since the choice of route among older adults especially with limited mobility is often determined by the presence of handrails [12].

4.1.5 Building Entrances

There are two criteria used to evaluate entrances and only 6 out of 9 building entrances compliant to the minimum requirements of BP 344.

- *Entrances should be accessible from arrival and departure points.*

All entrances were observed to be wide enough to accommodate volumes of people arriving and exiting the building premises.

- *Ramps should be provided if the entrance is at a different grade than the sidewalk.*

However, only 6 out of 9 building entrance passed the second criteria. These entrances could not provide ramps due to historical preservation efforts, and the lack of space with the limited area of the sidewalk.

4.1.6 Crossings

Based on assessment, there were only 3 crossings which can be found in General Luna Street. The data also revealed that all 3 crossings were only partially compliant to the given standards. This is very concerning considering that there are 11 intersections within the street and having only 3 crossings could be detrimental to the safety of pedestrians when crossing the road. On top of that, all 3 crossings were only partially compliant, which indicates that there are features of the crossings which lacks, prevents, or is inaccessible to PWDs and other pedestrians.

- *Crossings should be perpendicular to carriageway in the narrowest part, and should be contiguous with the normal pedestrian desire line.*

All three of the crossings had passed in this requirement and they were placed appropriately across General Luna Street.

- *Tactile markings should be provided within the vicinity of the crossings.*

None of the crossings assessed were able to provide tactile markings in any part of the crossing.

- *Crossings without channelized islands shall be placed in a 2 m setback from the edge of the carriageway of the intersecting road.*

Measurements were done and showed that all the crossings were able to pass this criterion.

- *Crossings should have a stop line 1.5 m from the nearest pedestrian lane and should be 450 mm wide.*

Unfortunately, all crossings failed to comply with this requirement lacking a painted stop line. Overall, the study deemed the total number of crossings to be very few, considering that General Luna Street is the busiest street within Intramuros.

4.2 Accessibility Enhancement Plan

The Accessibility Enhancement Plan is a systematic outline comprised of the interpreted data, down to the drawn conclusion from the conducted assessment done through the utilization of the evaluation index.

Particularly, the study has adapted the way how the Champaign County Regional Planning Commission (RPC) in East Central Illinois reported their recommendations, this particular local agency had also developed a database of sidewalk network features to where it can track the general condition of their particular area.

The outcome of the analysis is to obtain the compliance rate of General Luna Street. To note, the compliance rate is the degree of compliance of the facilities for accessibility. Hence, this does not serve as a representative data of the compliance rate of Intramuros itself. Moreover, partially compliant facilities for accessibility are generally counted as non-compliant to fully comply with the requirements of the law and to avoid facilities for accessibility being compromised. Hence, Table 2 presents the distribution of the facilities for accessibility compliance.

Table 2 Distribution of the Facilities for Accessibility Compliance

Status of Compliance	Actual Value
Compliant	14 (19.72%)
Non-Compliant	57 (80.28%)
Total	71

4.2.2 Compliance Recommendations

Compliance recommendation is a list of recommendations that focuses on ensuring facilities that have failed to comply BP 344 – IRR and DO 65, are to be provided with discussion of improvements in order to address such problems. Thus, Table 3 outlines the compliance recommendations:

Table 3 Compliance Recommendations

Type	Findings	Recommendations
Walkways	Selected walkways failed to comply to the minimum width of 1.2 m as required by the provisions of BP 344	Extend the walkway width temporarily towards the carriageway and allot traffic control devices such as the temporary bollards. For permanent extension provide installation of curb extensions.
Walkways	Selected walkways contain permanent obstructions along the pathway (e.g.,	If possible, with the help of utility providers, nearby electrical posts could be consolidated to reduce their amount along walkways.

Type	Findings	Recommendations
	electrical posts, sign posts, concrete bollard).	
Signages	The existing signages in General Luna Street lack raised symbols or text, or braille symbols	To improve existing signages by installing raised symbols or text, and braille symbols to help in providing information to the visually impaired.
Crossings	Absence of stop lines in all of the identified crossings within General Luna Street	Providing stop lines could aid the vehicle users to stop from an adequate distance that allows a safe space for the passing pedestrians.

4.2.3 Supplementary Recommendations

Supplementary recommendation was provided to outline the possible measures for the conditions, inclusions and modifications of facilities for accessibility for the improvement of accessibility and mobility of PWDs within General Luna Street. Thus, Table 4 outlines the supplementary recommendations:

Table 4 Supplementary Recommendations

Type	Findings	Recommendations
Dropped Curbs	Dropped Curbs were not provided before the intersections or pedestrian crossings in any of the identified road segments within General Luna Street.	Provide dropped curbs at the end of walkways to areas that may contain high volume of pedestrians that utilizes pedestrian crossings.
Curb Cut-Out	Visible cracks and difficulty in recognizing the international symbol for access that is present within the surface of the curb cut-outs.	Since there are no allotted dropped curbs, local governing agencies could allot local government budget for the repair and maintenance of curb cut-outs.
Walkways	There are many objects placed along the sidewalk in front of NCCA building which renders the area completely unpassable to pedestrians.	Coordinate with the local government to execute clearing operations by communicating with the residents in the area to remove or to displace the objects obstructing the sidewalk
Crossings	Absence of crosswalks on few identified intersections within General Luna Street	Consider providing more marked crosswalks within the intersections of General Luna Street, this serves as an early indicator to drivers to slow down and allot the right of way to pedestrians.
Ramps	Absence of building ramps on building entrances that are situated in a higher-level ground.	Provide portable wheelchair ramps for some building entrances that are now occupied by stairs.

5. Conclusion

Actual statistics of the barrier-free facilities was created to measure the compliance rate along General Luna Street. This could serve as an initial basis for the development of plans, processes, and policies for PWDs. Thus, the following conclusion are drawn from the findings of the study:

- The evaluation index created in accordance to the selected provisions of the Accessibility Law (BP 344) and the DPWH DO 65 Series of 2013 initially fulfilled the gaps in terms of compliance records of the facilities for accessibility within General Luna Street through a standardized and systematic method of evaluation.
- The parameters of the GIS database encompass the spatial information and compliance to the standards, to form maps of the facilities for accessibility along General Luna Street.
- The study has shown that General Luna Street has a compliance rate of approximately 19.72% for the facilities for the mobility and PWD accessibility.
- An Accessibility Enhancement Plan was incorporated to the Barrier-Free mobility assessment that initiates improvement

prioritization plans on the existing policies and evaluation procedures regarding accessibility standards.

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Comparative Analysis between Net Cost Method and Gross Cost Method - Case Study in Bangkok Blue Line and Purple Line-

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Abstract

In Bangkok, Thailand, serious traffic congestion has occurred due to the rapid increase in automobile use since the 1970s. To solve this problem, urban railways have started to develop from 1999, and in 2004, Bangkok's first subway "Blue Line" was opened. Even though this subway was constructed by the upper and lower separation method with BEM (semi-state enterprise) and MRTA (state enterprise), it turned into a deficit immediately after its opening because demand was overestimated and operation system was inadequate. The purpose of this study is to clarify the appropriate method for operating a railway business using a financial analysis model, considering 2 operating scenarios for urban railway operations: net cost method, and gross cost method. As a result, in the case of net cost method, the semi-state enterprise is in the red from the start of operations, while the state enterprise is expected to be in the black. Contrary, in the case of gross cost, semi-state enterprise can achieve stable profits because they receive a certain amount of concession fees regardless of fare revenues, and the state enterprise is also expected to be profitable. It was found that since the concession fees are large for revenues, unless concession fees are waived for a certain period after the opening, and the semi-state enterprise is likely to be in the red. If the payment is, however, waived to assist the semi-state enterprise, the state enterprise may into deficit. Therefore, it was concluded that the net cost method and the gross cost method have their own disadvantages and appropriate risk-sharing is necessary to prevent the semi-state enterprise from deficit.

Keywords: Railway, PPP, Business Operation, Financial Analysis

1. Introduction

Recently, traffic congestion caused by population growth is a major problem in Southeast Asia. In Bangkok, Thailand, economic reforms and liberalization since the 1990s have led to economic growth, traffic congestion and air pollution in urban areas have become a problem. In 1997, the construction of Thailand's first subway, Bangkok Blue Line began, and it opened in 2004. The Blue Line was built by the upper and lower separation method with MRTA (Mass Rapid Transit Authority of Thailand) which is the state enterprise and construct and own the infrastructure, and BMCL (Bangkok Metro), semi-state enterprise, operating the train. However, due to the problems of risk-sharing, a large difference between the actual number of passengers and the demand forecast before the opening, BMCL has been in the red since its first year of operation. And it lasts about 10 years after its opening. In 2015, BMCL was renamed BEM by merging with BECL (Bangkok Expressway), which operated expressways and was financially successful. After that, BEM succeeded in turning into black.

As mentioned above, the railway business requires a large initial investment in track, rolling stock, stations, and maintenance facilities, and it takes a long time to build a network with other transportation, so there is a risk of being in red in the early stages of operation. Therefore, this study aims to clarify the appropriate method for the operation of a railway business from a financial perspective by compared the Bangkok Blue Line with the Purple line.

2. Literature Review

Morichi et al. (1) conducted a risk analysis of PPP projects on three lines in Southeast Asia. They also analyzed the impact caused by the risks using financial simulations. As a result, they found that it is difficult to balance income and expenses when the railway is open, and that the financial situation generally tends to be difficult. After confirming and analyzing various risks, it was found that there were problems with the PPP method itself and urban development.

Furthermore, Morichi (2) explained the need of making transportation policy from a view of short-term perspective and a long-term perspective. He compared the desired future scenario with the do-nothing scenario and pointed out problems that may occur in the future. He then noted that policies that are effective in the short term may not be appropriate in the long term. In addition, he suggested that the successful example in developing countries is not necessarily suitable in Asia, and it may not be a solution to the urban transportation problems from a long-term perspective that Asian cities are currently facing.

Matsushita et al. (3) conducted a quantitative analysis of the risks that emerged during the planning, construction, and operation phases of each project using the financial and operational data from the Bangkok Blue Line and Manila Line 3, and quantitatively examined the amount of damage, schemes, and risk-sharing. For the Blue Line, the method of demand risk sharing was identified as a point of discussion. For the Manila Line 3, the risk with the greatest impact was identified as fare risk, but it was concluded that the operation scheme itself was a problem because it was difficult to ensure profitability without operating the line based on such a high fare level.

Hanaoka (4) conducted a comparative analysis of the application of the BOT method used to urban expressways and urban railways in large cities in developing Asian countries. As a result, it was found that government operators took excessive risks even though they were operated by private operators. He also noted the difficulty of applying a complete BOT approach to urban railway business in Asian cities due to the difficulty of forecasting demand.

3. Methodology

3.1 Evaluate Method

Making a financial model using VENSIM. VENSIM is the system dynamics software and can directly model relationships between elements by intuition considering the concept of time. By using the financial analysis model, the break-even point, the year of turning into the black at multiple years are compared. The Break-even point is the year when revenues and expenses equalize, and the current account balance turns into a surplus in a single fiscal year. The year of turning into the black at multiple years is the year when accumulated losses are finally eliminated (repaid). If the balance record surplus, it is defined as "balance is in the black" and the record deficit, defined as "balance is in the red"

3.2 Constitution of the Scenario

In this study, three scenarios that represent different management styles were set. The first scenario is the case of the net cost method and the second scenario is the case of the gross cost method. Both methods are the cases of construction by the upper and lower separation method in which the state enterprise is responsible for the railway construction and maintenance of lower sections, such as track. The semi-state enterprise is responsible for upper sections, such as train operations. The third scenario is the same method as the net cost method but with a 5-year delay in concession fee payments. Table 1 shows the constitution of the upper and lower separation method.

Figure 1 is the flow of the net cost method. The net cost method is mainly used in the Bangkok Blue Line. In the Blue Line, MRTA (state enterprise) is in charge of infrastructure construction and BEM (semi-state enterprise) is in charge of train operation. BEM pays a concession fee to MRTA by way of getting a fare revenue under the contraction with MRTA. MRTA's main source of income is the huge subsidy from the government and concession fee from BEM. BEM owns all ridership risk in compensation for getting all revenue and there is almost no risk at MRTA.

Figure 2 is the flow of the gross cost method. The gross cost method is mainly used for the Bangkok Purple Line. In the Purple Line, MRTA (state enterprise) is in charge of infrastructure construction and maintenance and BEM (semi-state enterprise) is in charge of train operation. Operation and maintenance are outsourced to BEM under a contract with MRTA. MRTA receives all fare revenue of Purple Line and pays a fixed amount of concession fees to BEM, regardless of the amount of fare revenue. Risk is shared between the MRTA and

BEM.

Table 1 Constitution of Scenario

	Net cost	Gross cost
Construction	State enterprise	State enterprise
Operation	Semi-state enterprise	Semi-state enterprise
Revenue	Semi-state enterprise	State enterprise
Concession Payment	Semi-state enterprise	State enterprise
Risk	Semi-state enterprise	State enterprise

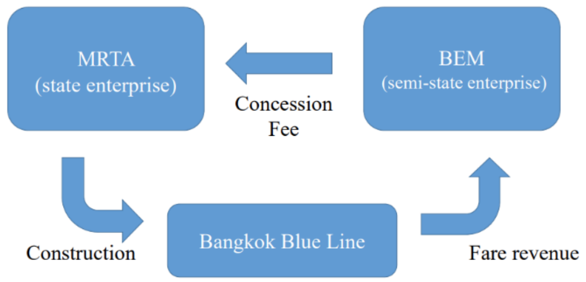

Fig. 1 Flow of net cost method

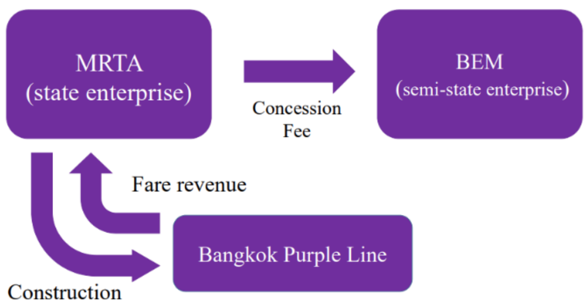

Fig. 2 Flow of gross cost method

3.3 Flow of the Model

The flow of the simulation model is shown in Figure 3. Fare revenue is calculated from the number of ridership and fares. The ratio of fare revenue to other revenues is 9 to 1. Adding these two sources of income, the total revenue is estimated. In terms of expenses, there are labour costs (number of employees multiplied by salaries), power costs, maintenance costs, and operations costs. To sum up the revenue and expenses, EBITA (Earnings before Interest, Taxes, and Amortization) is calculated. EBITA is used to analyze single-year balances. After subtracting taxes, principal and interest on long-term loans from EBITA, the financial surplus and deficit are calculated. Basically, it is desirable to be in the black, but at the beginning of a business, it is often in the red. Therefore, the shortfall of the funding is covered by short-term loans. Depreciation cost mainly considers the purchase of rolling stock. The model assumes a useful life of 5 years. A long-term loan considers construction costs. The repayment year of the Bank loan is 40 years, and the Repayment year of the ODA loan is 25 years.

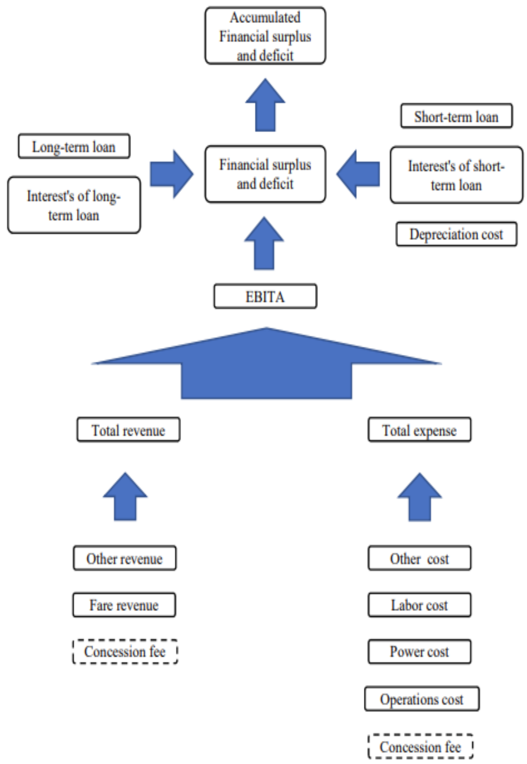

Fig. 3 Flow of the model

3.4 Values used in the Model

Table 2 shows the values used in the model. Table 3 shows the concession fee values for the net cost method and the gross cost method. Concession fee are based on Bangkok Blue line and Purple line. In the net cost method, it is consisted at fixed payment and revenue-linked payment within fare and other revenues, setting to increase as time passes since opening. Concession fee at gross cost is a certain amount and deformed according to operating lengths at Purple line.

By inputting these values into the models, break-even points, the year of turning into black at multiple years can be calculated. The values used in the models were calculated based on the annual reports of BEM and MRTA, JICA reports, and other sources. The exchange rate was 3 Yen/Baht. The fare elasticity for Bangkok was assumed to be -0.57.

Table 2 the values used in the model

Item	
Operating kilometer (km)	21.2
Ridership (trips)	54.75 million
The growth rate of ridership (%)	1
Average fare per trip (Baht)	24
The growth rate of fare (Baht/3years)	1
The Rate of Other Income (%)	10
The number of employees (persons)	500
The average wage (Baht)	469245
Operation cost (Baht)	32 million
Power cost (Baht)	20 million
Other costs (Baht)	204 million
Depreciation method	Straight-line method
Repayment method	Equal principal repayment
Useful life (year)	30
Depreciation rate (%)	20
The interest of short-term loan (%)	5
The interest of ODA loan (%)	0.075
The interest of Bank loan (%)	2.5
ODA loan (Baht)	64.2 billion
Bank loan (Baht)	55.4 billion
ODA loan plan (year)	25
Bank loan plan (year)	40

Table 3 Concession fee of the net cost method

	Net cost method		Gross cost method
	Fare revenue	Other revenue	
Fixed payment	Total: 43.5 billion Baht Payment from the 11th year to the 25th year	Total: 0.9 billion Baht	3.2 billion Baht/year
Revenue linked	1% from 1st to 14th years 2% from 1st to 14th years 5% from 1st to 14th years 15% from 1st to 14th years	7% from 1st to 25th years	

4. Results

4.1 Results of Break-even Point and the Years of Turning into the Black at the Multiple Years

Figure 4 and Figure 5 are the break-even point in the semi-state enterprise and state enterprise. In the net cost method, it took 28 years to achieve profitability in the semi-state enterprise. The state enterprise is black from the beginning of its operations. On the other hand, in the gross cost method, both enterprise are succeeded in making a profit but the profit of the state enterprise is very small compared with that of the net cost method and may into deficit if the demands decrease.

Figure 6 and Figure 7 are the years of turning into the black at the multiple years in the semi-state enterprise and state enterprises. In the net cost method, it took 46 years to eliminate accumulated loss in the semi-state enterprise. The state enterprise also took 21 years to eliminate accumulated loss. On the other hand, in the gross cost method, the semi-state enterprise is black from the beginning of its operations but the state enterprise took 40 years to eliminate accumulated loss.

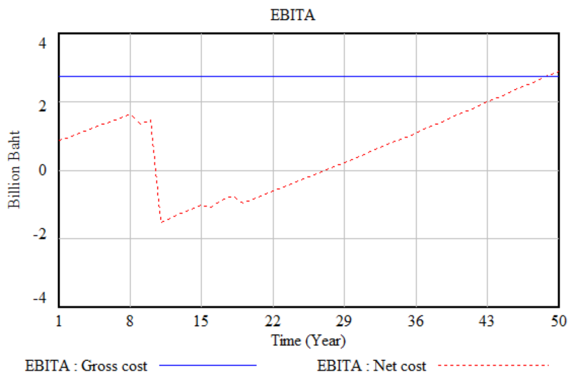

Fig. 4 Break-even point in the semi-state enterprise

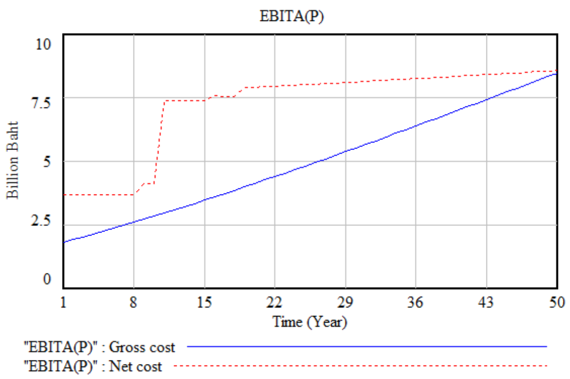

Fig. 5 Break-even point in the state enterprise

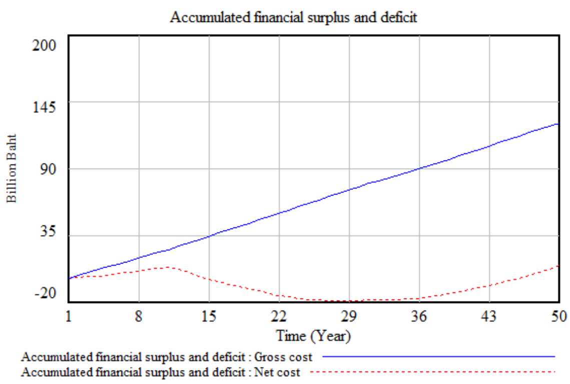

Fig. 6 The years of turning into the black at the multiple years in the semi-state enterprise

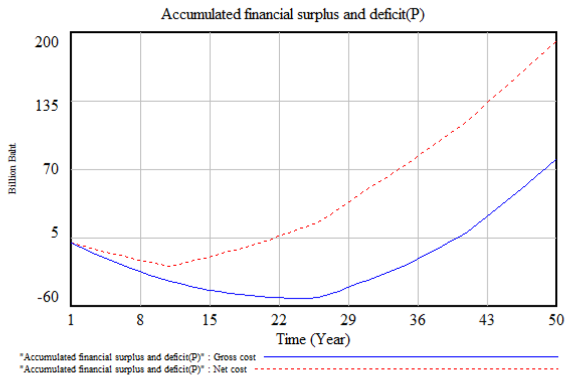

Fig. 7 The years of turning into the black at the multiple years in the state enterprise

4.2 Results of Break-even Point and the Years of Turning into the Black at the Multiple Years after Delaying Concession Payment

Figure 8 and Figure 9 are the break-even point in the semi-state enterprise and state enterprise after delaying concession payment. In the case of delaying concession payment, both of semi-state enterprise and state enterprise are in the black from the first year of opening.

Figure 10 and Figure 11 are the years of turning into the black at the multiple years in the semi-state enterprise and state enterprises after delaying concession payment. In the semi-state enterprise, it is in the black from the first year. On the other hand, the state enterprise is still in the red from the first year of opening and it takes 10 years more compared to the existing net cost scenario.

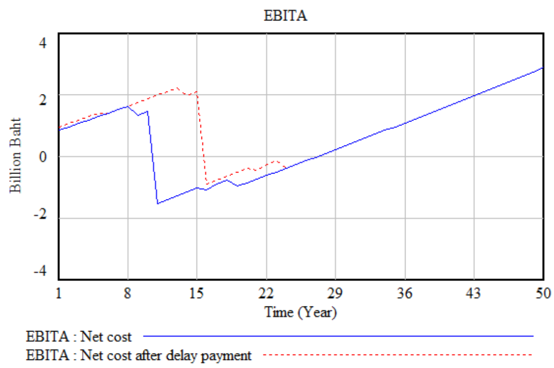

Fig. 8 Break-even point in the semi-state enterprise

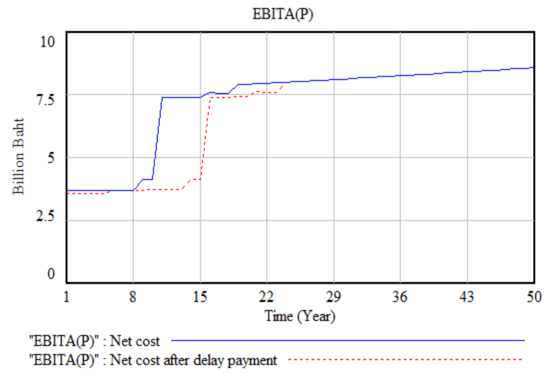

Fig. 9 Break-even point in the state enterprise

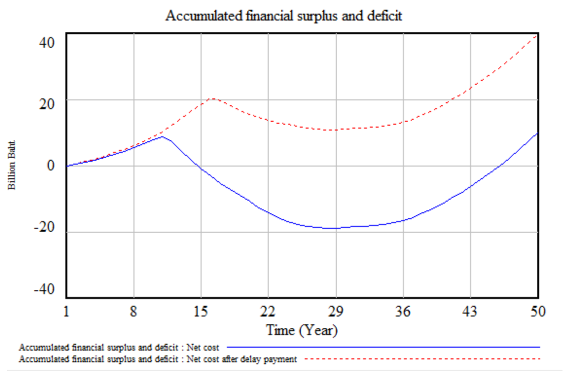

Fig. 10 The years of turning into the black at the multiple years in the semi-state enterprise

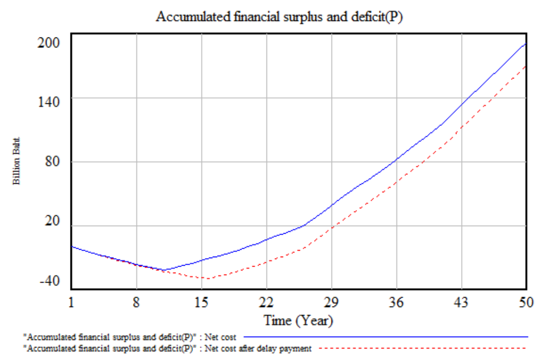

Fig. 11 The years of turning into the black at the multiple years in the state enterprise

5. Conclusion

In this study, the break-even point and the years of turning into the black at the multiple years were estimated in order to clarify the appropriate method for the operation of a railway business compared the net cost method with the gross cost method. The problem with the net cost method is the way of concession fees and its scheme. It was found that since the concession fees are large for revenues unless concession fees are waived for a certain period after the opening, the semi-state enterprise is likely to be in the red. If the payment is, however, waived to assist the private firm, the state enterprise may into deficit. In the gross cost method, the semi-state enterprise gains stable profits but the state enterprise owns demand risk. If demands are small, the state enterprise will be in deficit. As the result, the state enterprise takes a long time to eliminate losses than its net cost method.

From the above, the net cost method and the gross cost method have their own disadvantages. The state enterprise should bear a risk in infrastructure projects because of high publicness, but at present, the net cost method is still being used at another projects. Therefore, appropriate risk-sharing, such as reconsideration of concession fee payments, is necessary to prevent the semi-state enterprise from deficit.

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Research on the Applicability of the Shared Parking Model in the Downtown Area of Hanoi

Topic number: 2 Paper Identification number: AYRF 023-2022

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Abstract

The rapid increase in urbanization and the increasing number of personal vehicles cause a severe shortage of car parks in big cities in Vietnam. The current big cities can not implement the solution to expand the parking area due to the cost of premises, especially in the trading center areas wherein there are many businesses, trading, entertainment, and entertainment activities. This situation leads to the roadbeds and sidewalks encroaching for illegal parking. At the same time, due to the limitations of parking points and limited information provided, the driver has to drive around to find a parking space, hindering other vehicles and wasting time for drivers human. To solve this problem, the city government has been implementing a comprehensive solution on planning, investment in the infrastructure system, institutional solutions, and awareness raising. Information technology is effectively applied in parking management and operation in developed countries and can be an adaptable solution for regions/developing countries. The Shared Parking (SP) model is a technology solution that can link parking points into a network to share and guide the parking location to meet user needs. This paper analyzed the feasibility of the SP model for Hanoi city and showed that this is an effective solution, meeting the needs of solving urban parking problems today.

Keywords: Smart traffic, Parking lot, Shared parking, Hanoi

1. Introduction

Hanoi City is one of the two cities (along with Ho Chi Minh City) with the largest urbanization in Vietnam. According to the General Statistics Office of Vietnam (GSOV), in 2021, Hanoi has 8.4 million people, 5.7 million motorbikes, and more than 730,000 cars. With such a vehicle, if calculating the coefficient of operation is 60% of cars and motorbikes circulating on urban roads with a speed of 20 km/h, the area occupies 1.34 times compared to the capacity of the urban road system. The increasing urban population issue in Hanoi puts great pressure on transportation agencies and the city government. In particular, the lack of parking points and parking lots is a serious problem that has not been overcome. According to Hiep [1], the area for parking is only 0.3% in Hanoi, while the requirement needs to be guaranteed from 3% to 5% of the total urban area. Therefore, the parking infrastructure currently can not meet the parking needs of people inner city. In particular, there is increasing demand for parking lots in the central areas of Hanoi, such as commercial centers, shopping malls, schools, and hospitals.

As of 2021, Hanoi City constructed 57 public parking lots with a total area of 44.37 ha. The city government has arranged 562 parking points under the road, sidewalks, and median strips with a total area of 14.579 ha. However, the city has more than 200,000 individual transportation on average, while the parking area only meets about 8-10% of the demand. Therefore, many vehicles must be parked on the road, sidewalks, children's playgrounds, and the apartment building's yard. This has led to traffic order and safety violations, negatively impacting the urban landscape (Error! Reference source not found.).

In addition, the planning of the network of parking points and parking lots has not been distributed evenly, and the quality of services at the parking lots is still poor, causing difficulties in traffic order, safety, and urban landscape management. Moreover, there is a delay in the implementation of parking projects in the central area, such as Ba Dinh District, Hai Ba Trung District, and Hoan Kiem District. It has also caused many severe problems for the needs of the people.

With the current traffic situation in Hanoi, the rapid increase in transportation with the transport infrastructure has not met the needs of the people, causing a serious loss in terms of economic, social, and environmental aspects. In a developing city like Hanoi, traffic congestion or finding a parking lot will take a lot of time, leading to slow economic promotion. Currently, Hanoi City has been executing policies to solve the above problem, such as expanding roads, limiting the number of personal vehicles entering the city, and building more parking lots. However, the above solutions have not brought about the desired effect, in which the construction of new parking lots today is challenging because the land fund is increasingly limited. Hiep et al. [1] estimated that solutions to smart transport systems are adequate to solve urban traffic problems based on an information technology basis. It is considered sufficient and appropriate and ensures economic benefits, saving time, environmental protection, safety, and comfort for people, in the smart city.

Fig. 1 Status of parking lots on roadways and sidewalks in Hanoi.

Therefore, this study aims to evaluate the applicability of the shared parking (SP) model in the downtown area of Hanoi. This smart technology model helps to share existing parking lots in the city and thus has been applied in many countries worldwide and expressed positive effects. The introduction and application in Hanoi city should carefully study for specific traffic status to be able to apply most effectively.

2. Share Parking Model

2.1 Principle of Operation

Parking solutions can be understood similar how to sharing rooms or shared vehicles. An individual can let strangers come to rent anything they do not use through companies connecting supply and demand with smart application software. The development sharing model is thanks to the ability to effectively take advantage of supply, improve exploitation efficiency and use through the superior application of information technology.

The SP model will help users to avoid taking a lot of time to find a parking lot or find blanks to park the car. Especially in big cities, finding parking lots takes up to 20 minutes a day. The parking sharing model will contribute partially to reducing traffic congestion, improving the quality of life, and increasing people's production time and labor. In big cities, the vacant land is increasingly narrowed by urban construction plans, so the vacant land becomes rare and expensive. The situation in many areas falls into a severe shortage of parking, while the private parking lots of the authorities, private companies, or parking lots in the residents are not in use. According to Broaddus et al. [2], leaving space when not using it will not bring any profits, and thus, it is necessary to use management methods. Transport needs appropriately to adjust the needs of land use. The parking model will help this vacant space maximize the permission by creating a connection between the parking lot and the vehicle user looking for a parking space. The owner of the parking lot will profit from the unused property, and the drivers will save time and effort in finding the parking lot.

According to Error! Reference source not found. and Error! Reference source not found., central areas such as commercial centers, offices, and residential areas have differences in parking needs by the day and time of the week. It can be seen that the commercial centers have high parking demand at 8 am and 8 pm during the day and rise on the weekend. For residential areas, the need for parking is high when people tend to go home to rest in the evening (the demand for parking is gradually increasing from 8 pm). The trend of decline is from 7 am when people go to work. In addition, for the office area, the parking demand here is often focused at 9 am and 4 pm. Thereby, it can be seen that the above areas will have very high parking demand and the time when the parking needs are very low. In order to help drivers identify the available parking locations in the area, the SP model will guide the driver on which spaces are still empty and which areas are overcrowded in the parking lot.

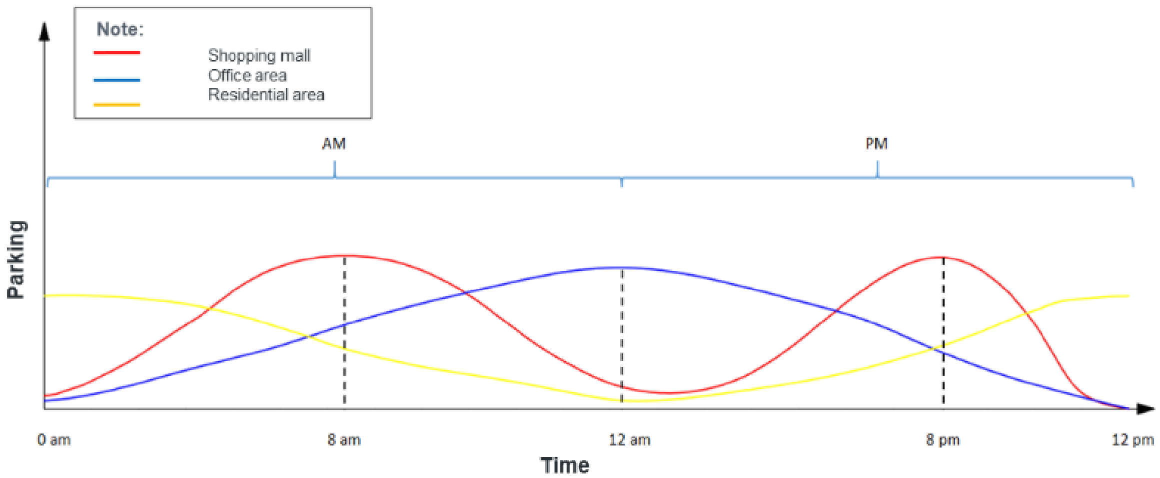

Fig. 2 Parking needs of each region during the day [3]

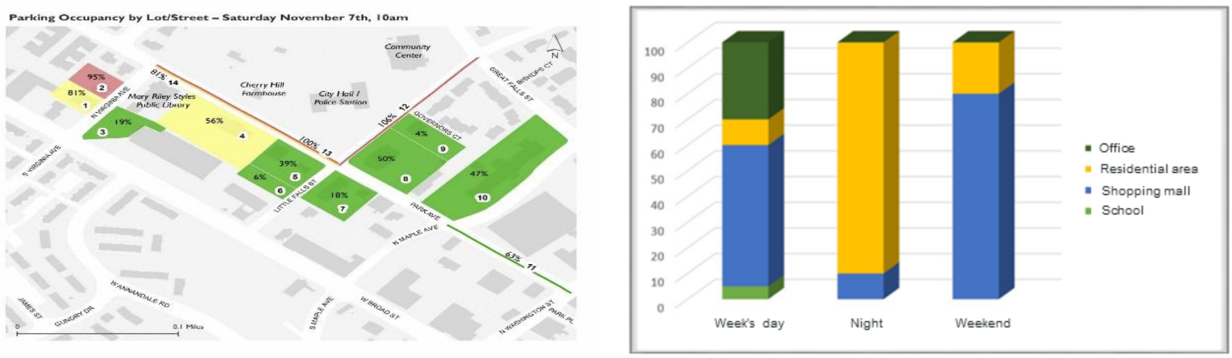

Fig. 2 The degree of shared space of each region [3]

The SP model is based on IoT Information Technology (Internet of Things), connecting the vehicle via IP (Internet Protocol) of the smartphone and sensors. Variable (sensor/detector) is placed at each position within the parking lot. The SP system can link parking lots (public and private parking areas) into a network to help users find, select, and guide the parking spots (Fig. 4). The main characteristics of the SP solution are as follows:

- Provide accurate information about the readiness of the parking position and allow drivers to book and reserve reservations when traveling to the parking spot;
- Make sure the parking space is empty to allow unauthorized parking or early arrivals to take up space;
- Automatically activates when the car has used the parking position to ensure a transparent system. This will prevent vehicles that are parked but not activated in a system like i-Parking;
- Combining the remaining parking spots of agencies, commercial areas, housing areas, and school areas.
- Increase the parking efficiency and enhance the occupancy factor of parking spots through a shared network between parking

spots and provide real-time information to drivers.

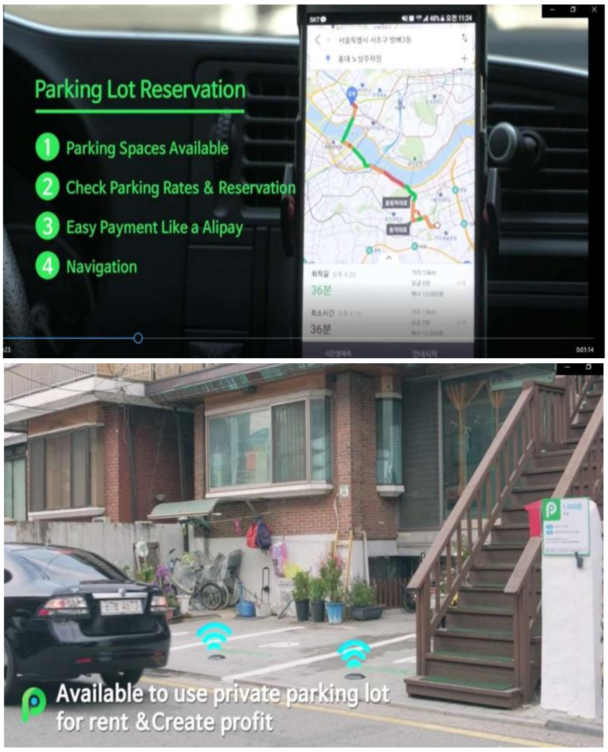

Fig. 3 Illustrate the Shared Parking model

The SP model can help drivers to save time when searching and confirming parking lots, saving fuel, reducing environmental pollution, limiting the driver from going around, and interfering with traffic congestion. Moreover, by applying high technology, the SP model can help drivers look for vacant parking lots and allow owners of parking spaces to update the vacant parking position on the SP system. The SP application needs to be developed on mobile operating systems and tablets or integrated on the car map for convenience for users. Therefore, the SP solution can give drivers convenience, accuracy, and reliability.

2.2 Factors Affecting the Applicability of the SP Model

The SP model is a commercial application for drivers and parking owners. Therefore, many factors affect those who use this model. Here are some main factors analyzed as follows:

a) Demand

With the increasing number of cars in Hanoi, private parking lots are increasingly being built. However, many vehicles still park on the road while the parking lots still have space. That fact requires an application that effectively optimize the need of the car users and the parking lot's owner. Along with that, the city government's policies directly support the user needs of people and car park owners, such as the incentives of encouraging the private organization to build the parking lot.

b) User psychology

The psychological factor of the user affects the successful application of the SP model. The distance from the parking lot to the required location is one of the top concerns of car drivers [2]. Thus, car drivers often park on the sidewalk or the curb to save time and travel distance. In addition, the users always want to park near the workplace safely. In payment, the user wants to be clear about the price.

c) Service

In addition to service criteria such as location, distance, and ticket price, users also have other service requirements in parking lots such as roofs, safety equipment, theft prevention, and fire exploding. This can ensure the driver's property. Furthermore, users want to integrate other services in the parking space, such as bars, car repair, and car wash [7].

3. Research Methods

3.1 General

In order to assess the applicability of the SP model in the center of Hanoi, it is necessary to study the reality of parking needs. According to the operating principle, the SP model operates based on the connection between the parking lot and the user. This connection might help fill the empty parking lots and save time for drivers to find the parking lot. In particular, this connection requires many factors such as parking location and user needs, in addition to technology and infrastructure factors.

The study selects the city center with high traffic volume and high parking demand for the pilot survey and analysis. There will be licensed car parks and parking spaces in the commercial center, office buildings, and houses in this area. Utilizing the empty space in the parking lots to coordinate parking needs will help solve the parking problem here. After that, the study analyzed traffic and parking time data and visited this area. This is an important step to provide an accurate analysis of the actual status and thereby evaluate the feasibility of the SP model.

3.2 Database

Based on a study by the Institute of Transport Planning and Transport Engineering (IPTE) [7], the data selected for analysis include (i) parking time and volume on the sidewalk and roadside and (ii) parking volume at commercial center buildings, office areas, and residential areas. These data were used to assess parking demand in the central area of Hanoi city and thereby evaluate the feasibility of the SP model.

3.3 Review Survey

The survey is an essential part of a better study of the current parking needs in addition to the collected data method. The change in parking demands or parking space is an important factor that this study needs to clarify to guide the development of the SP model. Therefore, the study will survey the street locations where the data has been analyzed.

The research will survey and monitor parking traffic in different areas and streets in Hanoi city at different times during the day and during the week. The selected streets are in the central districts with high parking density and large parking lots, while selected areas own empty parking lots but have not been fully exploited (e.g., parks, apartments, committee offices, office buildings). Accordingly, four-selected streets are Hai Ba Trung, Trang Thi, Nguyen Huu Huan, and Hang Tre in the Hoan Kiem district.

Fig. 5 The situation of parking on the sidewalk and under the road in the area of Hoan Kiem district

4. Surveying the Current Parking Status and the Ability to Apply the Shared Parking

4.1 Research Area

Through the actual survey, the study found that parking on the sidewalk and under the road in the Hoan Kiem district was ubiquitous, including the banned and not banned streets. The district has many commercial centers, office buildings, and apartments. These are places with great demand for parking. However, the self-sufficient parking capacity of these buildings is not enough (only about 50 - 60%, some places are 0%), so the rest is resolved by parking on the sidewalk and under the road (Fig. 5). That has caused a huge burden on traffic, especially peak hours when congestion often occurs.

4.2 The Status of Parking Areas in the Research Area

According to the current survey, the area around Hai Ba Trung, Trang Thi, and Nguyen Huu Huan streets are mainly shops, commercial centers, and office areas (Error! Reference source not found.). Along the streets, there is illegal parking on the road. During rush hour, the number of vehicles parked on this street is huge, causing difficulties for pedestrians. In addition, Hang Tre street is located in the Old Quarter area of Hanoi, wherein the street is very narrow, and the density is high, but mainly trading on the sidewalk. Thus, the number of vehicles in this area here is very large.

Fig. 4 Survey area map

4.3 Analysis of the SP Capability

4.3.1 The Status of Parking on the Sidewalk and under the Road

Hai Ba Trung Street is a long and large street with 17 parking spots (Error! Reference source not found.). The high demand for parking is formed by the system of restaurants, cafes, supermarkets, state agencies, and hospitals surrounding the street. The high parking demand on a working day is around about 8 am and 1 pm (for lunch and other activities) and 5 pm. The parking demand during peak hours is higher than in the evening due to breakfast and coffee activities. The parking demand on Saturday is quite similar to the day of the week because the stores are still open on Saturday. This time frame of the holiday. The drop in demand for parking at 5pm is caused by the habit of returning home for dinner at this time. On Hai Ba Trung Street, the daytime parking volume is usually higher than in the evening because this area occupies many office buildings, so mainly commuters park their cars. Therefore, the SP solution will be applied to fill the parking spaces here in the evening.

For Hang Tre street, the parking demand during the working day is higher than on the weekend (Error! Reference source not found.). The weekend rush hour is later than the working day parking rush because people get up later on the day off. It shows that this street mainly serves food and entertainment activities. During the holiday, around 8 pm, the demand for parking suddenly increased due to coffee and iced tea activities. At Hang Tre Street, the need for parking during the day will be higher than in the evening, and the demand for parking on weekends in the evening will increase dramatically due to the entertainment activities. Thus, the SP solution is applied to solve the excess space in the area in the evening or daytime on weekends.

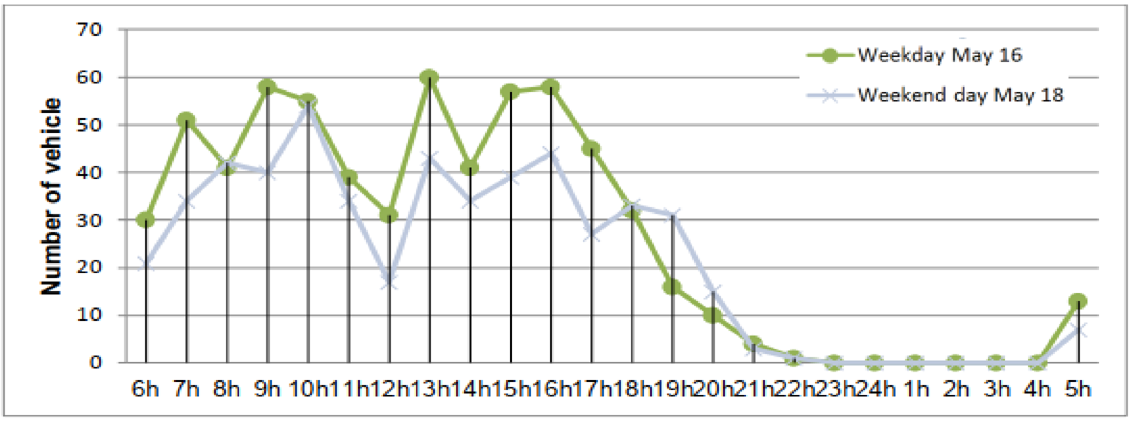

Fig. 5 Parking vehicles flow during the day and over time at Hai Ba Trung Street.

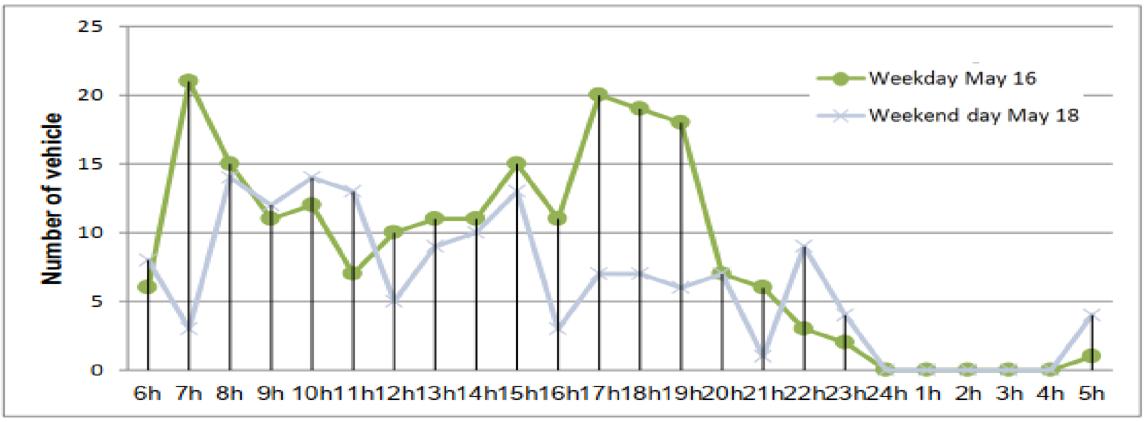

Fig. 6 Parking vehicles flow during the day and over time at Hang Tre Street.

At Trang Thi street (Error! Reference source not found.), the rush hour parking on weekends is later than on working days. Along Trang Thi street, there are no restaurants, so there is no rush to park around 1 pm but switch to around 2 pm to 4 pm due to daily activities. At Trang Thi street, traffic is concentrated in the afternoon. Parking demand often peaks on weekends because it is close to amusement parks and exhibition areas. There are many shopping centers on the street, so applying SP will help fill these empty areas in the mornings.

Nguyen Huu Huan street occupies coffee businesses, restaurants, barbershops, and small groceries (Error! Reference source not found.). During the weekend, the parking demand is higher than at the end of the week. At 8 pm, parking demand spiked due to weekend coffee and iced tea activities. During the weekend, the parking time is longer than the working day. On Nguyen Huu Huan street, the parking demand increases dramatically on weekends. Traffics on weekdays is also there but not much because there are many cafes and restaurants along this street. The applied SP solution solves the problem of excess parking during the daytime.

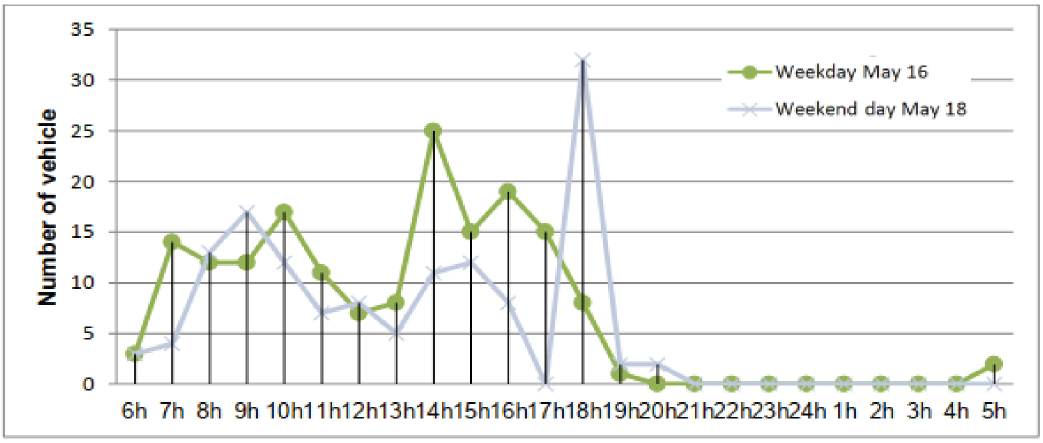

Fig. 7 Parking vehicles flow during the day and over time at Trang Thi street.

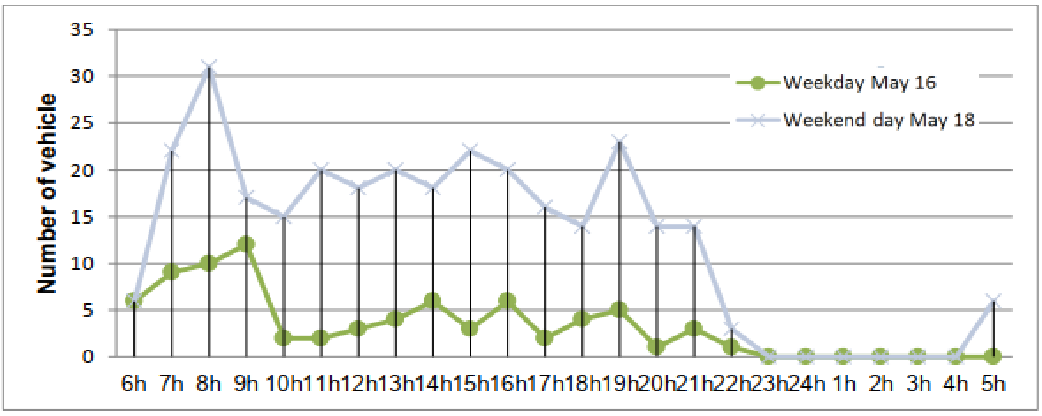

Fig. 8 Parking vehicles flow during the day and over time at Nguyen Huu Huan street.

4.3.2 Analysis of Parking Status of Commercial Centers, Office Areas, and Residential Areas

The study has conducted surveys of the parking demand for commercial centers, office areas, and residential areas within the scope of the survey. In the commercial center, the most concentrated vehicle is from 9:00 to 12 o'clock and from 13:00 to 19:00. During the above period, the flow of weekdays will usually be greater than the flow of weekends. However, at the weekend, the traffic volume is higher from 13:00 to 19:00. Regarding the parking time here, the time is widely distributed. On weekdays, most cars park for over 180 minutes and from 60 to 120 minutes. As for weekends, most cars only park for 30 to 60 minutes.

For the office area, the number of vehicles is most concentrated from 7 am to 9 am. During the above period, the traffic on weekdays will usually be larger than on weekends, but in the time frame from 8 am to 1 pm, weekends have a larger volume of traffic. Regarding the parking time here, the time period is widely distributed. Most cars are parked for more than 180 minutes on weekdays and weekends.

For residential areas, the peak traffic period is from 11 am to 6 pm. On weekdays, there is parking traffic from 6 am to 8 pm, but the traffic is not high, in which the time frames from 9 am to 11 am and 1 pm to 2 pm do not record traffic. For weekends, only focus on the time frame from 11 am to 1 pm and 3 pm to 6 pm. The parking time is widely distributed. Most cars are parked for more than 180 minutes, especially on weekends.

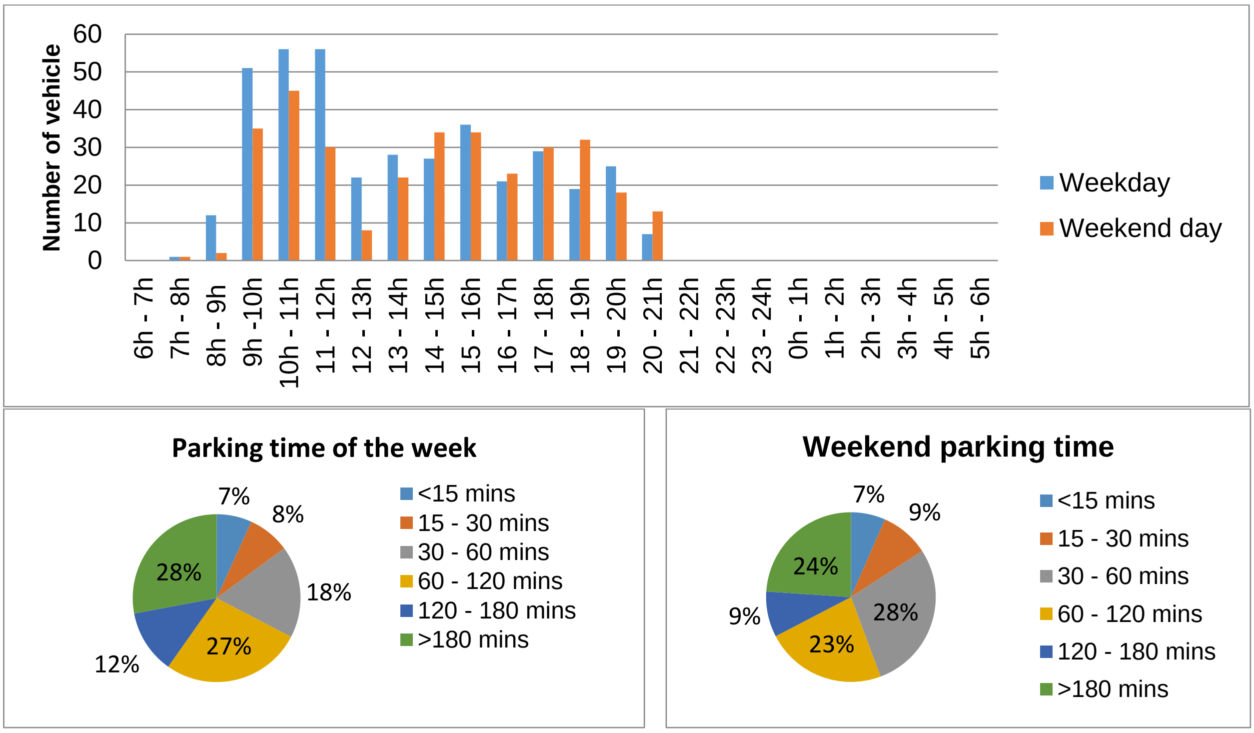

Fig. 9 Traffic flow and parking time in the commercial center

5. Orientation to the SP Model

5.1 Technology Solutions

The SP model is an application based on the smart parking system. The model is developed based on information technology, so the development orientation of technology is critical. The Shared Parking technology system is a multi-dimensional processing system that processes information for the driver and collects data from the parking owners (Error! Reference source not found.).

The system is created to support car drivers to find the nearest and most convenient parking space easily. In the above model, the driver will use the application to search for the nearest vacancy. Then the parking owner will be notified about the user's needs and provide information about the blank. Subsequently, the application will have the task of suggesting the parking lot for the driver. The driver needs to confirm the reservation information. All driver information will then be transferred to the park owner. Some technologies are integrated with the shared parking model as follows:

- The Shared Parking application can be combined with the Google Map map to refer to the driver;
- Payment system integrates many methods such as bank cards and e-wallets;

- Install sensors to monitor the current situation of the number of parking cars and the number of empty plots (Error! Reference source not found.);
- Install cameras at parking locations.

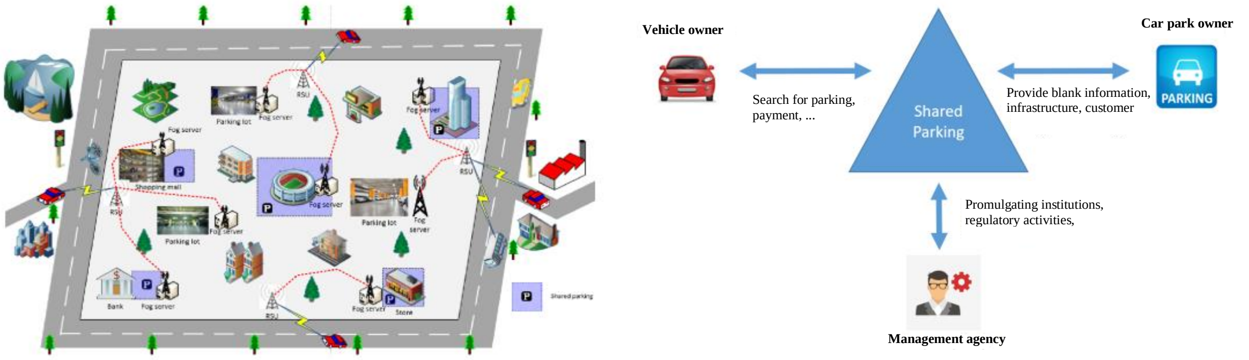

Fig. 10 Application simulation Shared Parking.

Fig. 11 The sensor system is located at the parking location

5.2 Solutions on Infrastructure

The infrastructure system at the current parking lots is still sketchy. Facilities such as roofs, paint lines, and fences are still not much. Fire and explosion prevention equipment and security monitoring equipment have not been upgraded. This status is displayed on the SP system to help drivers to choose a suitable parking lot. By doing this, parking owners need to upgrade their service to attract customers. In particular, for the SP solution, the issues of parking lots and installation of equipment such as sensors, cameras, and paint lines are fundamental in the operation of the model, specifically as follows:

- At the parking lots, parking locations must be painted by the line, meeting the technical standards;
- Installing devices such as sensors, surveillance cameras, and fire prevention equipment;
- Organizing traffic such as lane division and navigational lines at parking lots.

5.3 Management Solution

The SP model combines existing on-street parking lots and parkings in commercial centers, office areas, or at households. In order to apply the SP model, it is necessary to establish a management model to help the SP system operate more effectively. For existing parking lots, the SP model will integrate the owners of parking lots to monitor the operation of cars using this model. When the car drivers use this model to search for parking lots, the SP model system will notify the parking owner. The payment problem will be divided between the parking owners and government agencies.

Moreover, SP service can cooperate with building owners for commercial centers and office areas to receive operation permission. For parking lots in the housing area, the model collaborates with household owners, proposing to build a model in the housing area. The management method in the two above areas is similar to the available parking lots.

In addition, the standard for the SP facilities can be applied to all parking lots, such as sensors, surveillance cameras, and painted lines. Besides, the SP model could support the installation of parking lots without necessary facilities.

5.4 Institutional Solution

For the sake of practical work of the SP model, a mechanism is needed to facilitate the SP application. Thereby, it is necessary to form laws and legal institutions for applying the SP model and for related stakeholders, e.g., drivers and car park owners. Legal institutions help the model operate based on the law, which will help the system handle unnecessary problems between the parties involved in the model. This is also a way to help the system become a healthy competition environment between parking lots. Legal institutions focus on the following issues:

- Regulations on strategies to promote the use of the SP model;
- Specific provisions on facilities for parking lots must meet the minimum standards of vehicle property protection and fire prevention;
- Specify issues related to the ticket price: How to calculate the ticket price, the ticket price will be adjusted differently at different locations;
- Clearly specify the forms of payment when using the SP solution.

6. Conclusion

Hanoi City is facing rapid urbanization and thereby leading to an increase in the vehicle number. This fact results in a serious lack of parking lots. The study aims to evaluate the applicability of information technology to the SP model to improve the parking demand in the central area of Hanoi. The initial results of the study were synthesized as follows:

- The SP solution improves the quality of parking services for users by providing real information about the readiness of the parking position and permission for users to book and reserve reservations when moving to the parking spot;
- The SP model increases the efficiency of parking spaces and the occupancy factor of parking spots through a shared network between parking spots and drivers for selection and easy access;
- Solution "Shared Parking" promotes the public-private partnership (PPP) model through the participation of the private side to exploit the empty parking spots of the commercial area, the residential area, and the school area;
- Through evaluation of practical conditions, the current research proved the ability to apply the SP solution to the central area of Hanoi. The study also clarified the specific characteristics of the Hanoi urban area when using the SP model solution and provided issues to consider when implementing it into practice.

To apply the SP solution effectively in Vietnamese urban areas, it is necessary to have other studies. Mainly, it should focus on institutional policies, operation management, and coordination mechanisms between stakeholders (i.e., state management agencies, private enterprises, and private owners).

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SESSION 2.1: AYRF 2022 RESEARCH PAPER PRESENTATION

From Paper ID: 010-2022, 011-2022, 012-2022, 021-2022,

PAPER ID/ Page No.	Paper entitled	Presented by
010-2022 p.77-83	"Analysis of Impact of Spreading COVID-19 Infections on Usage Behavior of E-Commerce for Food"	**Ms. Rika KAKISHIMA** Nihon University, Japan
011-2022 p.84-90	"Solving static bike rebalancing problem by using Lagrangian Relaxation as stop searching criteria"	**Mr. Theethad Prohmpradith** Chulalongkorn University, Thailand
012-2022 p.91-99	"Analysis of Actual Condition of Walking Environment around Urban Railway Stations in Bangkok"	**Mr. Shogo SAEKI** Nihon University, Japan
021-2022 p.100-109	"An Equitable Transit-Friendly System: A Literature Review"	**Engr. Orlean G. dela Cruz** De La Salle University, Philippines

Analysis of Impact of Spreading COVID-19 Infections on Usage Behavior of E-Commerce for Food

Topic number: 6 Paper Identification number: AYRF 010-2022

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Abstract

According to a market survey on E-commerce by the Ministry of Economy, the e-commerce conversion rate increased by 1.32 percentage points, from 6.76% in 2019 to 8.08% in 2020. The global pandemic of COVID-19 infection particularly influences the rise in 2020. In Japan, issuing a state of emergency, increased store closures with shorter hours, transition to telework and online classes, and increased time to stay at home increased the use of e-commerce significantly. Therefore, this study conducted a questionnaire survey on the actual behavior restriction due to the spread of COVID-19 infection and the use of E-commerce for food which is affected by voluntary restraint from going out. Tabulating the frequency of eating out and purchasing at supermarkets showed that both were affected by refraining from going out due to COVID-19 infection control. By tabulating the frequency of E-commerce for food and the degree of fixation, refraining from going out due to COVID-19 infection control is accelerating the use of food delivery. The results showed that the spread of COVID-19 infection significantly impacted the use of E-commerce for food because "distance from home to the station" was dominant.

Keywords: COVID-19, E-commerce, Food delivery, Teleworking

1. Introduction

The Japanese government issued the first emergency declaration in April 2020 to respond to the spread of COVID-19 infection. In this declaration of emergency, the government recommended behavioral restrictions, including outings reductions and the introduction of telework and online classes to implement them. According to a report by the Ministry of Economy, Trade, and Industry (2021), the issuance of an emergency declaration increases the telework rate and home time, and the usage rate of e-commerce was increased by 1.32%, from 6.76% in 2019 to 8.08% in 2020. According to the Consumer Affairs Agency (2021), e-commerce for food increased significantly by 5.1%. This internet-based food purchase may have become established in civilian life and may continue even after the refraining from going out due to COVID-19 infection control has disappeared. On the other hand, e-commerce for food is increasing delivery services and causing new traffic problems, and it is necessary to consider how to manage them in the future. Therefore, in this study, we conducted a questionnaire survey to analyze the actual situation of e-commerce for food under COVID-19 infection and its impact on future food purchases and analyzed future trends.

2. Literature Review

Much research has analyzed the impact of COVID-19 on e-commerce uses and purchasing behaviors. For example, Kawasaki et al.[1)] conducted a questionnaire survey to understand the psychological intentions and reasons for Japanese consumers' use of e-commerce for food before and after the COVID-19 outbreak. They clarified that the percentage of E-commerce for food usage increased significantly immediately after the COVID-19 epidemic and the possibility of a positive correlation between in-home time and the importance of e-commerce. Yumoto et al.[2)] clarified changes in purchasing behavior before and after the spread of COVID-19 infections by association analysis using purchasing behavior data. They concluded a reduction in the size of purchasing areas, a decrease in the number of monthly purchases, and an increase in the amount of money spent per purchase. Takahashi et al.[3)] quantified changes in shopping behavior and identified shopper characteristics for commercial facilities in the COVID-19 impact by using membership card purchase histories for a shopping center. The results showed that the number of shopped stores and time spent significantly decreased due to COVID-19. Kostas et al.[4)] surveyed to evaluate the importance of online activities before COVID-19 and during the lockdown in Greece. They clarified a significant increase in use related to learning, and the increase in online shopping and online dating was moderate. Hung et al.[5)] investigated how the spread of COVID-19 infection affected online grocery shopping using the largest agricultural e-commerce platform in Taiwan. They clarified that sales increased by 5.7%, and the number of customers increased by 4.9% after the COVID-19 infection spread. Van et al.[6)] conducted a survey to determine how Vietnamese consumers' online shopping intentions changed during the COVID-19 outbreak. The results showed that COVID-19 significantly impacted Vietnamese consumers' online shopping intentions. And COVID-19 is a moderator role in consumers' utility perceptions, leading shoppers to shop online.

The existing studies summarized that after the spread of COVID-19, various types of e-commerce usage were affected. However, no studies have been conducted on using different food products by sale mode. There have been studies comparing the pre-COVID-19 period with the immediate post-COVID-19 period and studies predicting the post-COVID-19 period, but there have been no studies comparing the three-time points of pre-COVID-19, immediate post-COVID-19, and post-COVID-19. Thus, this study aims to clarify the relationship between purchasing behavior at three time points: before the COVID-19 outbreak, immediately after the COVID-19 epidemic, and after the end of the COVID-19 infection.

3. Methodology

3.1 Overview of Methodology

This study organized the contents of the survey, including the target regions and targeted e-commerce sites and, conducted the questionnaire survey online to the people who live in Tokyo Metropolitan area. The relationship between individual attributes and purchasing behavior, and changes in the number of times e-commerce for food uses are tabulated. Finally, the aggregated and analyzed data provide insight into the impact of the COVID-19 outbreak on food e-commerce usage behavior.

3.2 Categorization of E-commerce for Food

Electronic commerce refers to the buying and selling of goods and services over the Internet. In this report, we focus on e-commerce for food and categorize it into three types: "store delivery," "ingredients delivery," and "food delivery".

"Store delivery" means delivery by which restaurants prepare food themselves and deliver it directly to customers.

"Ingredients delivery" refers to a service that delivers ingredients ordered over the Internet to the customer's home or doorstep.

"Food delivery" refers to a delivery method in which a restaurant requests a delivery partner to deliver food and beverages prepared by the restaurant.

3.3 Outline of the Questionnaire Survey

Table 1 shows the outline of this questionnaire survey. The purpose of this questionnaire survey is to analyze whether the use of e-commerce for food caused behavior change in people due to the spread of COVID-19 infection and what factors contributed to the behavior change. The sample was selected by a simple random sampling method using Google form. As a result, 147 samples were collected. This survey was focused on people living in the Tokyo Metropolitan Area (Tokyo, Kanagawa, Chiba, and Saitama prefectures), which are strongly affected by COVID-19 such as state of emergency and restaurant closures. And it was forcused on people who have used one of the three types of services since before COVID-19. Excluding samples of these conditions, the available sample was 84. the analysis will be conducted from 84 samples.

This study conducted a questionnaire survey targeting E-commerce in three periods (T1: Before COVID-19 infection, T2: Increasing COVID-19 infections, and T3: Decreasing COVID-19 infections).

Table 1 Outline of questionnaire survey

Area	Tokyo Metropolitan area
Survey period	November, 2021
No. of samples	147
Survey method	Google form
Detail of the questionnaire	Personal attributes Frequency to use E-commerce for food Reason to use E-commerce for food Fixation degree E-commerce for food Intention to use E-commerce for food
Target period	T1 : Before COVID-19 T2 : Increasing COVID-19 infections (October 2021) T3 : Decreasing COVID-19 Infections (November 2021)

4. Results

4.1 Consideration of Frequency of Eating out and Purchasing at the Supermarket

The use of eating out varied significantly from period to period. In particular, the number of respondents who did not use the restaurant (0 use) increased by 29 from T1 to T2. On the other hand, it decreased again by 25 people from T2 to T3.

The mode of frequency of purchasing at supermarkets per month was 5-6 times for 26 respondents in T1 and 1-2 times for 27 respondents in T2. The frequency of use of supermarkets has decreased significantly. From the results, it can be inferred that COVID-19 has a significant impact on the frequency of eating out and purchasing at supermarkets.

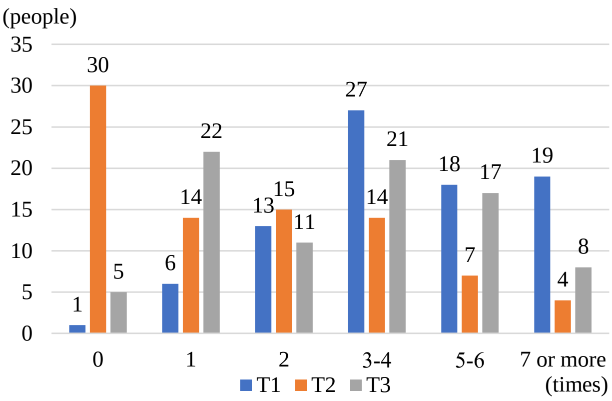

Fig. 1 Number of eating out per month

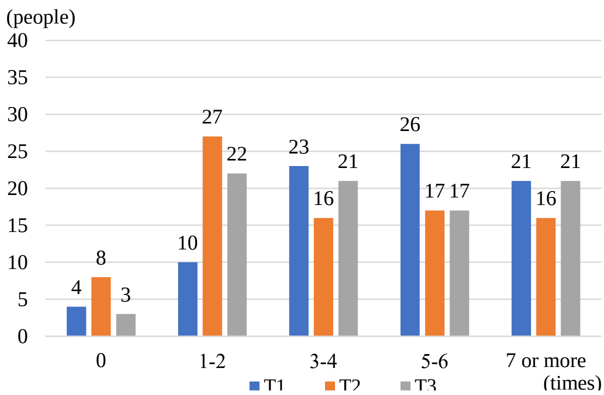

Fig. 2 Number of purchasing supermarkets per month

4.2 Results and Consideration of E-commerce for Food

Fig. 3 shows that the number of respondents who never used the store delivery (0 use) decreased by 6 from T1 to T2. And the number of respondents who used the store delivery multiple times increased significantly from 15 to 30. Fig. 4 shows that the number of respondents who never used the delivery of the ingredients (0 use) hardly changed from 63 at T1, 62 at T2, and 63 at T3. Little change by time period for both those who do not use food delivery (0 use) and those who have used food delivery multiple times. Fig. 5 shows that the number of respondents who never used food delivery (0 use) decreased by 2 from T1 to T2. On the other hand, the number of respondents who used food delivery multiple times increased significantly from 8 to 25 between T1 and T2. Fig. 6: The number of respondents who intend to use e-commerce for food in the future is the highest for food delivery (40 respondents).

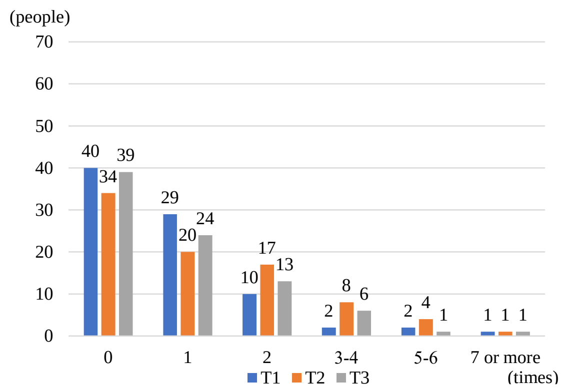

Fig. 3 Number of using store delivery per month

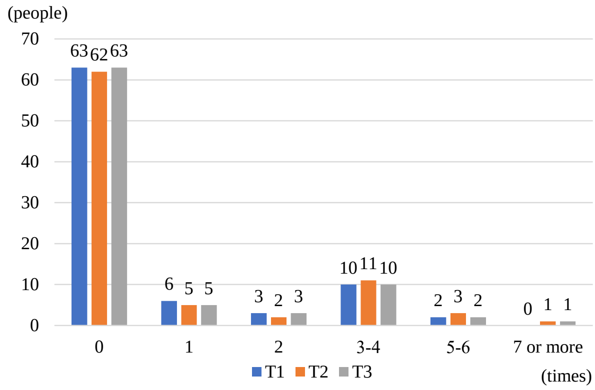

Fig. 4 Number of using ingredients delivery per month

These results indicate that the usage behavior of store delivery and food delivery has changed significantly since the spread of COVID-19 infection.

The intention to use food delivery is particularly high in the future, suggesting that the use of food delivery is firmly established.

4.3 Relationship between the Frequency of Food Delivery Uses and of Teleworking

To clarify whether the spread of COVID-19 infection resulted in food delivery, use cross-tabulation related to the frequency of food delivery uses and teleworking.

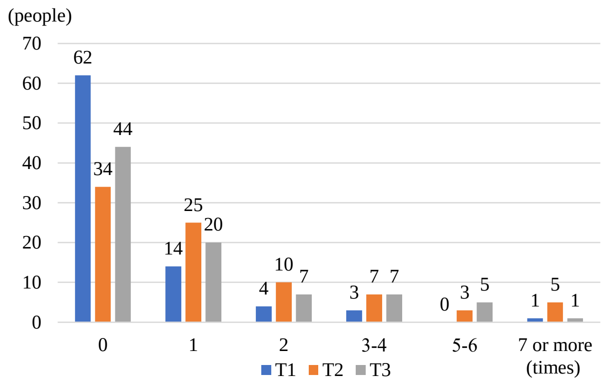

Fig.5 Number of using food delivery per month

Fig. 6 Intention to use E-commerce for food in the future

From T1 to T2, the number of people who had never used food delivery (0 use) decreased significantly from 62 to 34. This is because the use of food delivery was increasing during the period from T1 to T2. The number of people who worked at home once or more and used food delivery once or more was 16 persons in the T1 period, but it increased significantly to 29 persons in the T2 period.

From T2 to T3, the number of people who had never used food delivery (0 use) and the number of people who do not telework (0 times) increased slightly from 11 to 16. However, from T1 to T3 the number of people who teleworked at least once a month and used food delivery at least once a month increased from 16 to 24. This is not significantly different from the increase from 16 to 29 persons in T1 to T2.

Therefore, the frequency of food delivery uses and teleworking is clear that the spread of

COVID-19 infection is affecting food delivery usage. Also, these results suggested that food delivery usage may continue in the future.

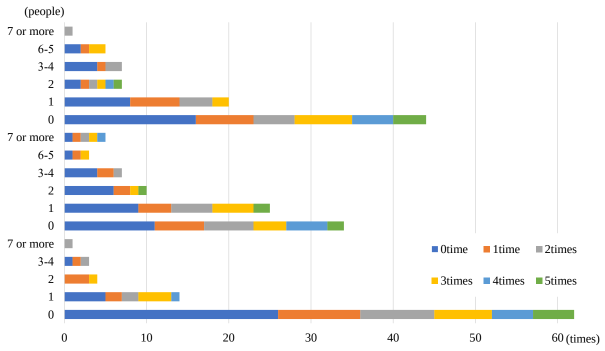

Fig. 7 Relationship between the frequency of food delivery uses and of teleworking

4.4 Analysis Results of Usage Factors of Food Delivery

This analysis was conducted to determine the factors that influenced food delivery usage behavior. The analysis used was a binary logistics regression analysis. Logistic regression analysis is one of the methods of multivariate analysis that explains the objective variable from the explanatory variables using the same technique as regression analysis. Binary logistic regression analysis is used when the objective variable is a binary variable. In this analysis, the method of increasing and decreasing the variables was employed as the method of variable selection. The variable increasing/decreasing method is a method that combines increasing and decreasing methods. It has the characteristic of selecting a small number of explanatory variables that have a strong influence on the objective variable, thereby improving the accuracy of the analysis.

The objective variable was "whether or not food delivery is used," and the explanatory variables analyzed were "age", "occupation", "household income", "distance from home to the station"," car ownership", and "Housing form" and "number of works at home".

The results of the binary logistic regression analysis are shown in Table 3. First, in the explanatory variables, the variable indicating "distance from home to station" remains. The results of the analysis show that the Wald-square indicating the significance of the regression coefficient is high at 2.64. However, the p-value indicating the significance of the model is 0.104, and the null hypothesis cannot be rejected. So, the alternative hypothesis is adopted. Therefore, the association with "distance from home to the station" is not significant.

The COVID-19 factor was cited as the reason why the accuracy of the analysis did not improve this time. Due to the COVID-19, it was not possible to conduct the questionnaire face-to-face. Therefore, the sample was inadequate, and bias may have occurred.

Table 2 Relationship between the frequency of food delivery uses and of teleworking

T1 — Frequency of food delivery (times) × Frequency of teleworking (times)

Frequency of teleworking (times)	0	1	2	3-4	5-6	7 or more
0	26	5		1		
1	10	2	3	1		
2	9	2		1		1
3	7	4	1			
4	5	1				
5 or more	5					
Total	**62**	14	4	3	0	1
						84

T2 — Frequency of food delivery (times) × Frequency of teleworking (times)

Frequency of teleworking (times)	0	1	2	3-4	5-6	7 or more
0	11	9	6	4	1	1
1	6	4	2	2	1	1
2	6	5		1		1
3	4	5	1		1	1
4	5					1
5 or more	2	2	1			
Total	**34**	25	10	7	3	5
						84

T3 — Frequency of food delivery (times) × Frequency of teleworking (times)

Frequency of teleworking (times)	0	1	2	3-4	5-6	7 or more
0	16	8	2	4	2	
1	7	6	1	1	1	
2	5	4	1	2		1
3	7	2	1		2	
4	5		1			
5 or more	4		1			
Total	44	20	7	7	5	1
						84

Table 3 Results using binary logistic regression analysis

Explanatory variable	Distance from home to the station
Partial regression coefficient	0.4187
Standard Error	0.2572
Wald-square	2.6437
P value	0.1040

5. Conclusion

In this study, we conducted a questionnaire survey on the dietary methods before and after restrictions on going out and the e-commerce for food, which were implemented as measures against COVID-19, and aggregated and analyzed the obtained data.

As a result of analyzing the frequency of eating out at supermarkets and purchasing at e-commerce for food, it was found that both were affected by the restrictions on going out due to the declaration of emergency. As a result of tabulating the frequency of e-commerce, it was clarified that the restrictions on going out due to the declaration of an emergency increased the use of e-commerce for food. Furthermore, as a result of cross-tabulation, it was shown that there is a clear relationship between frequency of food delivery and frequency of teleworking, and that the use of food delivery is due to restrictions on going out due to the declaration of an emergency. Finally, we used a binary logistic regression analysis to analyze the factors that affected food delivery by restricting going out due to a declaration of emergency. In terms of explanatory variables, the variable indicating "distance from home to train station" remains. However, the null hypothesis could not be rejected and the significance of "distance from home to train station" could not be shown.

In conclusion, the results indicated that the implementation of restrictions due to the declaration of a state of emergency influences the use of food delivery. However, it was not possible to find any factors influencing the use of food delivery.

6. Future Studies

As a future research issue, it is necessary to clarify the factors tthe factors that influenced food delivery usage behavior., which could not be clarified in this study. For this purpose, it is necessary to certificate explanatory variables other than "distance from home to the station. Further analysis with a larger sample size will help to identify the factors.

In addition, we will collect and analyze data on after-coronas, which is not conducted in this analysis. Future trends in the use of food delivery services can be determined.

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Solving Static Bike Rebalancing Problem by Using Lagrangian Relaxation as Stop Searching Criteria

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Abstract

Bike sharing system is a zero-emission transport mode which is widely adopted at the time since people are aware of climate change. Bike sharing is a bike rental business that allows users to rent and return by themself, and its operations are the crucial feature that affects user experience. There are many bike sharing problems. For example, if bike sharing station is unable to provide docking space for returning bikes or inadequate bikes for renting, the user may feel dissatisfied. Bike rebalancing solution is a transport planning method that aims to find the best path for bike sharing service providers to relocate bikes from the initial to the final number of bikes at each station. The static bike rebalancing problem is usually formulated as mixed integer programming, in which variables solution are binary or integer values. In the case of a large-scale bike-sharing network, the algorithm seems to take a very long time to solve the problem. Solving the rebalancing problem for large-scale bike sharing can consume computational time for bike sharing service providers. This study aims to implement lagrangian relaxation as bound for stop searching. From our experiment, the lagrangian relaxation method can be used as a stop criterion in branch and cut algorithm. In many cases, the solution using lagrangian relaxation as criterion is close to branch and cut solution with much less time in computation.

Keywords: Mixed Integer Programming, Branch and Cut, Static Bike Rebalancing Problem, Lagrangian Relaxation, Bike Sharing Operation.

1. Introduction

Bike sharing is bike renting service that is widely popular in many countries, such as the USA, Republic of China, Singapore, France, Germany, etc. Bike sharing can be categorized in two ways which are docking and docking less bike sharing. Firstly, the docking less bike sharing does not require a specific slot for parking bikes, so users can freely park anywhere in the service area that bike sharing service provider requires. On the other hand, docking bike sharing is the bike sharing operation that provides a specific slot for parking bikes which users are required to park bikes at the station. Therefore, the parking slots of docking bike sharing are a specific number which is helpful for bike management and operation to data collection and data correctness.

For large bike sharing networks, it may occur to bike rebalancing problems, for instance, the absence of bikes or parking slots. Then, bike sharing service providers need a tool for bike sharing management that route the shortest tour to make the number of available docks and available bikes to be appropriated and meet the predicted users' demand. Bike rebalancing solution will become an essential tool for bike sharing service providers to fix such problems, as well as to improve users' experiences and enhance users' satisfaction.

2. Literature Review

2.1 Bike Sharing Decision Support

Bike sharing decision support is broadly interested from many researchers. [1] presented the bike sharing decision support framework for bike sharing equipped with IT-system. This framework utilizes data mining and operation research area. The framework can be classified into strategic planning level and operational planning level. Strategic planning level is a level that demonstrate overview of maintain system such as bike station allocation. Operational planning level is level of demand prediction and routing for bike rebalancing. Data mining for bike sharing system can give complex bike operation such as cluster analysis and time series to predict the user demand. Operation research for bike sharing system is for bike sharing network design and bike fleet management or bike rebalancing solution.

2.2 Bike Rebalancing Problem

Bike rebalancing problem can be classified into static bike rebalancing problem and dynamic bike rebalancing problem. The static bike rebalancing problem (SBRP) was proposed by [2,3,4,5,6,7,8,9]. SBRP regarding the best route finding problem when no user in network, SBRP is normally used for relocating bike in nighttime. The dynamic bike rebalancing problem (DBRP) was proposed by [11,12,13,14] DBRP also regarding the best route finding problem as well as estimating users demand in network. To sum up, the problem mentioned above is to predict incoming users, returning bike or destination of bike along with finding the rebalancing route. Such problem is needed to minimize number of dissatisfaction incident that users will not be able to park or rent bike whenever they want to.

2.3 Static Rebalancing Problem and Mixed Integer Programming

[2,3,5,6,7,8] proposed SBRP which is formulated in a form of mixed integer programming (MIP) or the given solution in a form of both integer or floating number. Branch and bound, Branch and cut is commonly solving MIP Metaheuristics such as Genetic Algorithm, Tabu Search, iterated local search are also proposed by [4,9,10] to obtain the rebalancing route.

The branch and bound is divide and conquer algorithm. Initially, branch and bound relaxed the MIP in a form of linear programming (LP). The solver could solve LP in many different algorithms such as simplex algorithms (standard algorithm), or interior point method. Solution from LP may be not feasible due to variable lacking integer property. The constraints are continuously added to LP to improve solution from non-integer solution to be integer solution. Branch and bound also prevents spend time to solve the future node that can't give better solution. The Branch and bound is continuously solve linear relaxed problem as mentioned until ensure that the optimal is obtained. For more detail of Branch and bound, you can refer to [17].

The SBRP is usually formulated in form of MIP. The algorithm is often branch and cut algorithm such as in [2,3,7,8]. The branch and cut algorithm is a method of branch and bound with including the cutting plane method. The cutting planes is method that adding constraints to enhance solution to be more satisfied problem statement. The cutting planes usually utilized in the large size problem or the problem formulation that have a large number of constraints such as traveling salesman problem, vehicle routing problem, minimum spanning tree problem, etc. From [2] paper, the separation problem is a problem that find the violated constraint. The only violated constraints will be added to the problem which benefits for solver to consider only violated constraint which are capacity constraint ensuring solution is satisfied the vehicle capacity and connectivity constrain ensuring the solution or path fully connected as a route. From [3] paper, the branch and cut algorithm find separation bender cut problem to improve solution to not violate capacity constraints.

2.4 Lagrangian Relaxation

Lagrangian relaxation is proposed to solve branch and bound in LP and MIP by [15] to obtain the approximate solution. The lagrangian relaxation solution will be approximated from iteration and find the converge value called subgradient optimization. Lagrangian relaxation can briefly be explained that the method starts from transform the LP or MIP to be lagrangian dual problem. Thereafter, the lagrangian dual problem will be solve by LP solver such as simplex algorithm or interior point method and then assign new value to parameters until all parameters converged to one value. Then the approximated solution will be obtained. The benefits from lagrangian relaxation is that the solver will solve lesser number of constraints than LP and faster provide an approximated bound for the exact solution. The nature of solution for minimization problem from lagrangian relaxation will give approximated solution value with lesser than or nearly to exact algorithm such as branch and cut. For more detail on subgradient optimization, you can refer to [16].

In this paper, our contribution in the paper is to implement use lagrangian relaxation to be used as a stop bound for branch and cut from searching solution to solve SBRP in section 3. Moreover, performance of the algorithm is measured by experiment which comparing between using lagrangian relaxation and do not using lagrangian relaxation with the branch and cut algorithm shown in section 5.

3. Methodology

In this paper, we mainly test on SBRP formulation proposed by [2] as follow

$$Minimize \sum_{(i,j)\in A} c_{(i,j)}\, z_{(i,j)} \quad (1)$$

Subject to.

$$\sum_{j\in V} z_{(i,j)} = \sum_{j\in V} z_{(j,i)}, \qquad \forall i \in V \quad (2)$$

$$\sum_{i\in V\setminus\{0\}} z_{(0,i)} = 1 \quad (3)$$

$$\sum_{(i,j)\in\delta^+(S)} z_{(i,j)} \geq \mu(S), \qquad \forall S \subseteq V\setminus\{0\} \quad (4)$$

$$\sum_{(i,j)\in\delta^+(S)\setminus\delta(0)} z_{(i,j)} \geq \left\lceil \frac{d(S)}{Q} \right\rceil, \qquad \forall S \subseteq V \quad (5)$$

$$z_{(i,j)} \in \mathbb{Z}_+, \qquad \forall (i,j) \in A \quad (6)$$

In formulation, V is a set of vertices in network. $z_{(i,j)}$ is binary variable which assigns arcs *(i,j)* to be traversed in the rebalancing path. $\mu(S)$ are used as LHS to ensure that solution is only one tour. $d(S)$ is imbalance of node in set vertex S. S are the set of vertices specified by separation problem. Q is the vehicle capacity limit.

The problem is proposed to solve by using branch and cut algorithm. The cutting planes are generated by solving separation problem. Constraints (4) and (5) could be generated by solving separation problems. The constraint (4) called connectivity constraint ensure that feasible solution will be one route. The constraint (5) called capacity constraint ensure feasible solution can relocation bike without incident that number of bikes to be carried not over truck or vehicle capacity limit.

3.1 Lagrangian Dual Problem

Our Proposition, we relax Constraints by using Lagrangian Relaxation method then the following formulation is called Lagrangian dual problem, and our formulation will be as follows:

$$Max\ L_{\alpha\geq 0,\beta\geq 0}(\alpha,\beta)\ Min \sum_{(i,j)\in A} c_{(i,j)}\, z_{(i,j)} - \sum_{S\in V\{0\}} \alpha_S \Big(\sum_{(i,j)\in\delta^+(S)} z_{(i,j)} - \mu(S)\Big) - \sum_{S\in V} \beta_S \Big(\sum_{(i,j)\in\delta^+(S)\setminus\delta(0)} z_{(i,j)} - \left\lceil \frac{d(S)}{Q} \right\rceil\Big) \quad (7)$$

Subject to.

$$\sum_{j\in V} z_{(i,j)} = \sum_{j\in V} z_{(j,i)}, \qquad \forall i \in V \quad (8)$$

$$\sum_{i\in V\setminus\{0\}} z_{(0,i)} = 1 \quad (9)$$

We relaxed 2 types of constraints which are inequalities (4) and (5). The formulation above can be solved by subgradient optimization.

3.2 Subgradient Optimization

Subgradient optimization (SO) is a method to heuristically solve a Lagrangian dual problem. It iteratively adjusts the Lagrangian multipliers which is alpha and beta from formulation above. Algorithm can produce the approximated solution.

The following pseudocode refers to method that we utilize Lagrangian relaxation in branch and cut algorithm to stop algorithm from searching and don't waste the computational time. i indicate node number starting from $i = 1$. LP_{node1} indicate the initial linear problem of node 1. $Z_{bestIntSol}$ is the best integer solution. Active list is list of linear programs that haven't solved yet. $CurrLP$ is linear program selected from Active list. Z_{lagr} is solution from solving lagrangian dual problem. $CutPlane1$ and $CutPlane2$ are sets of cutting plane or violated constraints generated from connectivity separation problems and capacity separation problems respectively. $|CutPlane1|$ and $|CutPlane2|$ are numbers of new violated constraints generated from connectivity separation problem and capacity separation problem respectively.

Algorithm 1 Branch and cut with stopping criteria using Lagrangian Relaxation

$i \leftarrow 1$
$LP_{node1} \leftarrow Initial\ LP\ Problem$
Active list = $[LP_{node1}]$
$Feasible\ found \leftarrow False$
$Z_{bestIntSol} \leftarrow \infty$
While $length\ of\ Active\ list \geq 1:$
    $CurrLP = selectNode(Active\ list)$
    If $Feasible\ found$:
        $z_{lagr} \leftarrow LagrRel(CurrentNode)$
        If $0 \leq \frac{Z_{bestIntSol} - Z_{lagr}}{Z_{lagr}} \leq 0.1$:
            End if
        Break While Loop

End if
$foundCuttingPlanes \leftarrow True$
While $foundCuttingPlanes$ is True:
$Z_{LP} \leftarrow LPsolver(CurrLP)$
$CutPlane1 \leftarrow ConnSep(Z_{LP})$
$CutPlane2 \leftarrow CapacitySep(Z_{LP})$
If ***no*** $CutPlane1$ and $CutPlane2$:
Break While Loop
End if
Else if $|CutPlane1| + |CutPlane2| \neq 0$:
$CurrLP \leftarrow AddingCut(CurrLP)$
End else if
Else If $Solution\ is\ fractional$:
If $Z_{LP} < Z_{bestIntSol}$:
$AddNodes(Active\ list)$
End if
End Else if
Else if $Solution\ is\ Feasible$:
$FeasibleSolFound \leftarrow True$
$foundCuttingPlanes \leftarrow False$
If $Z_{LP} < Z_{bestIntSol}$:
$Z_{bestIntSol} \leftarrow Z_{LP}$
End if
End Else if
End While Loop
End While Loop

4. Testing Methodology

We are implementing all algorithms in Python 3.9. The LP Solver is Gurobi Optimization. We run all algorithm for solving instances on Google COLAB Pro CPU with Ram 32 GB. Our test instances are from http://comopt.ifi.uni-heidelberg.de/software/TSPLIB95/tsp/ which are ftv33, berlin-52, eil76, KroA100. For 50 stations instance from 2D Euclidean space and initial state and final state refers [3]. The 2D Euclidean space or position of each station will be in x-coordination and y-coordination uniformly distribution random pair or $[-500, 500] \times [-500, 500]$ pair. The initial states are set to 10 at every station. The final states are 10+d, d is a uniformly random value between -10 to 10 for station capacity equal to 20 slots. For station capacity with 60 slots, each final states will be equal to 30+3d, d is a uniformly random value between -10 to 10. The number sum of initial state values has to be equal to sum of final state values. Solution from the model will assign operator the best path of rebalancing operation. The number of bikes that assign a vehicle to carried can be solved by max-flow min-cut problem explained in detail in [2]. The number of bikes that operator pickup or delivery at each station can be calculate as well after we know. From Fig 1. The number above arc indicate the number of bikes to be caried between pair of stations.

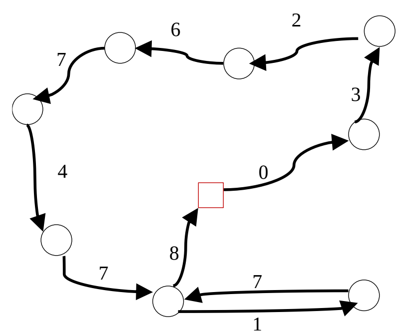

Fig.1 Example of bike rebalancing solution.

5. Computational Results

The results are shown in table 1. For details of each column will be explained below:

Q: vehicle capacity (bike)
C: station capacity (bike)
n: number of service station
L*: Value obtained from solving lagrangian dual problem (from the method using lagrangian relaxation)
Best Integer Solution: Total distance of tour length
Compute Time: Total computational time
No. columns at root node: Number of Variables at initial linear program of the problem
No. rows at root node: Number of Constraints at initial linear program of the problem
Added Cut: Number of constraints generated from separation problem
No. of Node: Number of nodes computed until the searching stop or time out

From our results, two methods are used in the experiment as follow:

1) BC+10%GAP: The branch and cut algorithm stopped when optimality gap lesser than 10% between lower bound and upper bound.
2) BC+10%LGr: The branch and cut algorithm stopped when the best integer solution and bound from lagrangian dual problem different lesser than 10%. (Our proposed method)

The computational time limit is set to 3,600 seconds or 1 hour because this time limit should be expected practical time for solving the problem.

Table 1 The computational results compared between Branch and cut with 10% optimality gap and Branch and Cut with Lagrangian Relaxation and 10% optimality gap

Instance name	Q	C	n	L*	Best Integer Solution (Lower is better)		Compute Time (Sec; lower is better)	
					BC +10%GAP	BC+ 10%LGr	BC +10%GAP	BC+ 10%LGr
ftv33	10	20	33	1838.55	1314.00	1986.00	3,600.02	15.04
ftv33	10	60	33	3752.43	2226.00	4002.00	459.99	15.61
berlin-52	10	20	51	14248.98	**13861.00**	**15050.00**	3,600.20	71.35
berlin-52	10	60	51	20749.70	12082.00	22713.00	3,600.20	89.62
eil76	10	20	75	1130.91	**936.00**	**1174.00**	3,600.19	283.11
eil76	10	60	75	3472.00	2587.00	3633.00	3,601.32	345.98
kroA100	10	20	99	58325.34	**61008.00**	**61008.00**	3,600.00	1,000.99
kroA100	10	60	99	89218.06	**94197.00**	**95634.00**	3,600.00	761.10
50A	10	20	50	11515.18	**12129.17**	**12511.75**	3,600.11	131.91
50B	10	60	50	19571.78	13155.51	21418.65	3,600.29	251.04
50C	10	20	50	10098.16	**10287.09**	**11079.89**	3,600.01	181.41
50D	10	60	50	29381.26	27148.17	30275.12	3,600.33	140.10
50E	10	20	50	11526.75	**12177.25**	**12500.40**	3,600.08	98.68
50F	10	60	50	24605.84	13422.85	27055.45	3,600.50	90.14

6. Discussion and Conclusion

From Table 1, our proposed method can give solutions which close to solution from the original algorithm or branch and cut method with 10% optimality gap stop in many cases such as berlin-52 for 20 station capacity, eil76 for 20 station capacity, KroA100 for both 20 and 60 slots of station capacity and 50A,50B, 50C for 60 slots of station capacity. As a result, all the mentioned cases will have their network size quite large, or more than 50 stations and station capacity is limited to 20 slots. Since lagrangian relaxation in the proposed method is used as a heuristic. The method stops the searching when it founds that a bound from the lagrangian dual problem (L*) of the current node is close to the current best integer solution lesser than 10%. The computational time between the original method and the proposed method is very much different in many cases since the proposed method doesn't consider the global lower bound but considers for a lagrangian dual solution to terminate the searching.

From the table 2., it shows that our proposed method adds much lesser number cutting planes and much lesser number of computed node than original branch and cut method in every cases. This is the cause that why our proposed method uses computational much lesser than the branch and cut with 10 % optimality gap.

As a result, our proposed method may suit a large bike sharing network with a network size between 50 to 100 stations and 20 slots of station capacity, and 10 slots of vehicle capacity. When station capacity and vehicle capacity are low, feasible solution space to the problem may be little. This could make a feasible solution of low capacity on station and vehicle problem is very satisfied as in the table 1. When feasible solution is founded, some of the lagrangian dual problem solution are lesser than and close to the feasible solution. This possibly the real optimality gap is adequately low for stop searching.

In future work, we can research more on a method to improve stopping bound from lagrangian dual to stop more efficiently by terminating searching solution close to or equal to the solution from branch and cut algorithm more frequently. Moreover, the lagrangian relaxation should also be tested with a dynamic bike rebalancing problem to find solution for a more realistic problem. Furthermore, research should provide mathematical proofs in the future on why solutions are close.

Table 2. The computational detail compared between Branch and cut with 10% optimality gap and Branch and Cut with Lagrangian Relaxation and 10% optimality gap

Instance name	Q	C	n	No. columns at root node	No. rows at root node	Added cuts		No. of Nodes	
						BC +10%GAP	BC +10%LGr	BC+10% GAP	BC+10%L Gr
ftv33	10	20	33	1122	35	2788590	7277	23935	53
ftv33	10	60	33	1122	35	501233	8969	3911	39
berlin-52	10	20	51	2652	53	3011984	55968	6920	128
berlin-52	10	60	51	2652	53	2421560	36304	8285	93
eil76	10	20	75	5700	77	1284421	122110	1816	165
eil76	10	60	75	5700	77	1253160	159050	2526	266
kroA100	10	20	99	9900	101	410876	316543	322	320
kroA100	10	60	99	9900	101	421727	206142	259	256
50A	10	20	50	2550	52	3084966	50613	6792	104
50B	10	60	50	2550	52	2361542	30485	10533	80
50C	10	20	50	2550	52	3145224	38840	8055	93
50D	10	60	50	2550	52	2872995	104466	8239	237
50E	10	20	50	2550	52	3013825	73691	5099	124
50F	10	60	50	2550	52	2588948	80303	9474	151

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Analysis of Actual Condition of Walking Environment around Urban Railway Stations in Bangkok

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Abstract

In Bangkok, Thailand, approximately 550 km of railway network and 300 stations will be constructed by 2040. Urban development is expected to be centered on the urban railway network when urban railways are developed. However, since the urban railway has not been developed for a long time, the urban development was not carried out on the premise that the urban railway station could be accessed on foot. Therefore, even if the urban railway is developed in the future based on the transport masterplan, the walking environment around the station is not constructed, and people will not be able to access an urban railway station on foot. Thus, this study evaluates the walking environment around stations by estimating the Walkability value. As a result of estimating the Walkability value, it was found that the Walkability value tends to be lower in suburban stations than in urban stations. It is necessary to improve the walking environment and urban development around urban railway stations.

Keywords: Walkability, Urban Railway Walking Environment, Developing Countries, AHP

1. Introduction

In Bangkok, to cope with the severe traffic congestion, 15 routes are being constructed and planned under the Bangkok Metropolitan Area Urban Railway Master Plan (M-MAP[1)]) formulated in 2010, and 5 new routes are being proposed in M-MAP 2[2)] Blueprint. Now, eight of these lines (BTS Sukhumvit Line and Silom Line, MRT Blue Line and Purple Line, Airport Rail Link, BMA Gold line, and SRT Dark Red Line and Light Red line) are in operation.

However, since the urban railway has not been maintained for a long time, urban development considering the walking environment around the urban railway station has not been fully implemented. Therefore, even if the urban railway is developed, the walking environment around the station is not maintained and insufficiently improved.[3)] Even when urban railway stations are properly developed, these stations remain inaccessible to pedestrians. Thus, a realistic option for accessing urban railway stations from neighboring residential areas is not walking but road traffic, including vehicles. Improving the problems around the urban railway stations in Bangkok will encourage people to shift to urban railways and ultimately reduce severe traffic congestion. In order to achieve this, the local government needs to quantitatively assess the state of the walking environment and improve it before the urban railway opens.

This study focused on understanding the walking environment around the urban railway station in Bangkok based on the developed Walkability index. The walking environment around the urban railway station in Bangkok was evaluated, and based on the results, the issues of the walking environment in future urban railway development were summarized and considered.

This paper consists of five sections. Section 1, the introduction, mentioned the study background and motivation. Section 2 discussed the summary of Walkability indicators and their problems. The methodology in Section 3 explained the evaluation method and validation of the Walkability index. Section 4 described the evaluation results and the application of this method inside Bangkok and suburban station areas. Finally, Section 5 concluded the outcome of this study and recommendations.

2. Literature Review

2.1 Organizing Walkability Concepts and Definitions

Studies on Walkability have been defined from various viewpoints. Commonly, Walkability is defined as an indicator of the urban environment around a city in developed countries. Frank et al.[4] developed a Walkability index consisting of four indicators: road connectivity, housing density, commercial density, and the degree of mixed land use. Similarly, NZ Transport Agency[5], Gebel et al.[6] and Heart Foundation[7] added housing density and buildings used as an indicator of Walkability and evaluated from the viewpoint of urban space.

Additionally, in Japan, Fujimoto et al.[8] defined Walkability as offering a better walking environment and realizing a healthy lifestyle. Specifically, Walkability is evaluated based on five indicators: traffic safety, security, landscape, land use, and infrastructure. Similarly, some developing countries applied to cities. For example, Azmi et al.[9] defined that Walkability is affected by around environment: settlement density, road connectivity, and mixed land use. This study calculates the Walkability score in Putrajaya, Malaysia, and focuses on the environment near the house. In developed cities where pedestrian spaces are planned according to guidelines, it is an important problem to manage cities from the viewpoint of safety and comfort. Walkability in these cities is evaluated from such a perspective. Land use patterns and overall connectivity of walking routes are important indicators for these cities.

Furthermore, many studies evaluated the quality of the environment from the viewpoint of health promotion. For example, the Neighborhood Environment Walkability Survey (NEWS), developed by Saelens et al.[10], has been used in many countries, and other studies for the elderly[11] and youth[12] have simplified versions of NEWS (ANEWS) [13] implemented. In these studies, housing density, mixed land use diversity, mixed land use access, walking/biking infrastructure and safety, aesthetics, traffic safety, and safety from crime were also adopted as indicators.

On the other hand, besides these perspectives, some studies focused on the walking environment. Krambeck et al.[14] defined the Global Walkability Index (GWI) based on factors such as safety and security, convenience, attractiveness, and support policies for the walking environment in urban areas. However, there are many problems with the walking environment in developing countries so that an evaluation framework that explicitly includes the needs for the walking environment. Like this point of view, a physical facility survey was developed for applying the GWI in Ahmedabad, India. It is necessary to evaluate Walkability as walkable from the viewpoint of improving pedestrian space due to pedestrian space do not have adequate in many cities in developing countries. In such cases, the main factors for evaluation are the degree of improvement of the walking environment and the presence or absence of obstacles (Table 1).

Thus, Wibowo et al.[15] revised the evaluation items of the GWI and applied it to Bandung, Indonesia. A similar Walkability audit tool was developed by the Centers for Disease Control and Prevention (CDC), and Smith[16] and Dannenberg et al.[17] included pedestrian facilities, pedestrian conflicts, crosswalks, maintenance, universal design, and landscaping for each road segment in their evaluation of studies. In the Asian region, the Asian Development Bank[18] and Leather et al.[19] conducted a pedestrian survey in 13 Asian cities based on pedestrian and other transportation complications, availability of walking routes and crossings, safety at crossings, driver behavior, equipment, obstructive infrastructure, obstacles, and safety from crime. This evaluation method scores rating factors based on the subjective evaluation of users.

Table 1 Evaluation Items of Walkability Indicators in Existing Studies

Existing studies on walkability	year	Walking infrastructure							Walking Environment								Other Transport					Land-use						Purpose
		Foot pass	Pathway	Condition	Crossing	Obstruction	Universal design	Amenities	Connectivity	Distance	Safety	Security	Crime prevention	Aesthetics	Management	Planning/Design Guidelines	Public Transport	Motorist behaviour	Law/regulation	Bicycle	Conflict	Residential Density	Commercial Density	Land-use mix (Res.)	Land-use mix (Com.)	Public Space	Landscape	
The metro Vancouver Walkability Index	2010								×													×	×	×	×			
Walkable neighborhood	2011	×							×	×	×		×				×					×	×	×	×	×	×	Urban Planning
Neighborhood environment indices	2015								×													×		×	×			
Walkability Audit Tool	2005	×		×	×	×		×						×							×							
NEWS	2003	×	×	×	×				×		×		×	×						×	×	×		×	×			Health promotion
ANEWS	2005	×		×					×		×		×	×							×	×		×	×			
The Global Walking Index	2006			×	×	×	×	×			×	×			×			×	×		×							
GWI in Bandung	2015	×			×	×	×	×			×	×						×			×							Walking Environment
ADB; Walkability and pedestrian facilities	2010		×		×	×	×	×					×					×			×							
Analysis of Walkway Network	2017	×		×		×	×											×			×							

As explained above, Walkability is the broad concept that reflects the local urban environment, including accessibility, attractiveness, and land use in the city in which walking environment was already developed. However, the walking environment in a developing city like around Bangkok's urban railway stations has insufficiently developed. Therefore, it is necessary to show specifically "which sections have problems" and "which sections need improvement." Accordingly, it is required to evaluate Walkability in physical terms as well as to evaluate quantitatively and visualize the condition of components and facilities that affect the walking environment.

2.2 Past Study of Walking Environment in Bangkok

Many existing studies were reviewed and analyzed regarding the walking environment in Bangkok. Chalempong et al.[20] conducted a questionnaire survey to understand whether socioeconomic characteristics (gender, age, occupation, car ownership, income, etc.), station properties (walking facilities, parking facilities, land use in the surrounding area, etc.), and road network properties affect the preference to access to the station on foot and a discrete choice model based on the results are developed about the access/egress mode of urban railway station. The model results indicate that distance to an urban rail station, walking facilities, physical characteristics, land use, road network infrastructure, and connectivity to other modes of transportation are important factors influencing the access mode to the station. The result of model indicates that distance to an urban rail station, walking facilities, physical characteristics, land use, road network, and connectivity to other transportation modes are important factors influencing the choice of access mode to the station.

Furthermore, Pongprasert et al. [21] showed that improvements in the walking environment promote accessing to urban railway stations change in motorcycles to walking. Chalermpong et al.[20] also indicated that there is insufficient separation between pedestrians and vehicles and many obstructions on the sidewalks make walking in central Bangkok difficult. These studies showed that pedestrians in Bangkok do not feel safe or comfortable in the existing walking environment. These studies showed that pedestrians in Bangkok do not feel safe or comfortable in the existing walking environment. The walking environment in Bangkok is likely to have problems in terms of structure, facilities, and surroundings (e.g., obstacles, road conditions, and dangerous areas). However, many studies have focused on identifying the factors that influence walking choices, rather than on evaluating the walking environment itself.

In contrast, Ito et al.[22] focused on the Walkability network, which is one of the components of the station area space, and analyzed the actual situation, evaluation, and formation process of the network for four stations of the Airport Rail Link. Similarly, the authors[3], [23] set Walkability indicators for physical requirements and evaluated the walking environment around urban railway stations in Bangkok.

3. Methodology

As said in section 2, walking environment in Bangkok should be evaluated physically. Therefore, evaluation of walking environments was focused on components of walking space. The authors from this viewpoint gave weights for components of walking space using AHP and proposed the method to evaluate walkability of walking environment. This method was applied in Bangkok and its applicability was confirmed by comparing with subjective judgments by residents of Bangkok. Thus, we applied this approach in this study also.

This section explains a method for calculating Walkability scores around urban railway stations based on the Walkability index developed by Ozawa et al.[24]. And the scoring method of the physical requirements of each road section and the AHP (Analytic Hierarchy Process) used to calculate the weight are represented.

3.1 Overview of Walkability Indicators

This study focused on the walking environment around 500m radius each station which was divided into walkable road sections every 25-30 m, and the physical requirements were scored for each evaluation item using Google Street View. Expressly, the item for evaluation of Walkability was set with three stages (upper, middle, and lower), as shown in Table 2. This walkability index only focuses on the physical requirement for a walking environment, such as separation of vehicle and pedestrian, sidewalk width, and obstacles.

The weights of each item were calculated from the AHP questionnaire results, which were answered only by experts with a certain level of knowledge. In this study, four Thai and three Japanese experts answered the AHP questionnaire. The weight for each item was assigned based on the survey results. The Walkability score for each road segment was calculated as shown in Equation (1). Each road segment was evaluated by multiplying the weights (importance) by the row score of each road section about physical requirements using Google Street View.

$$\gamma_i = a_1 \cdot \beta_1 + a_2 \cdot \beta_2 + \cdots\cdots\cdots\, a_n \cdot \beta_n \qquad (1)$$

γ_i: Walkability score
a_i: Row score
β_i: Weight (importance)
n: Number of evaluated items

The Walkability score for each road segment was calculated as a linear sum of the scoring results for each evaluation item multiplied by the weights. Furthermore, for each station, the calculated Walkability scores were standardized and compared based on Equation (2).

$$\varphi = \frac{\gamma_i - \gamma_{min}}{\gamma_{max} - \gamma_{min}} \qquad (2)$$

φ_i: Standardized Walkability score
γ_i: Walkability score for each interval
γ_{max}: Maximum Walkability score
γ_{min}: Minimum Walkability score

The walkability scores were expressed as standardized values from 0 to 1 and compared to each urban railway station. The walkability score is expressed closer to 0 for a less walkable walking environment and 1 for a more walkable walking environment. The specific calculatethods of the walkability score and weights are shown in section 3-2, and section 3-3 indicate the calculation method of the weights based on the AHP for each evaluation item. Section 3-4 and 3-5 discuss the validity of the proposed walkability index.

Table 2 Evaluation items of Walkability score

Upper	Middle	Lower
Construction	Sidewalk, step, Width, condition	Amount of step, width, and condition
Environment	Obstacle, cleanliness, Risk	Amount of obstacle, manhole, cable
Facility	Light, Signs, street furniture	-

3.2 Scores for Scoring Each Road Segment (Raw Scores)

Each evaluation item was categorized systematically, and each raw score was set for all items could be evaluated on a four-level scale. The items are categorized from level one to four according to their content, with some items having a positive impact and others having a negative impact individually. Also, the distribution of each score was set the continuous and discrete depending on the characteristics of each evaluation item. Table 3 and Figure 1 show the example of a raw score scale and level for separating pedestrians and vehicles.

Table 3 The example of a raw score scale setting

Evaluation Items	Condition level	score -5	-4	-3	-2	-1	0	1	2	3	4	5
Separation of pedestrian and vehicle	Lv.1 No separation Lv.2 Separation with line Lv.3 Separation with fence or curb Lv.4 Sidewalk is prepared				Lv.1		Lv.2		Lv.3		Lv.4	

Evaluation Items	<Condition level> Each evaluation item was classified from Lv.1 to Lv4 by walking environment condition level.	<Score of walking environment> The distribution of each score was set the continuous and discrete depending on the characteristics of each evaluation item

Fig. 1 Examples of each condition level

3.3 Scores for Scoring Each Road Segment

When the Walkability score calculates in each road section, the setting of the scores are a subjective evaluation result defined by the evaluator. Therefore, the weight of each component was calculated from the results of AHP questionnaire and multiplied by the raw score to calculate the Walkability score for each road segment. Thus, using the results of the AHP questionnaire, integrated evaluation can be carried out as objective indices. A pairwise comparison was conducted for each evaluation item, divided into upper, meddle, and lower rankings in the AHP questionnaire. The weights calculated from the questionnaire results are shown in Figure 2.

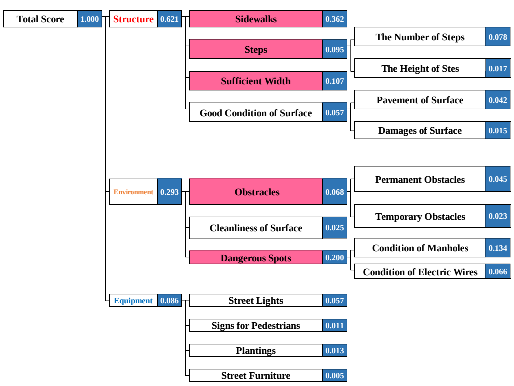

Fig. 2 Results of weight calculations

The results show that road structure (0.621) and sidewalk maintenance (0.362) were given high weights. These results were multiplied by the scoring score for each road item to calculate a walkability score for each road segment.

3.4 Validity of the Evaluation Using the Proposed Method

The validity of the proposed method for evaluating the Walkability score has been verified by conducting a questionnaire survey at residences in the Bangkok metropolitan area in a previous study. In the questionnaire survey, pedestrians were asked to rate the Walkability of each of the eight selected sections on a five-level scale (rating level 1 (very bad) to 5 (very good)) after viewing photographs of the actual walking environment. The questionnaire survey collected 109 samples in the Bangkok metropolitan region. Figure 3 shows the average subjective Walkability ratings of the eight selected sections and Figure 4 shows the results of a comparison of the evaluation values by the proposed method and subjective judgment. Although the subjective evaluation tended to be lower, the Walkability score calculated by the proposed method from the respondents' lowest scores showed a similar trend. The correlation coefficient between the two results is 0.899, suggesting that the proposed method can evaluate the actual walking environment around urban railway stations in Bangkok.

3.5 Validity of Score Calculation Method for Scoring

When the Walkability score is calculated in each road segment, the evaluator subjectively sets a scoring score. Therefore, the score for scoring may be different among evaluators. To verify this point, different evaluators set scores for the BTS Sukhumvit Line Phra Khanong station, calculated Walkability scores, and compared them (Figure 5: Evaluator 1, Figure 6: Evaluator 2). As a result, the Walkability score was higher (0.700 to 1.000) for the main streets for both evaluators. In comparison, Walkability scores for alleys were lower (0.000 to 0.200).

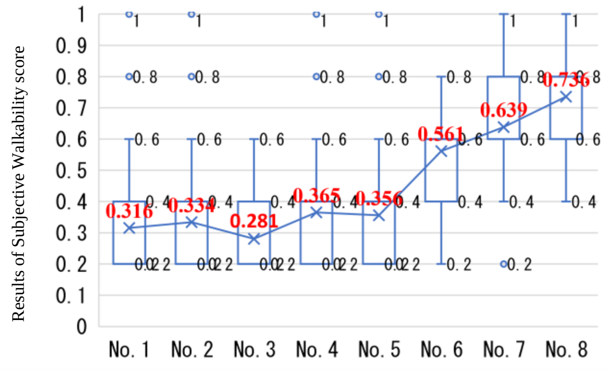

Fig. 3 Evaluation of the subjective walking environment

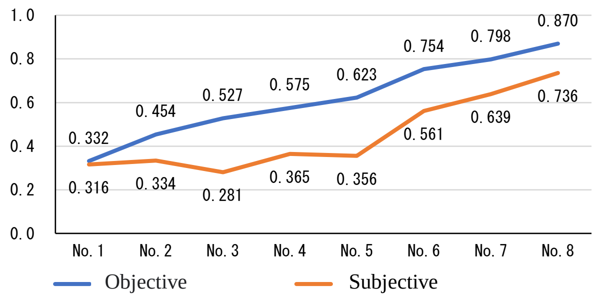

Fig. 4 Comparison of objective and subjective evaluation results

Figure 7 shows the results of comparing the Walkability scores of the same section for Evaluator 1 and Evaluator 2, where a point plotted on a 45-degree line indicates no difference in Walkability scores among the evaluators. The difference in Walkability score among the evaluators may be due to the difference in recognition. However, sidewalks' presence or absence and width are set as evaluation items. However, the number of sections where the difference in Walkability score among the raters was 0.1 or more was minimal, 43 (6.2%) out of the 693 sections set, and most of them were distributed on or around the 45-degree line. This result indicates that differences can be prevented by appropriately directing the judgment method when setting the raw scores based on the subjectivity of the evaluator.

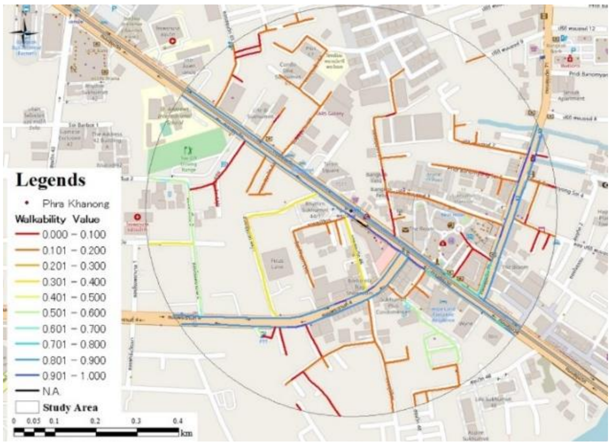

Fig. 5 Walkability score of Phra Khanong station by Evaluator 1

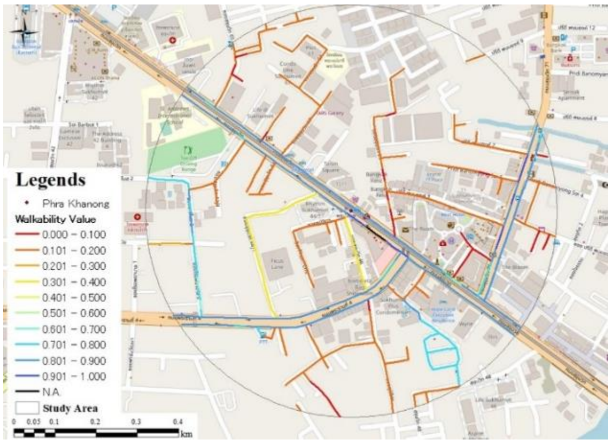

Fig. 6 Walkability score of Phra Khanong station by Evaluator 2

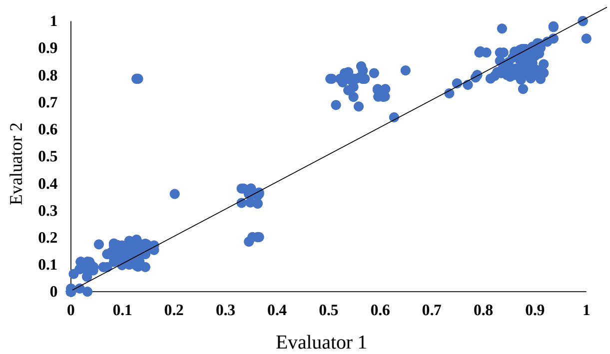

Fig. 7 Comparison of Walkability score by each evaluator

4. Results of Estimating the Walkability

This study focuses on the following lines in the Bangkok metropolitan area: three MRT Blue Line stations and one Purple Line station, ten BTS Sukhumvit Line stations and three BTS Silom Line stations, two Airport Rail Link stations, and one SRT Dark Red Line station. (Figure 8)

Results of estimation of the Walkability around urban and suburban railway stations are shown in Figures 9 and 10. The road sections where urban and suburban railway stations located are high-standard roads with sidewalks of sufficient width and relatively high Walkability scores of 0.700 to 1.000, making them walkable walking spaces for pedestrians. However, the Walkability score was relatively low around urban railway stations, ranging from 0.201 to 0.400, except for some sections. Therefore, it is challenging to access urban railway stations on foot.

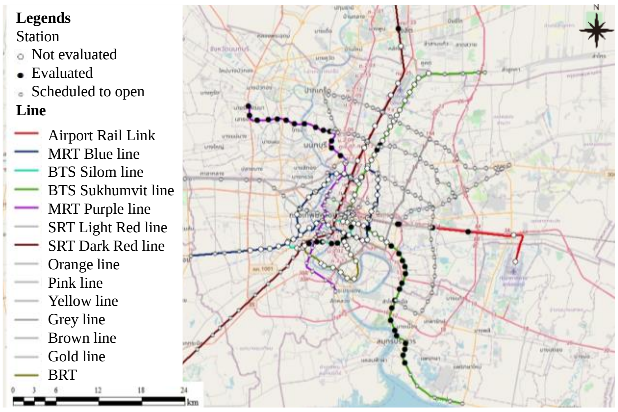

Fig. 8 Urban railway network and stations planned in M-MAP

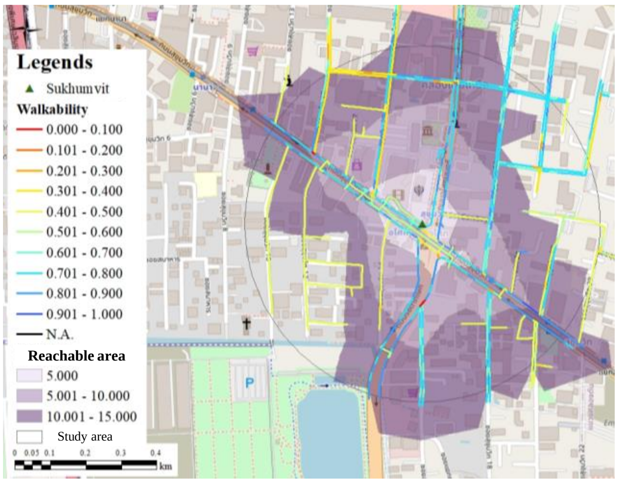

Fig. 9 Walkability score of Sukhumvit station

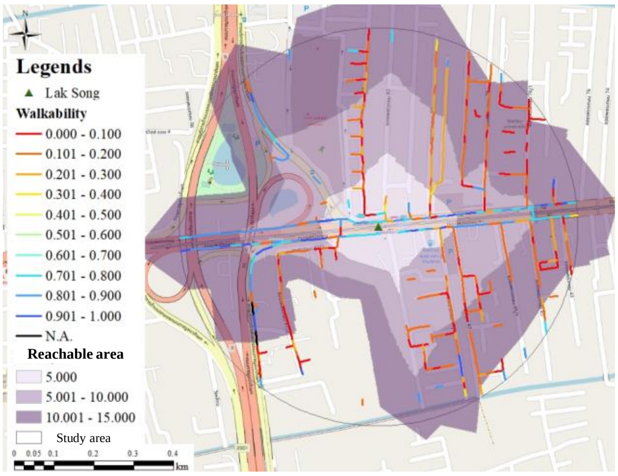

Fig. 10 Walkability score of Lak Song station

5. Discussion

The average Walkability scores for each station were compared. (Figures 11 and 12) The results show that suburban stations tend to have lower Walkability scores than urban stations within a 10 km radius. (Table 4)

This is because, in urban areas within a 10 km radius, sidewalks are being developed simultaneously as commercial and housing development in the surrounding urban railway station. However, there are few maintained sidewalks in suburban stations, except in front of the station; these sidewalks are not developed in an integrated manner. (Figure 13)

There are three significant common issues of the walking environment in which walkability scores are low: 1) construction of sidewalks, 2) Temporary or permanent obstructions, and 3) Safety of electric lines and maintenance holes.

1. Construction of sidewalks: In alleys, separating pedestrians and vehicles is not ensured, and it remains dangerous for pedestrians.
2. Temporary or permanent obstructions: Even if sidewalks are constructed in alleys, obstacles such as stalls and utility poles make it difficult to pass through.
3. Safety of electric lines and maintenance holes: In the center of the urban, Inadequate maintenance of maintenance holes and electric lines makes it dangerous for pedestrians to walk.

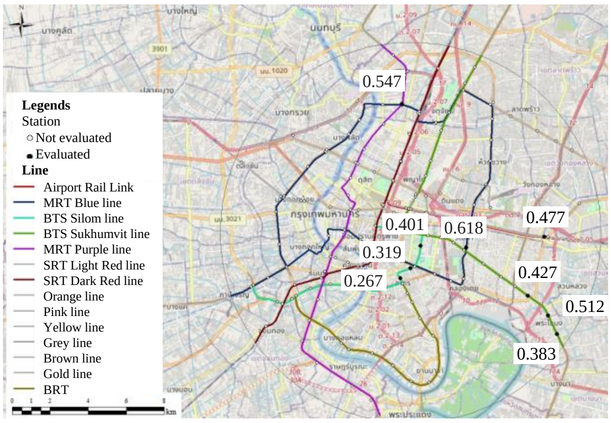

Fig. 11 Average Walkability (urban area)

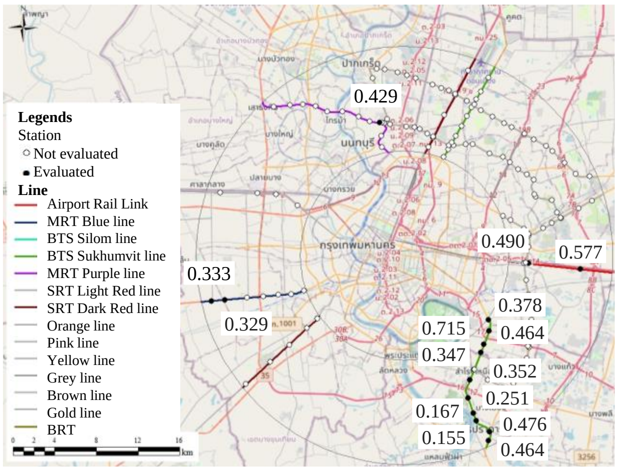

Fig. 12 Average Walkability (suburban area)

Table 4 Comparison of Average Walkability

Area	Line/Station	Walkability Ave.
Urban	BTS Silom line /Krung Thon Buri	0.267
Urban	BTS Silom line/Saphan Taksin	0.319
Urban	BTS Sukhumvit line/Bang Chak	0.383
Urban	BTS Silom line /Surasak	0.401
Urban	BTS Sukhumvit line/Phra Khanong	0.427
Urban	ARL/Ramkhamhaeng	0.477
Urban	BTS Sukhumvit line/On Nut	0.512
Urban	MRT Purple line/Tao Poon	0.547
Urban	MRT Blue line/Sukhumvit	0.618
Suburban	BTS Sukhumvit line/Bang Na	0.167
Suburban	BTS Sukhumvit line/Chang Erawan	0.251
Suburban	MRT Blue line/Lak Song	0.329
Suburban	MRT Blue line/Bang Khae	0.333
Suburban	BTS Sukhumvit line/Pu Chao	0.347
Suburban	BTS Sukhumvit line/samrong	0.352
Suburban	BTS Sukhumvit line/Punnawithi	0.378
Suburban	BTS Sukhumvit line/Phraek Sa	0.464
Suburban	BTS Sukhumvit line/Udom Suk	0.464
Suburban	BTS Sukhumvit line/Srinagarindra	0.476
Suburban	ARL/Hua Mak	0.490
Suburban	BTS Sukhumvit line/Bearing	0.715

Fig. 13 Condition of Sidewalk in Sukhumvit and Lak song St.

6. Conclusion

In this study, to evaluate the walking environment around urban railway stations, the Walkability index, which focuses on the physical requirements of the walking environment, was applied to a 500m radius around several urban railway stations in the Bangkok metropolitan area. Based on the calculated Walkability scores in each road segment, this study summarized the walking environment around the railway stations were summarized for future development. The results showed that the Walkability scores (0.700-1.000) of the road segments, which are located relatively closer to the urban railway station, are higher than those of other road segments, indicating that they are walkable spaces for pedestrians. In addition, the Walkability score (0.201 to 0.400) was relatively high in the area around the station in the city center, even for road segments far from the urban rail station, but it is not easy to access the urban railway station on foot. Comparisons were conducted between the average Walkability values for each station. The results showed that Walkability values tended to be lower at stations located in the suburbs than those in urban areas, indicating the need to improve the walking environment around urban railway stations and urban railway development.

7. Acknowledgement

The Walkability values in this study were estimated by many students and staff at Nihon University and Kasetsart University. The authors thank everyone who has cooperated.

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An Equitable Transit-Friendly System: A Literature Review

Topic number: 2 Paper Identification number: AYRF 021-2022

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Abstract

Transit service in large, car-dependent cities provides inconsistencies in access and mobility benefits. Despite mounting evidence of transportation equity's importance, questions remain about how transportation equity ideas are incorporated into planning processes. Besides, participation in society requires dependable transportation., and mounting data demonstrates the detrimental repercussions of limited access, particularly for low-income communities. Transit policies should prioritize enhancing public transportation and road infrastructure to increase mobility quality and equity. Therefore, this paper compiles the critical findings of scholars and methodically identifies leading research paths and trends for future work. The Latent Dirichlet Allocation (LDA) technique was utilized to extract significant research and summarize an idea for equitable transportation system, which were divided into four topics. From the collection of the past study, noticeable points need to be considered (a) limitation of the data of participants, (b) inappropriate representation of the demographics, including disparity in the gender representation, location, language barrier, and behavior of the participants, (c) time parameters and government influence. Moreover, several kinds of research focus on redefinition the equity concept. In addition, policymakers consider the characteristics of essential mobility and geographical and socio-demographic variation to make inclusive and equitable transportation planning and balance policy outcomes with local demands. This paper recommends the use of driving automation systems as one of the most anticipated developments in terms of transit-friendly system.

Keywords: Equity, Transit-friendly, Transportation facilities, Transportation system, Latent Dirichlet Allocation (LDA)

1. Introduction

Significant attention has been paid to the country's transportation infrastructure challenges throughout the last decade. Urbanization and elderly populations have become significant issues in many global cities. The built environment must be supportive and allow enough access to essential urban and social resources, such as work, education, medical, social welfare, and recreation, for all, including those with disabilities [1].

Several studies assess transportation networks to identify gaps or appropriate changes, focusing on equity principles or disadvantaged people [2]. Evaluation methods include defining transit service levels to assess disadvantaged people's access to public transportation projects [3]. The benefits of a transportation system can perhaps be best understood through the concepts of accessibility and mobility. Accessibility is defined as the number of potential opportunities for interaction [4] and focuses on the importance of reaching desired destinations, such as shopping, school, or work. Mobility, however, captures the ability to move between different places [5]. The capacity of accessibility indicators to provide corrective remedies and influence plan development by revealing which locations or populations are currently under-served is a valuable feature. Such solutions do not always necessitate changes to the transportation system; in some circumstances, accessibility can be improved more effectively by reorganizing the distribution of activities in the area and time [5], [6].

Individuals with enhanced access to transportation report higher quality of life and reduced levels of social isolation, making accessible transportation one of the essential components that foster community inclusion of people with disabilities [1]. Better transportation availability was associated with increased mobility and social participation, and hence a more precise sense of the quality of life [7] It is vital to establish where people travel to and from in a region and their level of access to public transportation to assess if a transit system is equitable and helps socially disadvantaged populations. Actual commuting patterns are less typically studied due to data availability, and few research look at how regions change over time [8].

This article aims to combine current literature and understanding of transit-friendly systems concerning social exclusion and transportation and raise policymakers' awareness of equity issues.

2. Methodology

This section outlines a systematic overview to summarize and use the knowledge to recognize patterns and justify creativity in a new research initiative or gather precious findings that could be used in a sense other than that in which it was created [9]. A systematic search strategy was used to identify relevant literature available on equitable transportation system. A keyword-based source such as Scopus was used to gather studies about interest and provide a comprehensive list of articles concerning all possible sources. Scopus supports Boolean syntax, a search that allows users to combine keywords with operators like AND. NOT and OR to further generate more accurate results. Scopus search was used in this paper because it tracks citation data for more journals and renders its journal impact measure (SNIP and SJR) available to all journals in the database [10]. The terms used as search strings were the following: "transportation equity" OR "transport equity" OR "equitable transport" advised by the Boolean operator. Based on the outcomes, the search was filtered by keyword type by checking transportation infrastructure and transportation system, and the search is refined to include only documents published between 2011 and 2022, allowing us to focus on the most up-to-date research in the field while avoiding any archaic literature.

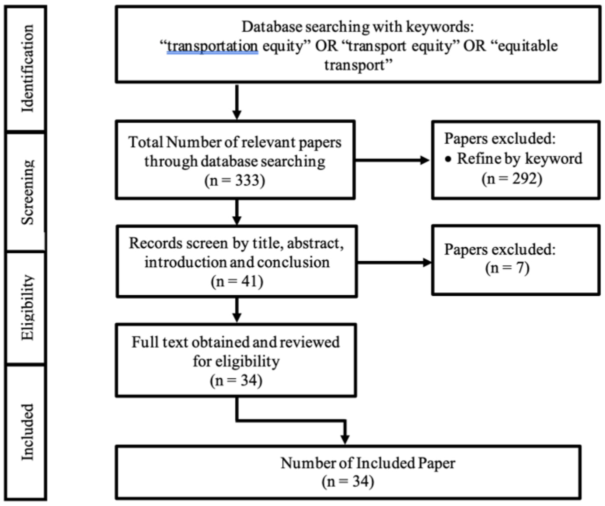

Fig. 1 Topic generated in 34 included articles through MatLab

The application of topic modeling is not new. However, astonishingly few papers use the strategy for categorizing research papers. It is mainly used in the social sciences to identify concepts and subjects within a corpus of materials [11]. Topic modeling has proven to be a practical approach for the exploratory analysis of many papers [12], [13]. Topic modeling is a method that models the search text as a collection of subjects and each subject as a collection of terms. Because the defined word sets represent the underlying themes that can be merged to characterize each text in a corpus, LDA is referred to as a "topic model" [14]. Topic modelling can be used for a variety of purposes, including the discovery of common themes or subjects within a large collection of documents; the creation of new topic modelling techniques; and the evaluation of existing ones. Most publications are driven by the idea that, with the help of topic modelling, it is now possible to conduct an analysis on a sizable body of text that previously would not have been feasible due to the time and effort required. Topic modelling can help you understand some of the main ideas in a text, but it can't tell you everything you need to know about what it means.

The abstracts were preprocessed using MatLab text data analytics and a Latent Dirichlet Allocation algorithm (LDA). There are four topics were obtained in the 34 included papers focus on the primary topics using the LDA as shown in Figure 2:
Topic 1 - mobility, transport, study, public, area
Topic 2 - social, transit, equity, and accessibility
Topic 3 - transportation and system

Topic 4 - neighborhood, high, travel, community, need

Topic 1 primarily focuses on the study of disadvantaged groups' mobility in public transportation. Topic 2 focuses on the social equity and transportation accessibility. Topic 3 focuses on the transportation system and Topic 4 is on creating a transit-friendly system. As shown in Figure 3, the topic mixture, and probabilities of the 34 included articles.

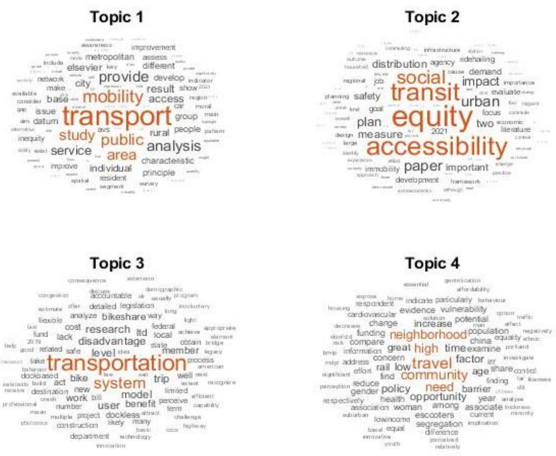

Fig. 2 Topic generated in 34 included articles through MatLab

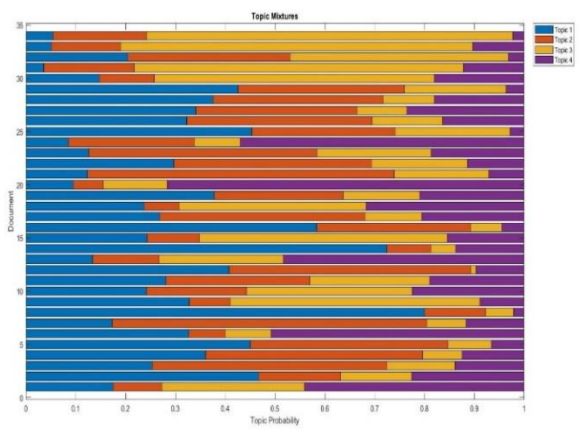

Fig. 3 Topic mixtures' probabilities using LDA in the 34 included articles

3. Discussion

3.1 Exploring Disadvantaged Group's Mobility

Mobility contributes significantly to social inclusion and quality of life [15], [16]. In practice, mobility has various contexts with varying meanings. Mobility is sometimes used interchangeably with travel [17]. Numerous studies have investigated the movement patterns, space-time constraints, and social exclusion of vulnerable demographic groups such as women, the disabled, the elderly, the youth, and the poor [18]–[22]. Mobility concepts comprise five elements: a) Potential travel, b) involvement in the local community, c) travel to achieve access to desired people and places, d) psychological benefits of movement, and e) exercise benefits [17].

Inequality in transportation and mobility is not a new topic in the transportation literature. Wachs and Kumagai, for example, highlighted physical mobility as a fundamental factor in social and economic inequality in the United States as early as 1973 [23].

Elders are more likely to travel locally with fewer excursions than their urban counterparts and rarely travel outside of town [24], [25]. Regarding fiscal resources and physical ability, the aged appear to be more prone to have unfulfilled travel demands due to limited access to services, facilities, and social networks [16], [26]. Measures to improve older people's mobility may let them live independently in their own homes for extended periods, matching their preferences and decreasing the expense of long-term care to society [17].

Knowledge of women's and men's travel behaviors and needs, as well as their determinants, is critical to ensuring people's equality in access to goods and services, and a gender perspective should be included in the analysis of mobility needs in order to avoid the creation of barriers and inequalities for women [27]. Men typically travel for jobs or business, whereas women typically travel for shopping, as companions of other people, especially children traveling to school, and to manage household-related administrative affairs [28], [29].

Among these notions, transportation-related exclusion and transportation poverty are the most commonly recognized [30]–[32]. The former asserts that certain groups cannot engage in the community's economic, political, and social life due to limited access to permanent jobs and social activities [32]. The latter explicitly addresses inaccessibility due to a lack of affordability and the ability to use adequate mobility means [33], [34].

3.2 Social Equity & Transportation Accessibility

"Equity" is typically defined as "fairness in the distribution of advantages and liabilities of transportation systems across people or groups in society" in the transportation context [35]. Many academics (e.g., those from low-income, minority, elderly, or disabled backgrounds) have taken an interest in transportation equity [36], [37]. Considering the equity implications of transportation policies and systems is essential to any transportation project's design. The complete identification of transportation disadvantages and opportunity inaccessibility is fundamental in resolving this social equity issue of inaccessibility [38]. A study discusses how specific values on the distribution of transportation-related benefits can increase or decrease existing social inequality [39]. Thus, equity concerns how social distribution can achieve social equality (Rawls, 1999; Sen, 1979) [40]. Most equity studies on accessibility use gravity-based approaches to accessibility calculation [41], [42] There are four identified critical components in the concept of accessibility [43]: (a) land use, (b) transportation, (c) time, and (d) individual. Considering cognitive component in evaluating transport-related social exclusion [44]. In the literature, various approaches to the definition of equity in transportation. Unless subsidies are defined, horizontal equity requires that resources be distributed evenly to groups (or individuals) [34]. Vertical equity implies that disadvantaged groups (or individuals) must be identified in urban transportation planning to design specific policies in their favor to improve their current conditions [34]. Changes in the accessibility level are triggered by changes in one or more of these components and their interactions [45]. Besides, the equity of accessibility distribution is the most studied topic in transportation equity [46].

Transportation disadvantages and travel time-based opportunity inaccessibility are multifaceted and play critical roles in transportation equity [38]. Various examples of the relationship between accessibility and equity can be found in the international literature, which emphasizes the importance of equity in formulating and evaluating public policies [47]–[50]. Hence, say that shared ways to evaluate policies, like cost-benefit or multi-criteria analysis, do not consider equity effects and risk counting the same benefits twice [49].

3.3 Transportation System

A fundamental principle of transportation systems analysis is that service demand is related to service quality; these service quality features are volume-dependent [51]. Buses, light rail, and subways are all examples of public transportation systems. These systems are open to the public, may charge a fare, and run at predetermined hours. The goal of establishing or expanding public transportation is to enhance access to and use of public transportation while decreasing motor vehicle miles traveled and traffic congestion.

Infrastructure for transportation has a significant impact on both social and economic development. The investment in transportation systems and proposals for additional infrastructure is massive [52]. Rising personal income, the greater availability of automobiles, and substantial public investment in highway systems have all combined to reduce the public demand for public transit [53]. However, uncharged transportation facilities would be insufficient to offset the building costs [52].

Based on a review of Rawls, they argue that it is inequitable for the current transportation system to provide more significant benefits to vehicle-owning individuals who take up a larger share of public space with a more significant environmental impact. Thus lower income, transit captive individuals who take up a smaller share of public space with a lower environmental impact deserve some compensation [54]. Studies that use simple accessibility measures to analyze public transit equity, on the other hand, have frequently relied on very coarse spatial scales and public transit journey times measured at the transportation analysis zone (TAZ) level [55]–[57].

3.4 Creating Transit-Friendly System

Commute time is an essential component of transportation equity [58]. So, reliable transportation is necessary for participation in society, and mounting data demonstrates the adverse effects of inadequate access, particularly for underprivileged groups. In the situations researchers examined, however, there was little evidence that it was a guiding factor in assigning public transit services [59]. Bus transportation and metro rail are the two primary components of public transit. These two major transportation systems are indispensable in enabling public transportation, and both systems are the people's essential part of their travel.

Regarding transportation planning, regional agencies have typically been responsible for analyzing public transit accessibility using four-step or activity-based travel demand models. These models require staff or consultant time to administer and maintain, costly and specialist software, and a considerable amount of time for a single run [41].

Therefore, it is essential to substantially enhance the proportion of public transportation among all types of transport [60].

Individual variables, such as age, wealth, and gender, determine a person's requirements and capacities concerning accessibility to transportation [61]. For instance, although knowledge of women's travel patterns is necessary to ensure equality in transportation, there is still a shortage of awareness of gender-differentiated behavior, and gender problems are rarely included in urban policy [62]. Despite some incremental policy modifications that accommodate transport equity concerns, the norms within which global transportation networks operate are inherently exclusionary [63]. The effects on mobility are unequally distributed at the community level due to the complexity and dynamism of the transportation system [64]. Hence, transportation services that are both appropriate and economical are a necessity for low-income workers [65]. Increasing worries over transportation disadvantage and widening socioeconomic disparities necessitate inventive approaches to enhance equity and improve transportation systems intelligence. Driving automation systems are one of the most anticipated advances in intelligent mobility. Autonomous vehicles (AVs) can potentially improve transportation systems' accessibility, cost, safety, and efficiency, but they also pose concerns, such as increased private car travel [66]. Also, the bulk of e-scooter excursions is utilized for transit, filling a niche in urban mobility. Finding that e-scooters are being used for transportation indicates a need for additional mobility options, especially for individuals without a car [67].

Dockless bike-share systems have the potential to replace traditional dock-based methods, mainly because they provide more flexibility for bike returns. However, many communities limit the number of dockless bikes deployed due to bicycle management concerns [68]. In addition, the growing emphasis on sustainable development has highlighted the significance of accessibility as a significant indicator for evaluating transit investments, urban policy, and urban form. From both the environmental and equity perspectives of sustainability, comparing car vs. public transportation accessibility is of the utmost importance [69]. Furthermore, protecting sites with vital transportation infrastructure, such as bridges, substantially affects the accessibility and mobility of the entire region, and the impacted areas extend beyond the immediate vicinity of the protection [64].

3.5 Challenges in Transportation System

Transportation equity concerns transportation services' effectiveness, cost, and mobility. Transportation equity examines accessibility to transportation for the most significant number of people, which, in conjunction with transportation equity, leads to the pursuit of equality in mobility and accessibility levels across race, class, gender, and disability [53]. Transportation equity is characterized by fair chances for various social groups, particularly disadvantaged groups, in terms of traffic service quality and accessibility [58]. The examination of transportation equity revealed the potential equity challenges that policymakers should consider [64]. From the collection of the past study, noticeable points need to be considered. First is the limitation of the data of participants[68], [70], [71]. Moreover, inappropriate representation of the demographics, including disparity in the gender representation, location, language barrier, and behavior of the participants, can influence the result [38], [59], [62], [67], [72]–[75]. Also, time parameters and government influence can modify the results [61], [69], [76], [77].

Some research achieves interesting results, although it needs enhancement [41], [60], [78]. Also, comparison from one location can determine some implementations of equity [40]. Moreover, several kinds of research focus on redefinition the equity concept [53], [79]. Hence, knowledge of a particular concept, such as Automated Vehicles, is needed to have an accurate result [45], [66]. Furthermore, social effects and urban transportation components can alter the result [64], [80].

4. Conclusion

Concerns about social equity are significant for proponents of public transportation. As a result, social equity must be increasingly considered in transportation planning and policy [2], [81]. Achieving transportation equity is a continuing challenge involving the equitable distribution of the benefits and costs of transportation investments across demographic groups and space. Hence, public transportation is a crucial component of how people get around. At the community level, the effects on mobility are unevenly dispersed due to the complexity and dynamism of the transportation system. The lack of knowledge of gender-differentiated behavior persists, and gender issues are infrequently considered by urban policy.

Besides, for low-income workers, affordable and suitable transportation options are essential.

The focus of transportation policies should be on improving public transportation services and road infrastructure to promote mobility quality and equity. Furthermore, understanding mobility characteristics and geographical and socio-demographic variance are critical for policymakers to make inclusive and equitable transportation planning and balance policy outcomes with local demands. This paper recommends the use of driving automation systems as one of the most anticipated developments in terms of transit-friendly system. Hence, it is vital to investigate how planners undertake social equality studies and develop improvement suggestions knowing that dependable transportation is required if the society is involved.

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SESSION 2.2: AYRF 2022 RESEARCH PAPER PRESENTATION

From Paper ID: 013-2022, 014-2022, 015-2022, 016-2022

PAPER ID/ Page No.	Paper entitled	Presented by
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Effects of Alternative Mobility Modes and Health Awareness on Mode Choice in Vietnamese cities

Topic number: 4 Paper Identification number: AYRF 013-2022

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Abstract

Motorcycles are rapidly changing transportation in Vietnamese cities. Hailed as a convenient, inexpensive solution for "door-to-door" and multi-purpose trips, motorcycles are dominant in all sixty-three provinces/cities of Vietnam and accounted for nearly 80 percent of passenger transportation. The sharp rise in motorcycle ownership and usage has contributed to several unique motorcycle-related transportation challenges in Vietnam, which are different from those in developed countries where car usage is predominant. These challenges include a high frequency of motorcycle-related accidents and fatalities; and increasing motorcycle-related pollution and congestion. To address these challenges, policymakers in Vietnam have introduced policies that promote alternative transportation modes replacing motorcycles. However, relatively little is known about the attractiveness of alternative mobility modes and health awareness in travel mode choice. This study aims to identify the influence of the appeal of alternative transport modes and health awareness on choosing a specific transport mode within a sample population. We surveyed 800 inhabitants in Hanoi, Vietnam, with 37.5% of respondents having ridden motorcycles, 25% ridden buses, and 18.75% split equally between cyclists and private car riders. Not surprisingly, motorcycles are seen as the most convenient way to travel compared to alternative transportation modes. Demographic differences were notable, particularly regarding benefits. Motorcycles were associated with household size and attitude toward transportation mode. However, respondents with good health awareness were significantly more likely than less aware respondents to intend to not use motorcycles. These findings suggest that motorcycles fill an important transportation niche but it may contribute to transportation inequity, and efforts to promote sustainable transportation modes could further provide benefits to the use of buses.

Keywords: Mode choice, Travel behavior model, Household size, Attitude, Health awareness.

1. Introduction

Motorcycles have appeared in the streets of Vietnam since the 1990s and rapidly changed travel in Vietnamese cities. Hailed as a convenient, inexpensive solution for "door-to-door" and other multi-purpose trips, especially for people who have low-to-medium income or live in neighborhoods with inconvenient, insufficient or inefficient public transport system, motorcycles are dominant in all sixty-three provinces/cities of Vietnam and accounted for nearly 80 percent of passenger transportation (Chu et al., 2019).

Despite these advantages, motorcycle use has raised challenges nationwide in many Asian countries, including Vietnam, which are different from those in developed countries where car usage is predominant. These challenges include high frequency of motorcycle-related accidents and fatalities; increasing motorcycle-related pollution and congestion.

Prohibiting or restricting the use of motorcycles can have significant impacts on urban travel mode choices because it forces current motorcyclists to switch to public transport, cars, bikes, or walking. Motorcycles are dominant traffic flow; thus, it is essential to understand the mode choice behaviors of motorcyclists when major Vietnamese cities are increasingly prohibiting the use of motorcycles.

Several researches have studied the relationship between the attitude toward alternative mobility modes and health awareness and the choice behaviors of road users (Beirão and Cabral, 2008; Bothos et al. 2014; Du et al., 2020b; Idei and Kato, 2020; Steg, 2005; Jin et al., 2018; Tajalli and Hajbabaie, 2017; Van et al., 2014). Alternative mobility modes such as public transport and active travel modes are expected to replace motorcycles to fill an important transportation niche. Several benefits of alternative modes such as safety, economy, and no parking, could help to push people out of using automobiles or motorcycles (Beirão and Cabral, 2008). Attitudes are composed of three main components: the symbolic, the instrumental, and the affective (Steg, 2005). One study from Van et al. (2014) revealed that attitude factors were all significant determinants for behavioral intention regarding the commuting mode choice in six Asian countries. Other studies also confirmed that two components of attitude, including symbolic and affective motives, play important roles in explaining the level of car use (Steg, 2005). Meanwhile, there are several applications developed to nudge users taking to account health effects (Bothos et al. 2014). Tajalli and Hajbabaie (2017) found that walking and using the subway are the healthiest modes of commuting. In respect of health-seeking behavior, previous studies have paid particular attention to the elderly's travel mode choice to seek healthcare (Idei and Kato, 2020; Jin et al., 2018; Du et al., 2020b).

Although several research studied influencing factors, little research has gone into in-depth analysis of the appeal of alternative transport modes in aspect of face consciousness. Moreover, the effect of health awareness of road users on their travel mode choice behaviors has not yet explored. Therefore, in this paper, we attempt to identify the influence of attitude toward alternative mobility modes and health awareness, combined with socioeconomic characteristics, trip attributes, vehicle characteristics, subjective norms, and environmental awareness, on mode choice behaviors.

The paper is structured as follows: Section 2 describes the method applied in this study. Section 3 exposes the results. Section 4 contains the conclusions.

2. Methods and Survey

2.1 Methodological Framework

In this study, we develop a multinomial logit (MNL) model to explore the influence of the appeal of alternative transport modes and health awareness, combined with socioeconomic characteristics, trip attributes, vehicle characteristics, subjective norms, attitude, and environmental awareness, on mode choice behaviors. The structure of the model can be performed by following path diagram, as shown in Figure 1.

2.2 Survey

This study is a case study of Hanoi, Vietnam. In the urban area of Hanoi, there is a relative public transport system composed of buses, taxis, one BRT line, and one Metro line. In 2020, motorcycles accounted for 78% of the mode share. Use of public transport, taxi, and driving accounted for 8.7%, 2.9%, and 4.99%, respectively (TDSI, 2020). Therefore, prohibiting motorcycle use would have a significant impact on travel behavior in Hanoi.

A questionnaire survey was conducted from April 1 to 15, 2021. Commuters who travel by motorcycles, bikes, buses, and private cars were the target population. The purpose of the survey was to investigate the benefits and barriers of motorcycles over alternative transport modes as well as the alternative mode choice of motorcyclists in the absence of their motorcycles. Table 1 summarizes the key statistics of respondents.

The questionnaire consists of eight parts: (i) the demographics and socioeconomic characteristics of the respondents: gender, age, occupation, household structure, income, and vehicle ownership; (ii) trip attributes: purpose, distance, and frequency; (iii) vehicle characteristics: travel time, travel cost, fast mobility, safety, reliability, comfort, convenience, and security; (iv) subjective norms were measured by four questions: Question one, "Do your family affect to you about which transport mode should be used?", Question two, "Do your friends/colleagues affect to you about which transport mode should be used?", Question three, "Do propaganda program from your company/school affect to you about which transport mode should be used?", and Question four, "Do media channels affect to you about which transport mode should be used"?; (v) the appeal of alternative transport mode were measured by eight questions: Question one, "Use public transport help you to save money", Question two, "Use public transport help you to not finding the parking", Question three, "Use public transport support you to work onboard", Question four, "Public transport is safer than motorcycle", Question five, "Use other private vehicle is more freedom", Question six, "Use other private vehicle help you to save the time", Question seven, "Use other private vehicle help you to come everywhere", and Question eight, "you keep the routine of using private vehicle"; (vi) environmental awareness were measured by three questions: Question one, "Public transport help to protect the environment", Question two, "Pubic transport help to reduce traffic congestion" Question three, "Public transport help to reduce traffic accidents"; (vii) attitude to the vehicle were measured by three questions: Question one, "Riding expensive private car and motorcycle enhance the business opportunity", Question two, "Riding expensive private car and motorcycle shows success and high social status", Question three, "Riding expensive private car and motorcycle shows a modern lifestyle"; (viii) health concerns were measured by four questions: Question one, "Motorcycle users are more directly affected by adverse weather conditions (e.g., rain, sunshine)", Question two, "Motorcycle users are more directly affected by dust", Question three, "Motorcycle users are more susceptible to be respiratory infections", and Question four, "Motorcycle users have a higher level of injury in a traffic collision".

A total of 800 respondents completed the survey. Table 1 presents a summary of the sample. More than 56% of the respondents were male. The majority of the respondents were young adults, i.e. younger than 40 years old. Over 67% of the respondents were either officers or students. Approximate 61% of the respondents had a university degree or above. More than 60% of the respondents had a monthly income of VND 14 million or below.

Regarding the appeal of alternative transport modes and awareness, about 57% of the respondents rated public transport as having a certain attractiveness, meanwhile 78% of the respondents highly appreciate the allure of private vehicles. More than 63% of the respondents were aware of health and environmental issues to a certain degree. On the other hand, only 25.4% of the respondents had a good attitude to private vehicles.

2.3 Instrument Validation

To confirm the structure of the factors "Environmental awareness", "Attitude", "Health awareness", "The appeal of public transport" and "The appeal of private vehicles", we performed a confirmatory factor analysis (Hair et al., 2006) using IBM SPSS. Table 2 shows the results of the Confirmatory factor analysis. The alpha coefficients for the six representative factors are ranged from 0.711 to 0.928, suggesting that the items measured each factor have relatively high internal consistency (Hair et al., 2006). All items had the factor loadings above 0.5, thus they were kept for further analysis (Bagozzi et al., 1991; Fornell and Larcker, 1981).

2.4 Regression Approach

In this study, we develop multinominal logit (MNL) model to identify the factors and to assess their impacts on motorcycle users' alternative mode choice preferences. The index i represents the individual road user $(i = 1, 2, \ldots, I)$, the index j represents the travel mode choice $(j = 1, 2, \ldots J)$. The utility U_{ij} that individual road user i will choose mode j is as follows:

$$U_{ij} = \beta_i X_{ij} + \varepsilon_{ij} \qquad (1)$$

where X_{ij} is vector of explanatory variables that affect the valuation of individual road user i choosing mode j. β_I is the corresponding vector of the coefficients of X_{ij}. ε_{ij} represents an error term assumed to be independently and identically extreme value Type I distributed. The probability P_{ij} that individual road user i will choose travel mode j is as follows:

$$P_{ij} = \frac{\exp(\beta_i X_{ij})}{\sum_{j=1}^{J} \exp(\beta_i X_{ij})} \qquad (2)$$

The likelihood function $L(\beta_i)$ for the travel mode choice set of road user is as follows:

$$L(\beta_i) = \prod_{i=1}^{I} \prod_{j=1}^{J} (P_{ij}|\beta_i)^{D_{ij}} \qquad (3)$$

where $D_{ij} = 1$ if j is selected, 0 otherwise

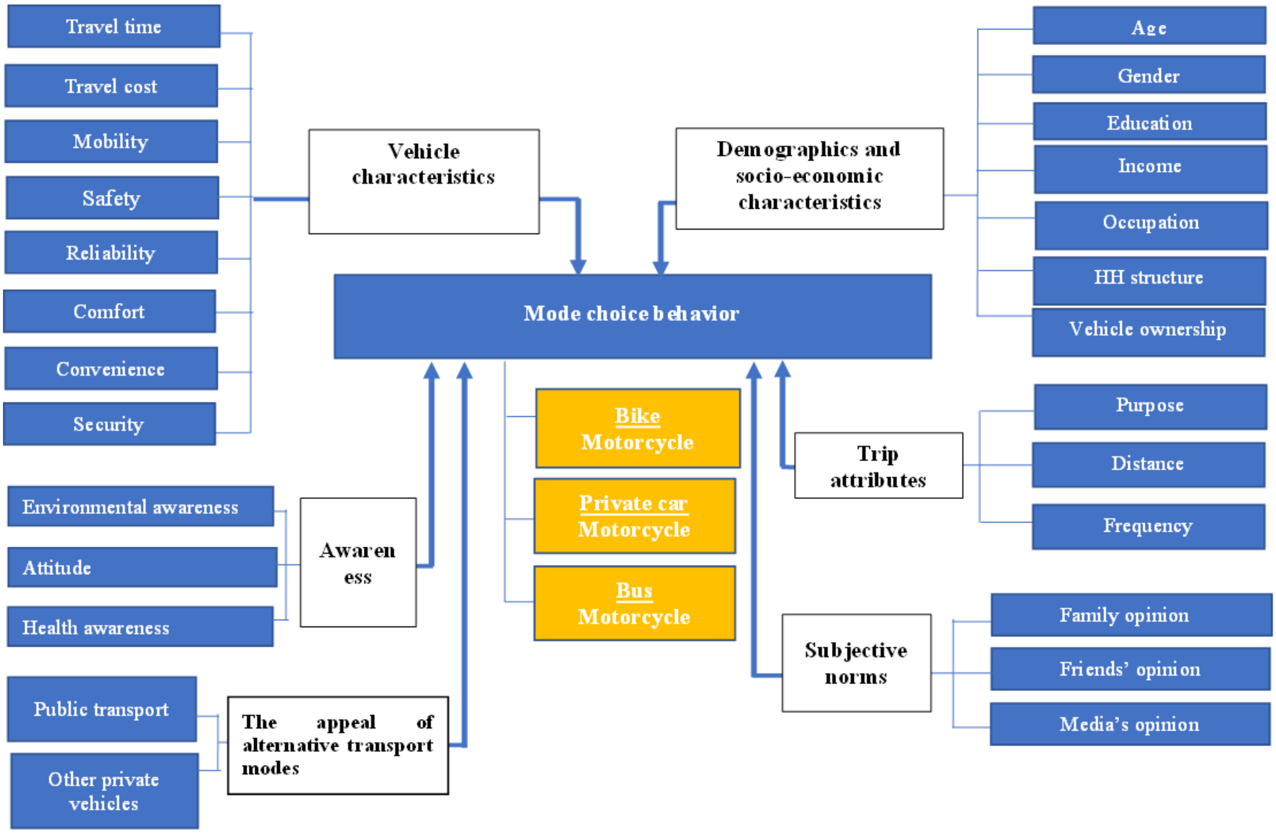

Fig. 1 Path diagram showing the relationship between mode choice and influencing factors

Table 1 Summary statistics of respondents

Variable		Car users	Motorcycle users	Bike users	Bus users	Total
Total number of respondents		150	300	150	200	800
Percent		18.75%	37.50%	18.75%	25.00%	100.00%
Demographics and socio-economic characteristics						
Gender	Male	82.67%	50.00%	48.00%	46.00%	56.67%
	Female	17.33%	50.00%	52.00%	54.00%	43.33%
Age	< 18			6.67%	2.50%	2.29%
	18-25		25.00%	54.00%	58.50%	34.38%
	25-30	6.00%	44.33%	8.67%	25.00%	21.00%
	30-40	45.33%	18.67%	2.67%	5.00%	17.92%
	40-50	28.67%	6.33%	4.00%	4.00%	10.75%
	50-60	18.67%	3.67%	6.67%	2.00%	7.75%
	> 60	1.33%	2.00%	17.33%	3.00%	5.92%
Occupation	Officer	58.67%	46.00%	1.33%	12.00%	29.50%
	Worker	0.67%	3.67%	2.00%	8.50%	3.71%
	Farmer		0.33%			0.08%
	Small business	22.00%	8.00%	3.33%	2.00%	8.83%
	University student		30.67%	57.33%	63.50%	37.88%
	Pupil		0.00%	8.67%	3.00%	2.92%
	Temporary job	2.00%	1.67%	0.67%	1.00%	1.33%
	Housewife/Retired	16.67%	3.33%	20.67%	4.50%	11.29%

Variable		Car users	Motorcycle users	Bike users	Bus users	Total
	Other		6.33%	6.00%	5.50%	4.46%
Education	High school or below	6.0%	25.7%	64.7%	65.5%	39.2%
	University degree	72.0%	62.3%	34.0%	30.0%	50.8%
	Master's degree or above	22.0%	12.0%	1.3%	4.5%	10.0%
Monthly income	Less than 7 mil. VND (~ 300 USD)		14.0%	42.7%	47.0%	14.2%
	7 – 14 mil. VND (~300 - 600 USD)	3.3%	49.0%	26.7%	38.0%	19.8%
	14 -21 mil. VND (~600-900 USD)	4.0%	24.7%	18.7%	12.5%	11.8%
	21-35 mil. VND (~900-1500 USD)	18.0%	9.3%	11.3%	1.5%	9.7%
	> 35 mil. VND (~ > 1500 USD)	74.7%	3.0%	0.7%	1.0%	19.6%
Vehicle ownership	Number of motorcycles per adult	1.05	0.79	0.41	0.34	0.66
HH structure	Number of secondary school pupils	0.39	0.15	0.08	0.14	0.18
	Number of primary school pupils	0.37	0.14	0.12	0.09	0.17
	Number of kindergarten kids	0.46	0.24	0.12	0.09	0.22
Trip attributes						
Purpose	To home	0.67%	4.67%	8.00%	8.00%	5.38%
	To school	0.00%	51.67%	10.67%	10.67%	24.04%
	To work	78.00%	21.00%	44.67%	44.67%	42.04%
	Private	8.00%	11.00%	14.00%	14.00%	11.75%
	To business	6.67%	2.00%	0.67%	0.67%	2.29%
	Shopping	2.67%	6.00%	9.33%	9.33%	6.83%
	Pick-up/delivery	0.00%	3.00%	6.67%	6.67%	4.04%
	Others	4.00%	0.67%	6.00%	6.00%	3.63%
Distance	< 2 km	2.67%	16.00%	54.00%	9.50%	18.17%
	2 – 6 km	40.67%	38.33%	39.33%	39.50%	29.58%
	6 - 10 km	24.00%	24.67%	5.33%	16.50%	13.50%
	10 – 15 km	18.00%	11.67%	0.67%	8.00%	7.58%
	15 – 20 km	4.00%	5.00%	0.67%	7.00%	2.42%
	> 20 km	10.67%	4.33%	0.00%	19.50%	3.75%
Frequency	1 - 2 trips per day	4.67%	11.33%	17.33%	73.00%	26.63%
	3 - 4 trips per day	2.00%	24.67%	50.67%	12.50%	22.25%
	5 - 6 trips per day	87.33%	60.33%	16.67%	9.50%	44.50%
	> 6 trips per day	6.00%	3.67%	15.33%	5.00%	6.63%

Table 2 Confirmatory factor analysis results

Construct Indicator	Item loading	Cronbach's Alpha (α)
The appeal of public transport		**0.905**
Use public transport help you to save money	0.829	
Use public transport help you to not finding the parking	0.861	
Use public transport support you to work onboard	0.801	
Public transport is safer than motorcycle	0.848	

Construct Indicator	Item loading	Cronbach's Alpha (α)
The appeal of private vehicles		**0.928**
Use other private vehicle is more freedom	0.802	
Use other private vehicle help you to save the time	0.727	
Use other private vehicle help you to come everywhere	0.808	
you keep the routine of using private vehicle	0.775	
Health awareness		**0.711**
Motorcycle users are more directly affected by adverse weather conditions	0.779	
Motorcycle users are more directly affected by dust	0.757	
Motorcycle users are more susceptible to be respiratory infections	0.741	
Motorcycle users have a higher level of injury in a traffic collision	0.601	
Attitude toward vehicles		**0.804**
Riding expensive private car and motorcycle enhance the business opportunity	0.792	
Riding expensive private car and motorcycle shows success and high social status	0.778	
Riding expensive private car and motorcycle shows a modern lifestyle	0.725	
Environmental awareness		**0.819**
Public transport helps to protect the environment	0.880	
Pubic transport helps to reduce traffic congestion	0.862	
Public transport helps to reduce traffic accidents	0.833	
Subjective norms		**0.817**
Do your family affect to you about which transport mode should be used	0.841	
Do your friends/colleagues affect to you about which transport mode should be used	0.872	
Do propaganda program from your company/school affect to you about which transport mode should be used	0.823	
Do media channels affect to you about which transport mode should be used	0.856	

3. Results

The dependent variable of the mode choice models has four levels, including motorcycle, private car, cycling and buses, where the base level is motorcycle. The explanatory variables considered are socioeconomic and demographic characteristics, trip attributes, subjective norms, the appeal of alternative transport mode, health awareness, environmental awareness, and attitude toward alternative vehicles, which are presented in Figure 1. Table 3 presents the results of the travel mode choice models. There are total 34 explanatory variables, of which 17 variables were statistically significant at the 90 confidence level and the parameters significantly varied across modes.

As shown in Table 3, the demographics of road users affect their travel mode choice preferences significantly at the 10% level. The coefficients of the variable "age" are significant and positive for private cars and cycling, which indicates that older people have a higher likelihood of choosing private cars and cycling. The coefficients of the variables "number of secondary school pupils" and "number of primary school pupils" are positive for private cars. These findings suggest that the family structure of having children at primary and secondary schools have a higher likelihood of -

Table 3 Results of MNL model

Variables	Private car		Cycling		Bus	
	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.
Constant	-38.367	.000	18.650	.000		
Socioeconomic and demographic characteristics						
Age	.466	.014				
Number of secondary school pupils	1.689	.004				
Number of primary school pupils	1.798	.009				
Number of kindergarten kids			-2.119	.028		
Number of motorcycles per adult	2.437	.017	-3.694	.000		
Trip attributes						
Trip distance			-.495	.000		
Frequency					-2.106	.019
Vehicle characteristics						
Travel cost/ Income	2.674	0.24				
Speedy					-12.968	.004
Cheap					8.855	.023
Convenience	-2.300	.035	1.635	.015	-6.794	.008
Comfort	3.404	.000				
Reliability					-8.411	.003
Safety	4.103	.000	2.487	.015	-3.784	.041
The appeal of alternative transport mode						
The appeal of public transport			1.972	.001	15.074	0.09
The appeal of private vehicle	1.887	0.63			-9.099	.011
Attitude toward the private vehicle	2.221	.039	-1.692	.008	-13.829	.001
Health awareness	3.979	.004	-6.722	.000	4.859	.058

Base level: Motorcycle, -2 Log Likelihood = 193.5, Chi-square = 1953.8, df = 60, Sig = 0.000, R^2 = 0.913

choosing private vehicles that are safer than motorcycles and can protect children from hard weather and dust. On the contrary, the coefficient of the variable "Number of kindergarten kids" is positive for cycling. This finding can be explained by the fact that most kindergartens are located in residential area, and families having kindergarten kids often rely on grandparents for taking care of kids, including pick-up kids to go to the kindergarten, hence elders have a higher likelihood of choosing cycling due to short distance and their physical conditions.

Additionally, the coefficients of the variable "number of motorcycles per adult" is positive for the private car but negative for cycling and bus. These results indicate that members of households owning both motorcycles and private cars have a higher likelihood of choosing private cars. In contrast, members of households owing motorcycles and bicycles have a lower likelihood of choosing cycling or buses. These findings may be attributable to the possibility that motorcyclists are more likely to shift to the car mode as their incomes increase, and using cars can be more affordable. This information is particularly important in light of concerns about safety and congestion due to replacing motorcycles with cars.

Trip attributes contribute to understanding the travel mode choice of road users. Road users with long distances have a lower likelihood of choosing cycling. Meanwhile, road users having several trips per day have a lower likelihood of choosing a bus. These findings likely reflect that motorcycles prove themselves as a convenient solution for "multi-purpose" trips, especially for those who live in areas with inaccessible cycling, or inconvenient, insufficient, and inefficient public transport systems

Six vehicle characteristics are found to affect the travel mode choice response. For example, road users who care about convenience have a lower likelihood of choosing a private car, cycling and a bus. Meanwhile, road users who care about safety and cheapness have a higher likelihood of choosing a bus. Similarly, those who care about safety have also a higher likelihood of choosing a private car and cycling.

The level of the appeal of alternative transport modes significantly affects the travel mode choice behavior. The coefficients of the variable "the appeal of public transport" are positive for a private car, cycling and a bus. These results indicate that people who highly appreciate the role of public transport have a higher likelihood of choosing public transit and cycling while they have a lower likelihood of choosing a private car. On the contrary, those who highly appreciate the role of a private vehicle have a lower likelihood of choosing public transit. Similarity, people who have good attitude of private vehicles have a higher likelihood of choosing a private car and a lower likelihood of choosing cycling and a bus.

Finally, health awareness significantly affect the travel mode choice behavior of road users. People who considered riding motorcycles mostly risky from environmental conditions and accidents are more likely to choose a private car and a bus. These results indicate that when the quality of life improves, people are more concerned on health issues. This is the time to change the road users' behaviors toward public transit instead of private vehicles. However, public transport needs to be improved quickly before people are economically eligible to switch to using a private car.

4. Discussion and Conclusion

Motorcycles are rapidly changing transportation in Vietnamese cities. However, because of safety concerns, there is an increasing trend of restricting the use of motorcycles, which, in turn, could result in significant changes in the travel pattern. However, relatively little is known about the attractiveness of alternative mobility modes and health awareness in travel mode choice. This study attempts to understand current road users' choice preferences by exploring the possible factors affecting decision making, including the attractiveness of alternative transport modes, health awareness, socioeconomic and demographic characteristics, trip attributes and others.

The level of appeal of alternative transport modes plays an important role in road users' travel mode choice. People who highly appreciate the role of public transport have a higher likelihood of choosing a less emission and congestion mode (bus and cycling) and a lower likelihood of choosing a high emission and congestion mode (private car). On the contrary, people who highly evaluate the comfort and freedom of private vehicle have a lower likelihood of choosing a bus. The findings suggest that a high level of public transport acceptance in terms of cost saving, safety, freedom from driving exerts a positive effect on the use of more sustainable transport modes. Such findings are supported by a number of previous studies (Aoife, 2011; Beiráo and Cabral, 2007; Chen and Chao, 2011).

The level of health awareness is another indicator affecting the travel mode choice of road users. People with high level of negative impacts of pollution and accidents have a higher likelihood of choosing a safer mode (private car and bus). Such findings are consistent with previous studies (Idei and Kato, 2020; Jin et al., 2018; Du et al., 2020b).

This study also found that the benefits of motorcycle riding seem to be broadly perceived, while the barriers to motorcycle riding are less discovered. For example, all road users indicated that a motorcycle is a fast, convenient, reliable travel option that allows people to travel and is a good option for multi-purpose trips. In contrast, the main barriers to motorcycle use, which related to safety and health awareness.

Overall, this study explored the effect of alternative transport modes and health awareness on road users' mode choice. The data were collected via a questionnaire survey in Hanoi, Vietnam. Using MNL models, we examined the relationship between road users' mode choice and the appeal of alternative transport mode and health awareness, combined with socioeconomic and demographic characteristics, trip attributes, vehicle characteristics, and subjective norms. The results indicate that factors including age, number of secondary school pupils, number of primary school pupils, number of kindergarten kids, number of motorcycles per adults, trip distance, frequency, road users's perception in aspect of vehicle characteristics like fast, cheap, convenient, comfortable, reliable, and safe, the appeal of private vehicle, the appeal of public transport, attitude toward private vehicles, and health awareness could influence road users' travel mode choice preferences. In particular, those with a high level of health awareness are more likely to switch to private cars and buses. This result could imply potential changes in the mode share, given the implementation of regulatory initiatives such as establishment of barriers to limit the convenience of private cars. Additionally, the results should inform education and promotion strategies that can promote a good attitude on public transport in terms of sustainable urban transport mode. Additionally, transport management and policy measures that can limit the efficiency of private car and motorcycle will be essential.

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Development of Autonomous Delivery Service Prototype in Chulalongkorn University

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Abstract

The rapid development of technologies, especially information technology and computational power, leads to the evolution of existing technologies in many industries including the automobile industry. There are 3 changes in technologies and 1 change in customer behaviors that have been mentioned in recent years, i.e., Electric vehicles, Autonomous vehicles, Connected vehicles, and Shared mobilities. 3 of mentioned changes have been developed and commercialized already. Although, the autonomous vehicle is still being developed in terms of technology and use-cases. In this research, we developed an autonomous vehicle prototype and also explored one of the possible use cases of autonomous vehicles, i.e., autonomous delivery service. The autonomous vehicle was developed by modifying Toyota Hamo to be able to be controlled by an electrical signal, namely drive-by-wire. In addition to the drive-by-wire system, we also developed an IoT-delivery box for carrying goods to the customers, which can be commanded using the mobile application. The autonomous software stack was implemented from Autoware.ai, the open-source autonomous vehicle software framework. The merchant web application was developed to communicate with the vehicle, including a front-end web application, a back-end database, and autonomous vehicle communication. After finishing the developing phase, we also carry out the full pilot test with fix scenario. From the pilot test, we found out that the vehicle can operate as intended. The vehicle can operate in the route created from the purchase order and return to the standby position after the task is finished. The vehicle can avoid the collision by both braking and steering maneuvers, while there is an obstacle blocking the vehicle's path. However, the vehicle must be carried out the pilot test in a real scenario, i.e., real purchasing orders, and real traffic conditions, with the overseer of the safety drive, before being deployed in a real business manner.

Keywords: Autonomous Vehicle, Autonomous Delivery Service, Connected Vehicle

1. General Introduction

The rapid development of technologies leads to the evolution of existing technologies in many industries including the automotive industry. There are 3 changes in technologies and 1 change in customer behaviors that have been mentioned in recent years, i.e., Electric vehicles, Autonomous vehicles, Connected vehicles, and Shared mobilities. 3 of mentioned changes have been developed and commercialized already. Although, the autonomous vehicle is still being developed in terms of technology and use-cases. Nowadays, autonomous vehicle technology has been widely developed for various purposes both as personal or public vehicles, such as autonomous shuttle vehicles, Autonomous on-demand Vehicles, etc., or even Autonomous Delivery Vehicles either in enclosed or in public areas. Although, there are limitations to implementing autonomous vehicles on Thailand's public roads, for example, autonomous vehicle-related laws and regulations, and supporting infrastructures. Regarding the limitation, Autonomous Delivery Vehicles in a specific area have more possibilities than other applications during this period 0. Moreover, Autonomous Delivery Vehicles can be integrated with the existing business to enhance customer experience and can be further implemented in other areas, such as factories, universities, hospitals, businesses, and residential areas.

To explore the possibilities, an autonomous vehicle prototype based on Toyota Hamo was developed. The prototype was designed to be able to operate in the enclosed area and predefined route at speeds of 10 km/hr. with the following function, avoiding crashes with obstacles automatically, receiving and delivering products through the mobile application, and operation monitoring system.

2. Literature Review

2.1 Level of Driving Automation

Society of automotive engineering international has divided the levels of driving automation into 5 levels 0, as shown in Fig. 12. The differences in each level are the responsibility of the human driver and the autonomous system. Our prototype is considered a level 3 vehicle because the autonomous system is responsible for the vehicle control only in the defined area with the supervision of a safety driver, otherwise, the vehicle will be controlled by the human driver.

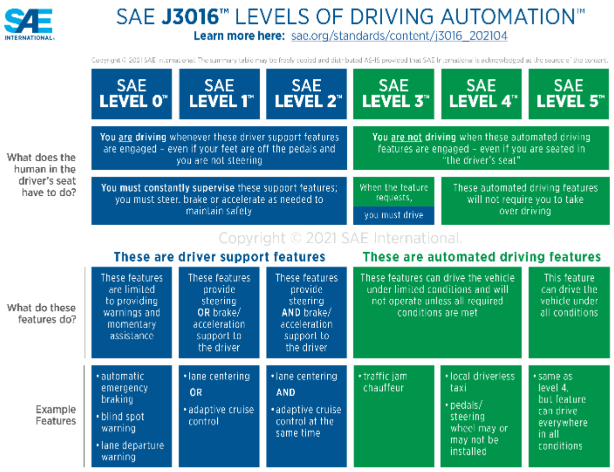

Fig. 12 Level of driving automation 0

2.2 Autonomous Vehicle Application

Regarding the growth of the sharing mobility market, large enterprises and start-up companies have been developing autonomous vehicles for sharing mobility applications. For example, Easy Mile uses autonomous vehicles for ride-hailing and ride-sharing services 0, and Easy Ride, the cooperation between Nissan and DeNA, uses autonomous vehicles as Robo-taxi. Sharing mobility is growing because the concept of owning a vehicle is obsolete. Sharing mobility leads to a lower total cost of traveling, therefore the customers will be looking for Mobility as a Service, which can serve them to be able to travel from point A to point B without concern about owning the vehicle.

2.3 Autonomous Vehicle Architecture

The autonomous vehicle software can be simplified into 3 layers 0, as shown in **Fig. 13**.

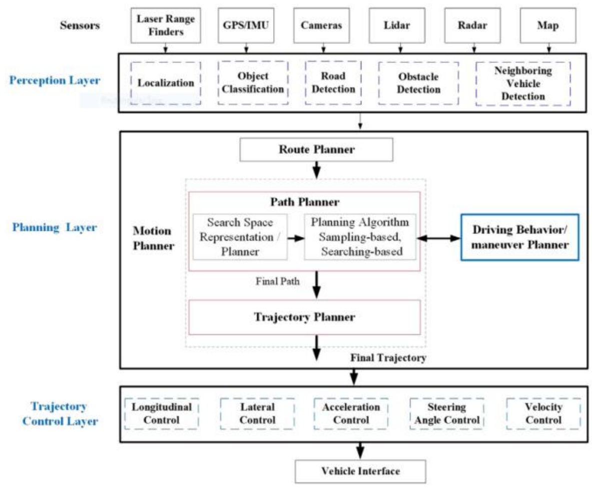

Fig. 13 Autonomous vehicle software architecture 0

- The perception layer receives sensor raw data as inputs. Then process into 2 types of data, the environment data, and the vehicle location data.
- The planning layer can be divided into 2 types of planning, Route planning or global planning and Motion planning or local planning. Global planning is the high-level planner to plan the vehicle traveling route from start to the determined destination under some constraints, such as short distance, fastest route, or most energy efficient route. Local planning plans the vehicle motion regarding the surrounding environment. The local will plan the vehicle state according to the environment data received from the perception layer. The planning motion would include acceleration, braking, turning, or avoiding obstacles.
- The trajectory control layer receives planning command from the planning layer and then converts it into low-level control command which can be used to control the actuators of the vehicles.

3. Methodology

In this research, Toyota Ha:mo the 1-seat electric vehicle was developed into an autonomous delivery service vehicle. There were 4 parts of the modification done to the vehicle as follows.

Fig. 14 Toyota Ha:mo

Table 2 Toyota Ha:mo specifications

Specification	
Dimension (W*L*H)	1,095*2,395*1,500 mm.
Wheelbase	1,530 mm.
Vehicle weight	455 kg.
Min. turning radius	3.2 m
Max speed	60 km/hr
Distance per charge	50 km
Recharging time	6 hrs.
Rated power output	4 kW
Max. power output	5 kW
Max. torque	250 N.m

Source: CU Toyota Ha:mo project

3.1 Low-Level Control

The vehicle is needed to be modified to be able to control by electronic signals (by-wire vehicle) by installing the embedded control system. There is 3 system in the vehicle that has been modified.

1) Steering control system

The DC motor was installed at the steering column just above the pinion gear of the original steering system. The motor drives the steering column via pinion and bevel gear, as shown in Fig. 15. The steering angle of the vehicle was fed back to the embedded controller via 10 bits rotary encoder installed next to the pinion and bevel gear.

A 1-dimensional PID controller is utilized in a low-level steering control system. The controller received a required steering angle from the high-level control then the controller determined the output signal which is defined as a duty cycle of the pulse width modulated DC voltage. The output was sent to the H-bridge DC motor driver to control the steering motor.

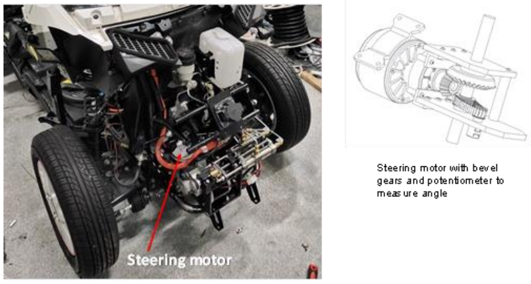

Fig. 15 Steering Motor

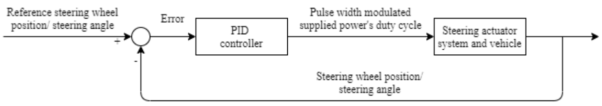

Fig. 16 Steering control diagram.

2) Braking control system

The DC motor was implemented in the braking control system similar to the steering system. However, secondary brake cylinders were invented which allow the braking motor to work simultaneously with the brake pedal, as shown in Fig. 17.

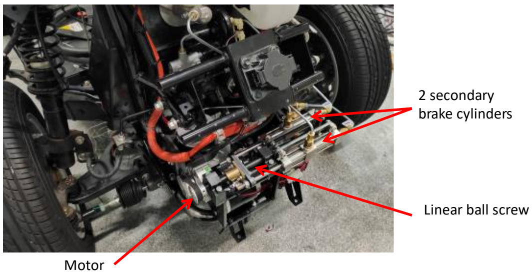

Fig. 17 Braking motor

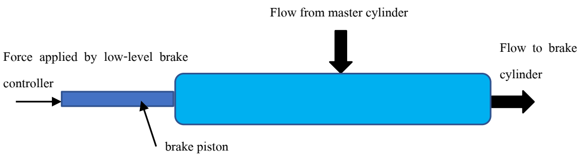

Fig. 18 Secondary brake cylinder

The braking system does not have a specific control for the braking system but the braking system will operate together with acceleration control and take vehicle odometry as feedback in the speed control system.

3) Speed control

To control the vehicle's speed, both brake and acceleration are needed to operate synchronously. Though the braking control mechanism was explained in the last section, the acceleration also is needed to be controlled. Hence, the original acceleration is an electronic acceleration pedal, the modified acceleration control was designed to intercept the original acceleration signal before sending it to the vehicle's ECU. Using an embedded controller allowed to intercept and modified acceleration signal then send to the vehicle's ECU allowing the vehicle to perform accelerating as desired.

First of all, the simple PID controller was implemented in the speed control system as in the steering control system. However, to control the vehicle speed 2 actuators, braking, and acceleration, were implemented to accelerate and decelerate the vehicle respectively, as shown in Fig. 19.

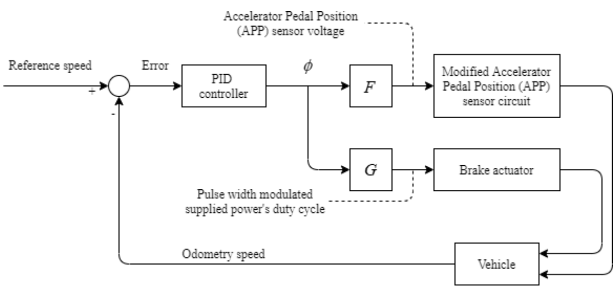

Fig. 19 Speed control diagram 0

The vehicle sensed speed is subtracted from the reference speed received from the high-level control system resulting in a speed error. Then, the PID controller determined the output (∅) which can either be positive, the vehicle needs to accelerate, or negative, the vehicle needs to decelerate. Then, the PID controller output (∅) plugged into a discontinuous gain transfer function *F* and *G* 0, gives the appropriate braking and acceleration command to the actuators. The discontinuous gain transfer functions *F* and *G* can be defined by equations (1) and (2).

$$F = I(\emptyset) \quad (1)$$

$$G = \left(1 - H(\emptyset + \delta)\right)\left(\alpha\left(1 + \frac{\delta}{\emptyset}\right)\right) \quad (2)$$

Where $H(x)$ represents the Heaviside step function. Since the vehicle regenerative braking is activated when is accelerator pedal is in a released position which leads to a deceleration 0. The output of the discontinuous gain *F* and *G* given the PID controller output (∅) is shown in Fig. 20.

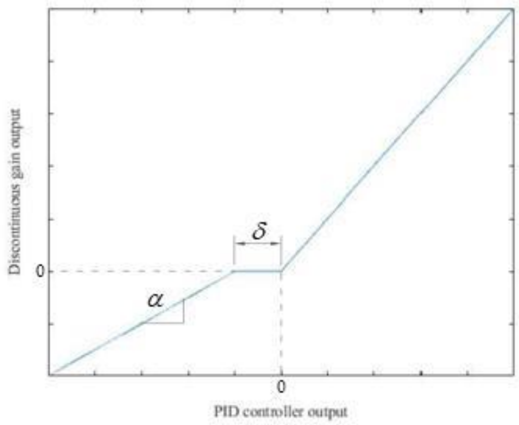

Fig. 20 Output of the discontinuous gain transfer function 0

3.2 Hi-Level Control

To be able to implement autonomous software, a high computational mini pc was installed together with additional sensors, Lidar and GNSS. The open-source autonomous software framework Autoware.ai 000 was used. The autoware.ai allows developers to easily implement autonomous driving ability in their vehicles. The autoware.ai system architecture is shown in Fig. 21.

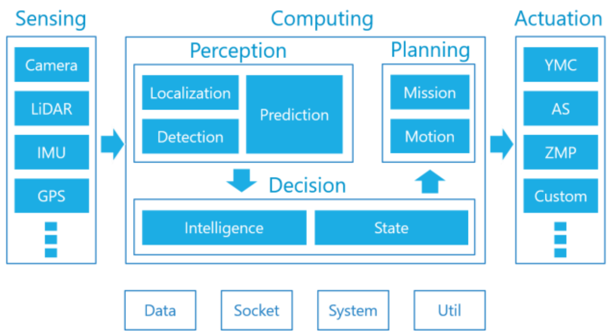

Fig. 21 Autoware.ai system architecture 0

Autoware.ai is developed based on a Robot Operating System (ROS) framework which comes with many sensors drivers suit for the autonomous vehicle as well as perception and planning algorithm. In this research, raw data from the Lidar sensor was plugged into the lidar ekf contour obstacle detection algorithm 0 to detect objects surrounding the vehicle. Lidar raw data together with GNSS data was used to localize the vehicle location using a normal distribution transformation

(NDT) matching lidar localization algorithm 000Then, the vehicle location and surrounding data were given to the open planning algorithm 0 which consist of both global planning and local planning algorithm to generate the appropriate waypoint for the vehicle to follow. Finally, pure pursuit waypoint follower 0 was used for waypoint tracking which output the control command later send to the low-level controller to control the vehicle accordingly.

3.3 Delivery Box

To carry purchased goods, an IoT delivery box was installed at the back of the vehicle. The box worked together with the mobile application to allow customers to control the delivery box and prevent taking goods from the wrong order.

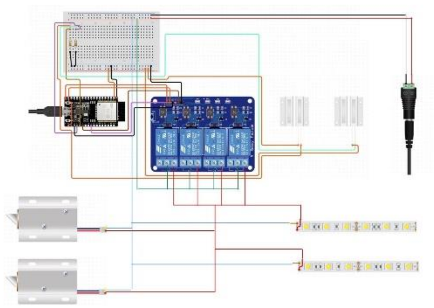

Fig. 22 IoT delivery box circuit diagram

The delivery box is connected to the online database (Firebase) which gives to user permission to open the box regarding their order. The mobile application was developed to allow the users to communicate with the vehicle. The application has features that allow customers to place an order and select the delivery destination. When the vehicle reaches the destination the customer can use the application to send the command to unlock the box which contains their order. After, the customer finished receiving the order the vehicle will return to the standby location.

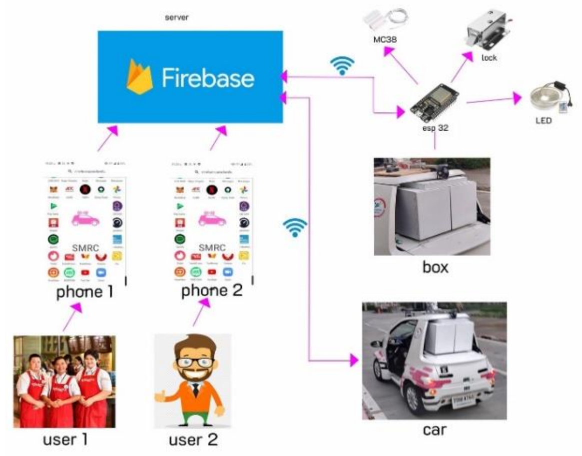

Fig. 23 Autonomous delivery vehicle connectivity architecture.

3.4 Testing Preparation

Before operating the autonomous vehicle, there are 2 maps needed to be prepared, a points cloud map and a vector map. The points cloud map represents the environment of the testing area and is used in the localization algorithm to locate the current position of the vehicle. The points cloud map could be created by using different slam algorithms. In this research, HDL graph slam 0 was used because HDL graph slam implemented pose-graph optimization algorithm and loop detection algorithm to achieve high accuracy points cloud map.

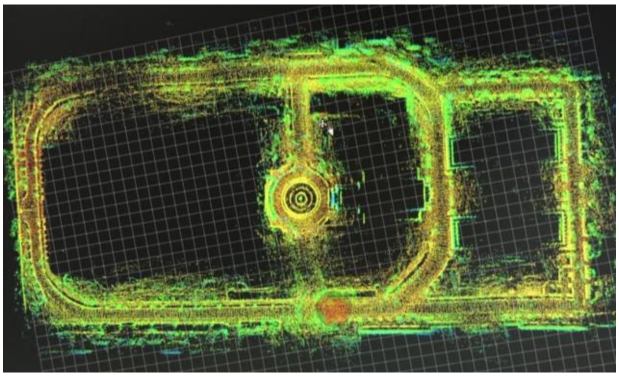

Fig. 24 Points cloud map

The second map is a vector map that contains the lane information to allow the vehicle to correctly navigate in the traffic. There are 2 formats of vector maps that can be used in Autoware.ai, Asian Technology Vector map, and lanelet vector map.

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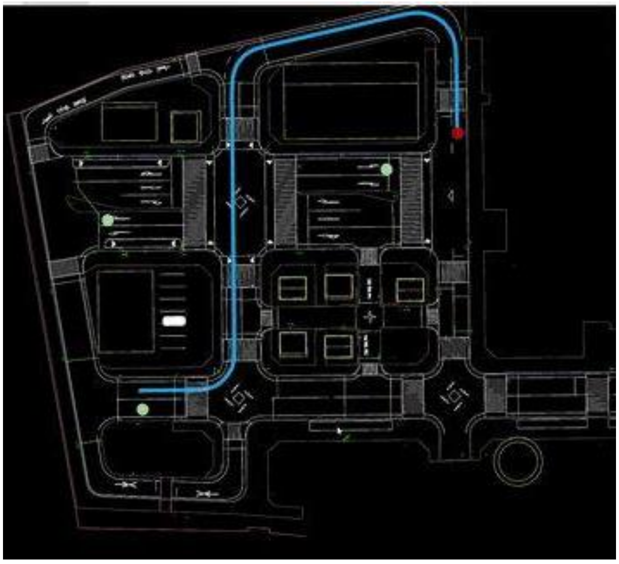

Fig. 25 Vector map

3.5 Field Operational Test

The autonomous delivery service vehicle was tested in the Chulalongkorn University area, as shown in **Fig. 26**. The vehicle operated at a low-speed, 10 km/hr., to minimize the risk factor. To start the test, a user placed an order via the mobile application the vehicle will approach the destination. During the operation, the obstacle was deployed to test the vehicle obstacle avoidance algorithm.

The field operational test was conducted to evaluate an overview of the operation, also if the operation procedures follow the desired procedures.

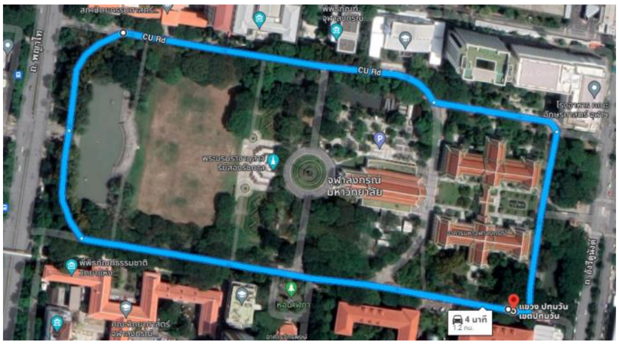

Fig. 26 Testing route

4. Results

From field operational testing of autonomous delivery service, the results can be separated into 3 parts.

1) Mobile application

The application operated as intended on both customer and vendor sides. However, there was some short delay that occurred while sending the box to unlock command due to the update frequency of the database.

2) IoT delivery box

After the customer opened the box, the box's components, electric latch, LED light, and door sensors works as expected.

3) Autonomous vehicle

The autonomous vehicle was able to efficiently follow the desired route at low speeds, around 10 km/hr., in terms of steering control, braking control, and ride comfort.

Hence, the prototype was able to operate together with a mobile application as expected via wifi connection. However, the autonomous delivery service includes a mobile application were still in the prototyping phase, there will be factors to be improved, in terms of user experience, speed of operation, how to handle thermal sensitive products, as well as the implementation of 5G communication instead of wifi connection.

5. Conclusion

In this research, we can achieve 2 research objectives. The first objective is to develop the autonomous vehicle into an autonomous delivery service including a navigation system, obstacle avoidance system, and monitoring system. The second objective is to develop and test an autonomous delivery system at low speed.

Toyota Ha:mo was chosen to be modified by installing by-wire systems as a low-level control system. The low-level control system receives a controlling command from the high-level control system. The open-source autonomous software framework, Autoware.ai, was implemented together with 2 additional sensors, Lidar and GNSS. Lidar was used to detect the surrounding object and together with GNSS to localize the vehicle location. Before starting the operation, a points cloud map and a vector map are needed to be created to later use in the path planning algorithm. The vehicle can follow the desired path regarding the customer's order while avoiding the obstacle that blocks the vehicle's path. The delivery system consists of an IoT delivery box, front-end mobile application, and delivery service back-end, using firebase.

The autonomous delivery service was tested by simulating the purchasing order using the mobile application. From the field operational test, the system worked perfectly. The mobile application worked together with the vehicle as intended, the vehicle can safely and accurately navigate from the goods receiving location to the destination which can prove that the system can be operated in the defined environment.

To use this system in a real scenario, extended testing and development are necessary to ensure the reliability of both system hardware and software. Also, teleoperting and telemonitoring systems are needed to ensure normal operation during unexpected circumstances.

There are other approaches to ensure the safety of the operation. The first approach is implementing V2X communication. V2X communication allows the vehicle to connect and receive additional data from the surrounding object, such as traffic lights, and road infrastructures. The second approach is giving a dedicated lane for the autonomous delivery service.

6. Acknowledgement

This research is funded by True Lab under the memorandum of understanding between True Lab and Smart Mobility Research Center.

Toyota Ha:mo was provide by CU Toyota Ha:mo project in the previous research project, Autonomous vehicle relocation system, which provide us the vehicle to modify by installing by-wire system. Therefore, Toyota Ha:mo is later able to be used in this and others research projects.

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Transportation Noise Investigation and Modeling Using multiple linear regression

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Abstract

Transportation noise is among the prominent sources of noise pollution in urban areas. Frequent and excessive exposure could result in adverse effects such as hearing damage especially for noise above 70 decibels (dB). Philippine standards provide little emphasis on noise generated from traffic streams, with no local transportation noise models that can be applied in noise regulation or project evaluation. The objective of this study was to collect equivalent sound pressure levels (L_{eq}) along nine selected roads in Metro Manila and compare them with existing allowable standards. A multiple linear regression (MLR) was also generated to relate transportation noise with contributing road and traffic characteristics. The resulting average L_{eq} does not significantly exceed the 70 dB threshold, nor 75 dB as stipulated by local standards. The developed MLR model exhibited reasonable accuracy with the logarithm of traffic volume, percentage of heavy vehicles, and lane count being the most significant variables.

Keywords: Transportation noise, vehicular traffic, equivalent sound pressure level, multiple linear regression

1. Introduction

1.1 Background

Sound is defined as a mechanical unsettling influence from a state of balance that proliferates through an elastic material. Any sound that is perceived as undesirable or exceeds the threshold of hearing can be referred to as noise [1]. One of the most pronounced sources of noise pollution is derived from roadside vehicles, otherwise referred to as transportation noise [2]. This is evident particularly in urban settings such as Metro Manila. Transportation noise stems from a wide array of factors wherein at significantly high volumes, may become a nuisance to its nearby surroundings. Moreover, frequent and excessive exposure to such noise has been known to negatively impact human behavior and performance [3]. Table 1 enumerates the approximate sound pressure levels for various daily activities as cited from the Center for Disease Control and Protection (CDC) [4]. It has been noted that prolonged exposure to noise above 70 dB, which includes transportation noise, may result in adverse health effects such as hearing damage [4].

Table 1 Common sources of noise and decibel levels

dB Reading	Everyday Equivalent
10 dB	Normal breathing
20 dB	Watch ticking
30 dB	Soft whisper
40 dB	Refrigerator hum
60 dB	Normal conversation
70 dB	Washing machine
80–85 dB	City traffic or lawnmower running
95 dB	Motorcycle
100 dB	Car honking 5 meters away
105–110 dB	Rock concert
120 dB	Standing near sirens
140–150 dB	Firecrackers

According to the World Health Organization (WHO) [5], 40% of the population in European Union countries experience transportation-related noise exceeding 55 dB, while 20% are exposed to sound levels greater than 65 dB [3]. Thus, WHO suggested that controlling the exposure to such forms of noise must be a high priority to assure the overall well-being of neighborhoods and communities.

In the Philippines, laws and standards stipulating the maximum allowable noise levels are given by the defunct National Pollution Control Commission (NPCC) which considers zoning and land use [6]. In a study of the Department of Public Works and Highways (DPWH), the recorded noise levels along selected major roads ranged between 75 to 89 dB – all of which are considered to yield high levels of annoyance [7]. In addition, studies have shown that select urban roads in Metro Manila generated noise exceeding 60 dB, affecting both nearby residential and commercial establishments [8]. Regardless, such laws have given little emphasis on noise that is generated particularly from traffic streams. Furthermore, there are no specific models used in the Philippines pertaining to transportation noise that can be applied in the evaluation of future projects and developments. Despite having multiple transportation noise models available internationally, such models cannot be easily applied due to varying local conditions [9].

1.2 Objectives

This study aims to investigate sound pressure levels derived from vehicular traffic along major thoroughfares within Metro Manila. Specifically, the objectives are (1) to measure the level of transportation noise along nine selected roads in Metro Manila in terms of the Equivalent Continuous Sound Pressure Level (L_{eq}); (2) to compare the measured transportation noise with existing standards pertaining to allowable noise levels; (3) to generate a multiple linear regression model that relates noise levels with contributing road and traffic characteristics; and (4) to verify the accuracy of the generated models.

1.3 Scope and Limitations

The scope of this research involves investigating and modeling the transportation noise levels along select roads within Metro Manila. The selection of roads and sample sites shall be based on a predetermined criterion. The methodologies for data gathering are adapted from similar studies [2], [10], which are thoroughly discussed in the succeeding sections. The collected noise levels are measured in terms of the equivalent continuous sound pressure level which is from a combination of noise sources, and thus does not consider individual and instantaneous events.

1.4 Significance

By investigating the relationship among its contributing factors, this study could help in predicting and estimating transportation noise levels along a given road segment. The determination of transportation noise levels is essential, particularly in urban areas such as Metro Manila, as it is a key contributor in environmental noise pollution which affects productivity and the quality of life within the surroundings. Thus, the models generated from this study may serve as a guide or mechanism for the monitoring, regulation, and assessment of transportation noise levels.

Moreover, this research could also assist road and urban planners in establishing and implementing action plans to address noise pollution. Given the lack of emphasis from existing laws, the results from this study could potentially provide insights and recommendations in developing an integrated transportation noise policy. This would include noise management measures such as establishing noise emission standards for road and off-road vehicles, regulating the speed limits of vehicles, road surface, tires, and engine modification, and enforcing traffic management regulations such as night-ban and prohibiting unnecessary loud honking during nighttime.

2. Review of Related Literature

2.1 Modeling Transportation Noise and Its Contributing Factors

Several models have been developed with the main objective of predicting transportation noise levels for monitoring and control purposes. Such models utilize multiple variables with the emphasis on source emission and sound propagation [11]. Among the simplest models formulated incorporates fundamental parameters into linear-logarithmic expressions [8].

Filho et al. [12] investigated the effects of traffic composition on the equivalent noise level (L_{eq}) along road segments with similar characteristics in Florianopolis, Brazil simple linear regression. It was observed that the percentage of heavy vehicles with respect to the total number of vehicles significantly affected the noise emissions. The resulting regression line was compared to a similar formulation for UK roads and was found to have relatively similar slopes, but the estimated noise levels differed by 2 dB. A similar study by Golmohammadi et al. [13] utilized 282 samples of noise measurements obtained from roads in Iran. The model, which was generated using multiple regression analysis, yielded a high coefficient of determination (R^2=0.901). The key explanatory variables included traffic flow and the speed of vehicles. Other variables considered were road characteristics such as road length and gradient.

As shown from the studies enumerated, empirical and numerical models have been developed and validated in several countries to obtain comprehensive data regarding noise levels attributed to road traffic. Most of which involve road and traffic characteristics such as traffic volume and composition [14], [2]. One of the primary applications of such models is the generation of noise maps, which can predict the number of people exposed to noise levels in a specific area. However, due to the variation of physical, meteorological, and other factors affecting the source and propagation of sound, applications of these models remain best suited in the particular country of origin [11].

2.2 Noise Standards and Regulations in Metro Manila

The appropriate noise standards currently used are based on the provisions issued by the National Pollution Control Commission (NPCC) [6]. The maximum allowable noise for general areas is defined in Section 78 of Memorandum Circular No. 002 issued in 1980 (Table 2). A correction factor is subsequently applied for areas directly facing a public transportation route or urban traffic artery. 5 dB are added in areas directly facing a four-lane road, while 10 dB are added for wider roads [15].

Table 2 Environmental quality standards for noise in general areas

Category of Area	Daytime (9 AM–6 PM)	Morning & Evening (5–9 AM; 6–10 PM)	Nighttime (10 PM–5 AM)
AA - section or area which requires quietness, such as an area within 100 m from school sites, nursery schools, hospitals, and special homes for the aged	50 dB	45 dB	40 dB
A - residential purposes	55 dB	50 dB	45 dB
B - commercial area	65 dB	60 dB	55 dB
C - light industrial area	70 dB	65 dB	60 dB
D - reserved as a heavy industrial area	75 dB	70 dB	65 dB

3. Theoretical Framework

To further investigate and analyze the collected transportation noise levels, multiple regression analysis would be conducted to develop a Multiple Linear Regression (MLR) model which quantifies the transportation noise as a function of related road and traffic characteristics.

MLR is a statistical technique that presents the same logic as simple linear regression but with the inclusion of two or more explanatory variables. The MLR is usually expressed in the form presented below [16].

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_p x_{pi} + e_i \quad (1)$$

Where
y_i : dependent variable
x_i : explanatory variable
β_o : constant term
e_i : residual

The coefficient of determination (R^2) determines the magnitude of association between the explanatory variables and the response variable. In statistics, R^2 indicates the proportion of variation in the dependent variable that can be predicted or explained from the set of independent variables in a multiple regression equation. R^2 values range from 0 to 1 wherein, as the values lean closer to 1, it indicates better goodness of fit between the regression equation and the data. In terms of modeling, R^2 values greater than 0.5 are considered high and acceptable. After obtaining the R^2, t-testing is conducted to determine the statistical significance and interpret the effects of the individual explanatory variables which were used to explain the response variable.

The Root Mean Square Error (RMSE) is an approach commonly used to quantify the accuracy of an established model [17]. This is determined by the equation as shown below.

$$RMSE = sqrt\left(\Sigma \frac{(P_i - O_i)^2}{n}\right) \quad (2)$$

Where
P_i : predicted values
O_i : observed values

RMSE assesses the performance of the generated model as it shows how close the predicted values are to the observed values [18]. In interpreting RMSE, lower values indicate a better fit and performance of the model. If the objective of the model is aligned with prediction, RMSE is one criterion to further evaluate the established model [19]. In the study conducted by Hustim et al. [20] regarding road traffic noise prediction, RMSE was also utilized as a measure to determine whether the model was sufficiently valid.

4. Methodology

4.1 Selection of Study Sites

Data collection was performed on January 3, 5-6, 2022 during off-peak hours only (9AM – 3PM). This was due to mobility limitations caused by the COVID-19 pandemic. The nine study sites consisted of Roxas Boulevard, Dr. Arcadio Santos Avenue, Epifanio Delos Santos Avenue (EDSA), Aurora Boulevard, TM. Kalaw St., Mindanao Avenue, Quirino Avenue, Boni Serrano Avenue, and Santo Domingo Street. Specific locations along the roads to be used as study points were selected based on a predefined criterion. Key factors were considered to minimize the effects of background noise. These criteria include (1) flat or at-grade road sections; (2) no active construction within the area; (3) no nearby factories, railways, generators, etc.; and (4) no excessive pedestrian traffic.

4.2 Sound Pressure Level Measurement

An RS PRO RS-8852 Sound Level Meter (SLM) with Datalogger was utilized, which measures sound pressure levels from 30-130 dB with an accuracy of ±1.4 dB. The A frequency weighting was employed to better approximate human hearing [10]. Moreover, the SLM was set to the FAST response time, with a time constant of 1.0 second per reading. The sound pressure level was obtained at specified locations by mounting the SLM on an isolated tripod 1.5 meters above the ground level and was balanced parallel to the ground surface. The tripod was also supported by a foam pad to prevent the influence of vibrations from the pavement surface. Moreover, the device was mounted at a horizontal distance of 0.7 meter from the roadside to allot for sidewalk clearances (Fig. 1).

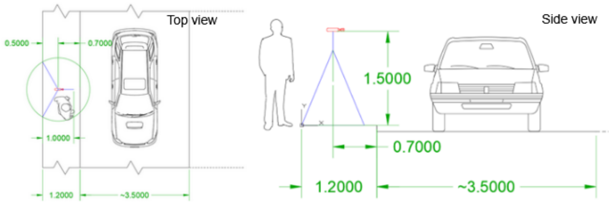

Fig. 1 Data collection setup

The sound pressure level was measured continuously for 15 minutes without any disturbance. This was repeated at an additional four intervals (for a total of five 15-min intervals per location) to increase representativeness. The data from the sound level meter was later offloaded onto a laptop for recording and documentation. The L_{eq} values would then be obtained from the average of each 15-min interval and were classified according to the location (i.e., road).

The noise measured along the thoroughfares is assumed to be derived primarily from the moving vehicles as a collective. However, special cases such as passing aircraft or ambulance sirens were also considered and taken note of in case of such presence and significant sound pressure levels were recorded. Photos of the adjacent surroundings were also taken to obtain supplementary information regarding building facades, pedestrian traffic, weather, etc.

4.3 Road and Traffic Characteristics

As what previous studies have claimed, transportation noise is heavily influenced by traffic flow and composition, particularly heavy vehicles such as trucks, buses, bulldozers, etc. [12], [21]. Thus, a video camera recording of passing traffic along the chosen study sites was employed simultaneously with sound pressure level measurement. Manual counting of the different vehicle types was then included in post-field procedures.

The video footage was closely observed to identify the types of vehicles passing through each study area for every 15-minute interval. These were manually tabulated and classified under three categories: light, medium, and heavy vehicles. The sum of these data would correspond to the total traffic volume for each interval. Additional parameters were also considered which were obtained from field data and Google Maps, as summarized in Table 3.

Table 3 Details of road and traffic parameters

Parameter	Description
Road Classification	Either – Primary, Secondary, or Tertiary – as designated by the DPWH
Lane Count	Number of lanes per direction
Road Barriers	Divided: a physical barrier is present which separates opposing lanes Undivided: there is no central barrier to separate opposing lanes
Road Surface	Material at the top surface, whether Asphalt or Concrete
Upstream Intersection	Distance of SLM to the nearest intersection where incoming traffic has passed through (km)
Downstream Intersection	Distance of SLM to the nearest intersection to which outgoing traffic is headed towards (km)
Vehicle Speed	Average vehicle speed along road segment obtained from Google Maps (kph)
Total Vehicles	Total count of vehicles passing through road segment for every 15-min interval (veh/15 min)
%Light Vehicles	Percentage of motorcycles, scooters, tricycles, etc., out of total vehicle count
%Medium Vehicles	Percentage of cars, jeepneys, taxis, vans, etc., out of total vehicle count
%Heavy Vehicles	Percentage of trucks, buses, bulldozers, trailers, etc., out of total vehicle count

Fig. 2 Vehicles considered in the traffic stream

4.4 Data Processing

The full dataset was randomly split in two, with 75% of the data being used for model generation while the remaining 25% was used for model validation. The Statistical Package for the Social Sciences (SPSS) software was used to generate an MLR model that predicts the transportation noise levels along a certain road, given the selected input variables. The regression coefficients, coefficient of determination (R^2), and significance of each variable were tabulated and interpreted. Cross-validation was performed using the separate dataset in which the Root Mean Square Error and percentage error between the predicted and observed sound pressure levels was calculated.

5. Results and Discussion

5.1 Analysis of Resulting Equivalent Sound Pressure Levels (L_{eq})

A total of forty-five (45) equivalent sound pressure level measurements for 15-minute intervals were obtained from the 9 study sites within Metro Manila. This yielded an average of 70.806 dB and a standard deviation of 3.335 dB. This slightly exceeds the allowable threshold of 70 dB, in which prolonged exposure may result in adverse health effects such as hearing damage [4]. However, results from the performed one-tailed t-test ($p=0.056$) showed that the mean of the measured noise levels is not significantly greater compared to the 70 dB standard. Likewise, the obtained average sound pressure level was also compared with the maximum allowable noise level designated for commercial areas stated on the provisions issued by the NPCC which is 75 dB. Based on the t-test results ($p=1.000$) at a significance level of 5%, there is not enough evidence to conclude that the mean of the measured noise levels is greater than the 75 dB standard.

Out of the 9 study sites (Table 4), Mindanao Avenue had the highest recorded average L_{eq} of 76.06 dB which exceeds both CDC and NPCC standards. Noting its significantly high average vehicle volume, it also yielded the highest proportion of heavy vehicles, as shown in Fig. 3.

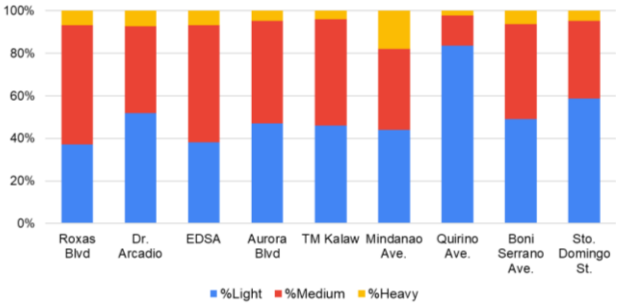

Fig. 3 Average vehicle mix per study site

The collected data was also analyzed whether certain variables yielded a significant difference in the measured sound pressure level. Mean comparisons were performed in SPSS using independent samples t-tests (Table 5). Levene's test was also performed to assess the equality of variance between the two subgroups. It was found that there is a significant difference in noise levels depending on the presence of road barriers, wherein divided roads yielded higher average L_{eq} values compared to undivided roads. Meanwhile, no significant difference was found among L_{eq} values depending on the type of road surface, whether asphalt or concrete. Additional t-tests were also performed to determine any significance of the DPWH road classification (i.e., primary, secondary, and tertiary) to the resulting noise level. Results showed no significant difference in average L_{eq} values between primary and secondary roads, while a significant difference in mean values was observed between primary and tertiary roads, as well as between secondary and tertiary roads.

Table 4 Average results per study site

Location	Average L_{eq} (dB)	DPWH Road Classification	Lane Count	Road Barriers	Road Surface	Upstream Intersection Distance (km)	Downstream Intersection Distance (km)	Vehicle Speed (kph)	Total Vehicles (veh/15 min)
Roxas Blvd	73.397	Primary	4	Divided	Concrete	0.12	0.44	14.30	883.60
Dr. Arcadio	73.286	Primary	4	Divided	Asphalt	0.50	0.46	17.00	690.20
EDSA	69.136	Primary	4	Divided	Asphalt	0.20	0.17	12.00	531.00
Aurora Blvd	72.664	Secondary	3	Divided	Asphalt	0.41	0.70	14.25	757.20
TM Kalaw	70.549	Secondary	3	Divided	Asphalt	0.11	0.19	10.93	227.40
Mindanao Ave.	76.063	Secondary	3	Divided	Asphalt	0.11	0.12	13.50	853.40
Quirino Ave.	67.764	Tertiary	2	Divided	Asphalt	0.27	0.29	9.16	168.00
Boni Serrano Ave.	69.737	Tertiary	1	Undivided	Asphalt	0.18	0.32	18.00	192.40
Sto. Domingo St.	64.656	Tertiary	2	Undivided	Concrete	0.33	0.10	24.30	62.80

Table 5 Comparison of mean L_{eq} values for different categories ($\alpha = 0.05$)

Categories	Levene's Test for Equality of Variances		T-test for Equality of Means	
	Levene Statistic	Significance	Test Statistic	Significance
Undivided vs Divided	0.262	0.611	-4.729	0.000
Concrete vs Asphalt	19.896	0.000	-1.484	10.834
Primary vs Secondary	0.083	0.776	-1.396	0.174
Primary vs Tertiary	0.077	0.784	5.644	0.000
Secondary vs Tertiary	0.001	0.974	6.687	0.000

5.2 Multiple Linear Regression Model

5.2.1 General MLR model

The general MLR model generated using 75% of the complete dataset (n=34) is presented below:

$$L_{eq}\,(dB) = 51.13 + 8.104Log(Vehicles) + 16.07(\%Heavy) - 0.777(Lanes) \qquad (3)$$

Where,
Vehicles: total vehicle volume per 15 min
%Heavy: percentage of heavy vehicles in total volume
Lanes: number of lanes per direction

The magnitude of the constant, which is approximately 51.13, would correspond to the ambient noise or the sound pressure level when no traffic is present along the road. This value is comparable to the lowest L_{eq} values (within 1 second) recorded along tertiary roads particularly Sto. Domingo St., which also had the lowest vehicle count. Moreover, this sound level is within the 55 dB allowable noise standard for residential areas according to the provisions of the NPCC. Moreover, the obtained regression coefficients indicate that the sound pressure level has a positive correlation with the logarithm of the total vehicle volume and percentage of heavy vehicles. This means that the sound pressure level is to increase by 8.104 dB and 16.07 dB for every one-unit shift of the log(vehicles) and %heavy variables, respectively. On the other hand, the lane count was observed to have an inverse correlation with the sound pressure level given the negative coefficient. This suggests that the L_{eq} is predicted to decrease by 0.777 dB when the variable lanes go up by one. All predictor variables of the generated model are also observed to be statistically significant given that their p-values are less than the significance level of 0.05. Furthermore, no severe correlation between each of the predictor variables is expected as their corresponding Variance Inflation Factor (VIF) are all less than five (5).

Additionally, the generated regression model has also provided an acceptable coefficient of determination (R^2) value of 0.876 which suggests that 87.6% of the variation in the dependent variable is explained by the independent variables. Conversely, this indicates that, given the significant independent variables included in the model, the sound pressure level is predicted with an accuracy of 87.6%. A standard error of the estimate of 1.235 is also obtained for this regression model implying that the actual sound pressure level varies by ±1.1235 dB compared to the predicted sound pressure level.

5.2.2 Categorical MLR Models

Regression models were also generated per category depending on several factors (Table 6). Similar to the general model, Log(Vehicles) and %Heavy were the independent variables that were most significant for divided roads. However, the model for undivided roads had only one significant variable, which is Log(Vehicles). This may be due to it having a smaller dataset compared to divided roads. Furthermore, the constant of the divided model was observed to have a higher value compared to that of the undivided model. This agrees with the mean comparison of L_{eq} values performed in the previous section, which states that divided roads yielded higher mean L_{eq} values compared to undivided roads.

Table 6 Regression equations of categorical MLR models

Category		Model	n	R^2
Road Barriers	Divided	$L_{eq} = 55.599 + 5.405Log(Vehicles) + 23.212(\%Heavy)$	35	0.745
	Undivided	$L_{eq} = 46.78 + 10.016Log(Vehicles)$	10	0.912
Road Surface	Concrete	$L_{eq} = 51.084 + 7.572Log(Vehicles)$	10	0.991
	Asphalt	$L_{eq} = 57.046 + 4.797Log(Vehicles) + 25.255(\%Heavy)$	35	0.864
DPWH Road Classification	Primary & Secondary	$L_{eq} = 57.793 + 4.617Log(Vehicles) + 23.894(\%Heavy)$	30	0.63
	Tertiary	$L_{eq} = 68.602 – 1.973(Lanes) + 3.108(Surface^*)$	15	0.895

**Surface*: 0 – concrete roads, 1 – asphalt roads

Similar results were observed from the generated models depending on the road surface, comprising of concrete and asphalt. Log(Vehicles) and %Heavy were the variables which yielded the highest correlations with the sound pressure level, with only the former having a sufficient p-value to be used in the final model for concrete roads.

Lastly, MLR models were generated depending on the DPWH Road Classification. For primary and secondary roads, the variables that yielded significant correlations with L_{eq} are Log(Vehicles), and % Heavy. This was also observed with the previous models. On the other hand, for tertiary roads, Lanes and Surface were the variables which exhibited significant correlation with L_{eq}. Note that Surface is taken to be a dummy variable with a value of 0 representing concrete roads while a value of 1 pertains to asphalt roads.

As mentioned in the earlier analysis, the magnitude of the intercept corresponds to the noise level when there is no present traffic on the road. As observed, the intercept of the tertiary roads model had a significantly higher magnitude compared to the other categorical models as well as the general model which utilized 75% of the complete dataset. This discrepancy could be attributed to the kind of environment present on the study site, particularly in Quirino Avenue. As shown in Fig. 4, several establishments such as markets, hardware shops, and stores surround the length of the road and significant pedestrian volumes are also present. Thus, the high value of the model intercept may imply that the ambient noise along tertiary roads are also heavily affected by its external environment aside from the passing traffic.

Fig. 4 Vicinity of Quirino Avenue

Given the formulated regression models, the general model using 75% of the complete dataset would still be the most acceptable model because of its sufficiently high R^2 value of 0.876, and the higher number of independent variables which were considered significant. Although some of the categorical models yielded R^2 values greater than 0.9, these only had one significant independent variable. Moreover, these models were limited to a relatively small dataset and thus may have low representativeness.

5.3 Cross-Validation of the MLR Model

To determine and verify the prediction capability of the generated MLR model, cross-validation was performed using the remaining 25% from the total collected data. Given the information from the testing dataset, the model was used to predict L_{eq} values for each datapoint. The RMSE and average percent error were then calculated which yielded values of 1.3695 and -0.77% respectively. RMSE values and percent error magnitudes closer to zero would indicate better performance of the prediction model. Thus, it can be said that the MLR model has a sufficient prediction capability. It is also worth noting that the negative sign in the average percent error would indicate that the predicted L_{eq} values are generally lower compared to the actual measured values.

The predicted output from the model has been tested against the actual L_{eq} values using simple linear regression (Fig. 5). As shown, the model yielded a satisfactory coefficient of determination value (R^2=0.849) which reflect acceptable goodness of fit. Moreover, the slope of the fitted line is relatively close to 1.0, which indicates a high degree of accuracy in predicting L_{eq} values.

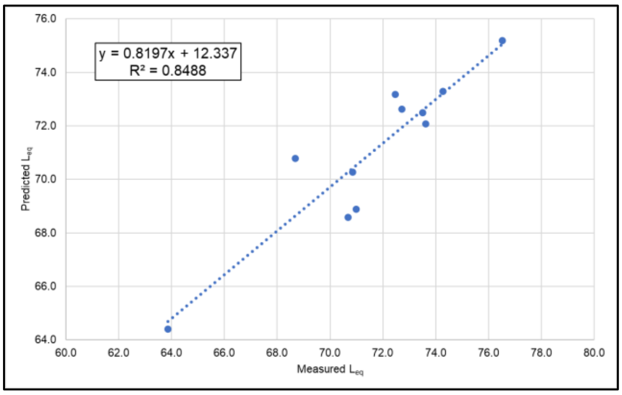

Fig. 5 Predicted vs measured L_{eq} plot

6. Conclusion

Transportation noise derived from roadside traffic continues to be a concern in highly urbanized areas such as Metro Manila, where frequent and excessive exposure to noise may negatively impact human behavior and performance. Based on the results from data collection, the average equivalent sound pressure level (L_{eq}) obtained from the nine study sites was 70.806 dB. Results from the performed one-tailed t-tests showed that the mean of the measured noise levels is not significantly greater compared to the 70 dB threshold stated by the CDC and well below the 75 dB threshold for commercial areas according to the provisions of the NPCC.

Of all multiple linear regression models generated, the general model was the best given its resulting R^2 of 0.876. The model showed that the equivalent continuous sound level (L_{eq}) along a given road segment is a function of the number of lanes, percentage of heavy vehicles, and the logarithm of the total vehicle volume over a 15-minute duration. All the independent variables were observed to be statistically significant ($p < 0.05$) and have no severe correlation with each other (VIF < 5). The magnitude of the model intercept was approximately 51.13 dB and is observed to be near the lowest recorded L_{eq} values along tertiary roads. This value would correspond to the sound pressure level when there are no vehicles present.

Similar with what most studies have suggested, the presence of large traffic volumes and a high percentage of heavy vehicles significantly contribute to noise generation along urban roads. Noise mitigating measures are important particularly in the case of Mindanao Avenue which was observed to have high vehicle volumes and percentage of heavy vehicles, and thus yielding the highest average L_{eq} of 76.06 dB. Several hospitals are present along Mindanao Avenue - given this, the high value of the measured L_{eq} greatly exceeds the maximum daytime allowable noise for hospitals and other healthcare facilities of 60 dB as established by the NPCC [15] and exceeds the allowable threshold of 70 dB stated by the CDC. To mitigate the transportation noise associated with the aforementioned factors, one strategy to consider is regulating the traffic by either totally prohibiting entry or imposing a specified time period to allow road access for the heavy vehicles. However, it is worth noting that solutions to mitigating transportation noise are seldom achieved by a single program but rather rely on a combination of programs.

This study also has the following recommendations to succeeding research:

1. To improve representativeness, it is recommended that future studies expand the dataset by increasing the number of study sites or the recording period for each location.
2. It is recommended to perform a more extensive study which considers more variables affecting sound propagation such as reflective surfaces, wind, and temperature gradients.
3. During the data collection process, the researchers were limited to recording from only one side of the road due to the limited equipment available. In line with this, the sound levels and video footage for both sides of the road could be recorded simultaneously to determine if there will be significant differences between the resulting datasets.
4. Long-term studies are important to investigate traffic seasonality in Metro Manila. In seasons where there is an increase in traffic volume, changes in equivalent sound pressure level may be observed. Thus, a more generalized model that considers the temporal variations within a day or even a year may be developed.

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Real-world Autonomous Vehicle and Environment Simulation in Chulalongkorn University

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Abstract

In recent years, autonomous vehicles correspond to the line attracting significant interest from investors and developers and were expected to be the prominent form of transportation in the future. However, prior to entering a market or operating a vehicle on the road, testing procedures and systems are necessary to evaluate the systems and decision-making of the vehicles to assure that they are capable of operating without endangering people or property. Still, there are some difficulties due to various constraints, i.e., the high cost of testing on actual vehicles, the amount of time required to prepare the vehicles as well as some limitations of the vehicles. Furthermore, testing in some scenarios, like the simulation of a pedestrian crossing in front of a vehicle, is risky and challenging to set up. On the grounds of this, testing in a virtual setting using built-virtual vehicles is utilized rather than testing in the real world to avoid damages and conveniently observe how the autonomous driving system performs in various circumstances. This study aims to create a digital twin map for Chulalongkorn University, build an autonomous vehicle model, and carry out virtual tests. Along with the collaboration between the open-source programs, including Carla, Autoware, Roadrunner, and Blender. Using the information we gathered from the actual world, such as pointcloud and the road dimensions. Roadrunner and Blender are used to create the virtual environment on the map, including roads, buildings, and trees. Together with the connection between Roadrunner and Carla, the map we created is implemented in Carla, the open-source simulation which will then generate scenarios using the map we created in collaboration with Autoware and ROS to operate the autonomous vehicle. To verify the simulation, the responses of the autonomous vehicle in the virtual world is expected to function approximately to the operating in the real world. Therefore, we compared reality and the digital world in low-speed changing lane situations. The results of the experiment revealed that the response was nearly the same in the actual world and the virtual world except for the origin of the map. Nevertheless, it made no difference to the experiment because the experiment is performed at low-speed.

Keywords: Autonomous Vehicle, Digital Twin

1. Introduction

An autonomous car is expected to be the vehicle of the future. In fact, the current algorithm has been developing over time. To ensure that it is safe enough to be operated with a vehicle on public roads, testing is key. Nowadays, tests such as receiving and delivering vehicle orders and algorithms, as well as road safety testing are available. Furthermore, considerably more testing is necessary to certify a vehicle's functionality. At any point, testing might fail, which will result in harm to both people and property, whether it is tested in a prepared place or in a predefined circumstance. Furthermore, setting up a car involves money and time, as damage to the vehicle is possible. There are also some limitations, such as car batteries and complex scenarios which are difficult to be conducted. In order to avoid possible damage, adopting virtual simulation in place of real-world testing can be a great way of testing. It is straightforward and takes less time and resources. This project intends to create a virtual place surrounding Chulalongkorn University along with a virtual comparable detailed automatic car. As it is conducted in a virtual environment and without external distractions, any variables can be determined instantaneously. It also paves the way for complex scenarios to be created, such as a simulation at an unsafe location like a red-light junction or a pedestrian crossing in front of a vehicle Additionally, it provides developers with a cost-effective tool to test their algorithms.

2. Literature Review

Digital twin

Virtual simulation is becoming increasingly important in vehicle development. For autonomous vehicles as well as ADAS [1], it is essential to use virtual simulation in terms of testing vehicle decision-making on relevant scenarios. The validation of virtual simulations versus real-world data has an impact on experimental outcomes. It is associated with vehicle dynamics. Accordingly, the road model needs to be accurate.

Available software

Software for creating virtual simulations is widely accessible. One of which is the Gazebo simulator [2], Gazebo uses the Open Dynamics Engine to generate physically convincing simulations in three dimensions that account for friction, forces, and rigid body dynamics [3].
rFpro is a simulation platform for testing and validating automobiles in photorealistic surroundings. To create detailed surroundings, the business provides LIDAR-scanned road surfaces and supports the HD map format [4].

Simulation

Unreal engine is a free and open-source programme for dealing with 3D models [5]. Along with Carla, a flexible simulation platform with complete management of static and dynamic actors and the ability to construct custom maps is available [6]. Also, it allows the plug-in with Autoware and RoadRunner. Carla can be used mainly in 3 approaches to evaluate autonomous driving, a modular pipeline which assesses visual perception and planning, end-to-end deep network training via limitation learning and the last one is end-to-end deep network training via reinforcement learning [6]. With the use of RoadRunner, the interactive editor, a custom map is able to be created. Roadrunner also supports the visualization of lidar point clouds, aerial imagery, and GIS data [7]. As well as Blender, the 3D editor program which Blender's comprehensive array of modeling tools make creating and transforming [8].

3. Methodology

This project is a representation of a virtual autonomous testing simulation in Chulalongkorn University's environment. It has been created in order to replace actual autonomous vehicle testing with simulation, which consists of three main parts: data collecting, model generation, and collaboration between programs. Along with the use of open-source programs as shown in Fig. 1. We divide programme utilization into three categories. The first is the builder, which includes Blender for modeling buildings and automobiles [8] and Roadrunner for modeling roadways and dealing with environmental car navigation. Secondly, the simulator, is a virtual simulation platform built with Unreal Engine and Carla. In the last one, we use Autoware as a controller for delivering commands to an autonomous vehicle in both the real-world and the virtual world.

Fig. 1 The three categories of programmes utilized in the project

With the collaboration between the programmes shown in Fig. 1, we are able to create the virtual testing simulation. Nevertheless, the predefined scenario is necessary to compare responses between the two worlds; the real world and the Digital twin. Respectively, we arranged a simulated circumstance in which we observed how the vehicle reacted in both the real and virtual worlds by giving the desired speed as the input to the Real vehicle and virtual world as shown in Fig,2. Then the vehicle is commanded to follow the path and speed we determined thorough Autoware.

3.1 Data Collecting

Data is needed in order to create vehicle models as well as a map. The information gathered will be used in two key ways, modeling a vehicle and modeling a map.

A low-speed test is a boundary of this project. Therefore, the parameters, required to set up the vehicle specification, are relevant dimensions of the vehicle, i.e., width, length, height, frame, wheel size, wheelbase, rear overhang, and front overhang [9] that as shown in Fig.3.

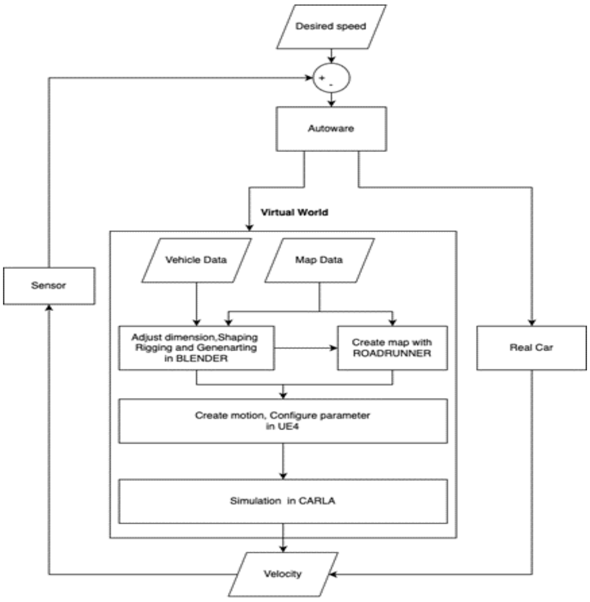


Fig. 2 Flowchart of the overall process

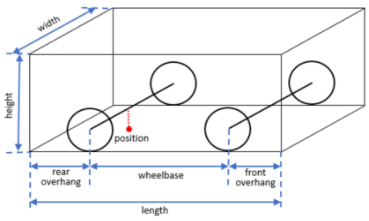


Fig. 3 Parameter required to configure a virtual autonomous vehicle.[9]

Similarly, modeling a map. GIS data such as OSM has been applied beneficial to get distributed buildings, the shape and also the length of the roads. Nevertheless, having precise and reliable data is also essential. As a consequence, measuring tools and VIDEO recording have been combined to identify road width and road direction in complicated situations.

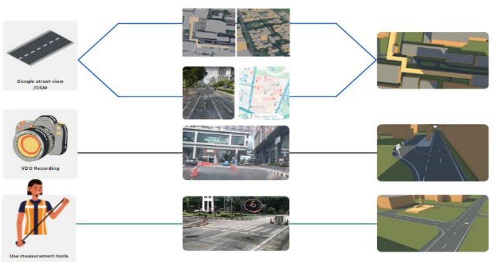


Fig.4 Three approaches for modeling a map

3.2 Model Generation

A vehicle modeling

Blender is used to model automobiles with the information we gathered. Olli Driverless Local Motor Bus 3D model was modified with Turing T2 specification regarding a dimension parameter. UE4 rigging Plug-in is utilized for rigging a model that is shown in Fig.5.

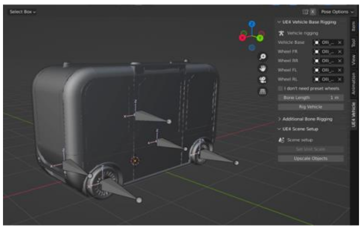


Fig. 5 Rigging a model using UE4 rigging Plug-in

The Unreal Engine 4 programme is used to configure parameters such as vehicle colliders, material and animation as shown in Fig.6.

Fig. 6 Configuring vehicle model material in Unreal Engine 4

Moreover, The CU TOYOTA Ha:mo virtual model was made using Blender. The BMWISetta, vehicle model available in the UE4 library was editing dimensions, i.e., width, length, wheel size, wheelbase, etc. according to the physical one as shown in Fig.7.

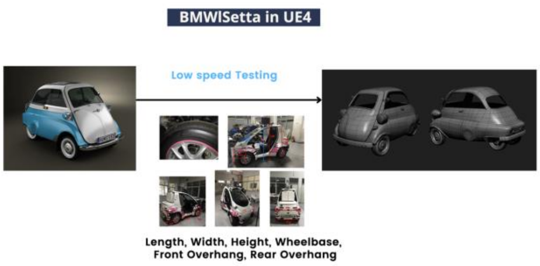


Fig. 7 Editing dimensions of BMWISetta models available in the UE4 library using CU Toyota Ha:mo specification.

A map modeling

Roadrunner is used to make the characteristics of the whole map, which are built by specifying all of the parameters as if they were collected. Since the test is only undertaken at moderate speeds, the Dynamics model of the vehicle has no substantial impact on the outcome. Contrarily, the discrepancy in road width might lead to unexpected outcomes, particularly in narrow cornering situations. Some scenarios, such as autonomous decision-making, need the environment and also pedestrians. For this reason, the routes all over the map are also crucial.

Fig. 8 Comparison between the real-world and the virtual world

3.3 Collaboration between Programs

To implement and achieve this project objective, we used a simulator named CARLA for generating the ego vehicle, a vehicle that attached all required sensors to use in an autonomous algorithm and environment. The Carla simulation consists of client-server architecture. Everything related to the simulation itself is handled by the server, including sensor rendering, physics calculation, or updates on the world-state and its actors. Moreover, users are able to write python or CPP scripts to call the actors on scene and set world condition [10]. Within the simulation, the vehicle's physical engine interacts with the environment, such as vehicle dynamics, behaviors when crashing the objects, contacting between the vehicle's wheels and road surface, etc. Thus, Unreal Engine 4 performs the physical engine together with Carla simulation. Carla's architecture is shown in Fig.9.

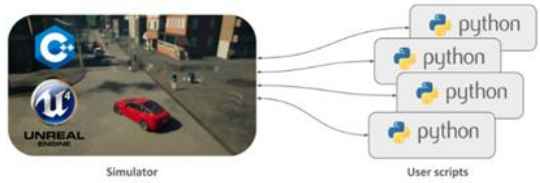


Fig. 9 Carla simulation architecture

The Carla simulator was also integrated with Autoware.ai, an open-source software stack for self-driving vehicles, built on the Robot Operating System (ROS). It includes all of the necessary functions to drive an autonomous vehicle from localization and object detection to route planning and control [11], for autonomous driving control in ego vehicles. Autoware.ai system architecture is shown in Fig.10.

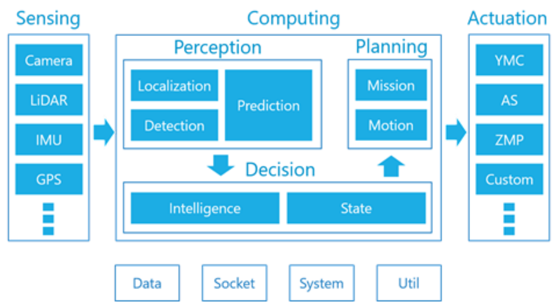


Fig. 10 Autoware.ai system architecture

To connect both software, ROS bridge and Autoware bridge were used for sending messages to each other shown in Fig. 11.

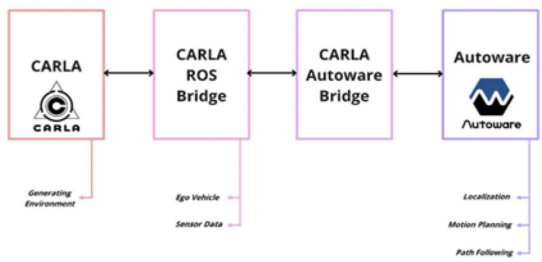


Fig. 11 Carla & Autoware integration

To operate the autonomous driving system, we need a point cloud map which gathers from a lidar sensor used for the localization algorithm. This map is crucial to locate the vehicle itself. To collect the point cloud data, ROS bridge has a service that spawns ego vehicles on the scene to be controlled by the user in manual mode. The point clouds data is shown in Fig. 12.

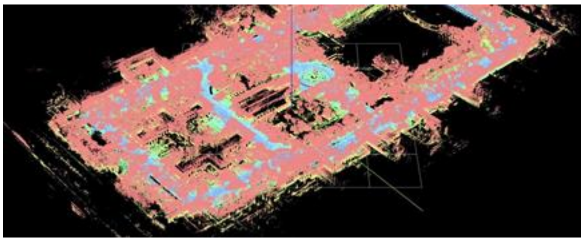


Fig. 12 point cloud data

After the point cloud map is generated, we also build a vector map which gives information of the road network for navigation [12] using TierIV vector map builder and assure map tools. The vector map is shown in Fig. 13.

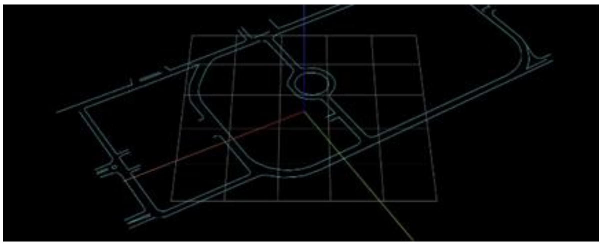


Fig. 13 vector map

4. Evaluation

To begin with, the waypoint was defined as the route that was received from manual driving the CU Toyota Ha:mo in low-speed. The path was defined as the route that was automatically generated with the Path Following function via Autoware.

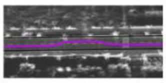
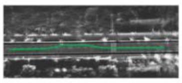
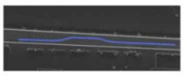
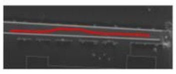
	Waypoint	Path (Autonomous)
Real world		
Virtual world		

Fig. 14 Waypoint and Path between the Real-world and Virtual-world

This project compared the data of way point in real world from manual control (pink line graph) and the data of waypoints in the virtual world from transforming real world origin to virtual (blue line graph). The data is shown in Fig. 14. To find the characteristic of the route in virtual-world. In addition, the pink line graph was generated path in the virtual world (red line graph) and path in the Real-world (green line graph) for observing the response of the autonomous vehicle by comparing the pink, red and green line graph and finding the value of offset distance.

5. Results

The results were divided into 3 main parts. As a consequence, we developed the digital twin worlds with all of the details in specific areas as well as the virtual vehicles in order to simulate the autonomous vehicle for testing in specific circumstances. Lastly, we evaluate by comparing the responses between two worlds; real world and virtual world by giving them exactly the same commands.

For the map models. We developed the five maps that represent the Digital Twin world model, as illustrated in Fig. 15. Map3 was primarily used in the evaluation. The surroundings are thoroughly described on the map, including the buildings, white lines, trees, road width, and road direction.

Fig. 15 Map boundaries

Although, the dynamic model of the virtual vehicle come with default setting from Unreal Engine 4 due to low-speed testing, The virtual vehicle "Turing T2" had identical dimensions as the real-world vehicle using Blender program and same material that configuring in Unreal Engine 4 as shown in Fig.16.

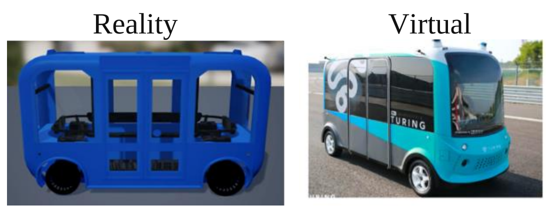


Fig.16 Comparison of the autonomous vehicle between the real-world and virtual-world

Accordingly, the virtual CU Toyota Ha:mo model was modeled using the BMWISetta model from UE4 library as a blueprint and had identical parameters that were relevant dimensions of the vehicle with the CU Toyota Ha:mo as shown in Fig.17.

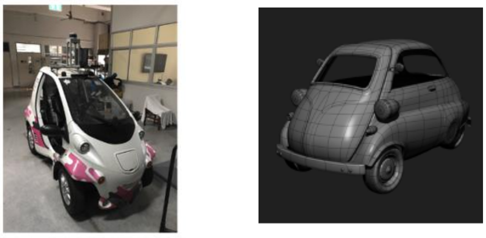


Fig.17 Comparison of the autonomous vehicle between the real-world and the virtual world

A waypoint comparing the actual and virtual worlds indicated that the outcome was nearly the same, although the virtual world's origin rotated 0.96 degree counterclockwise from the real one. The data was shown in Fig. 18. However, a virtual autonomous car executed orders perfectly because there was no external disturbance.

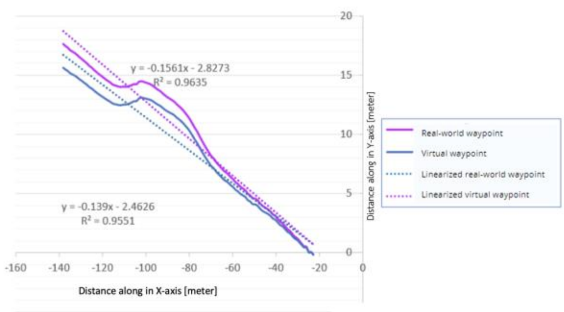


Fig. 18 Graph of comparison between Real-world waypoint and Virtual-world waypoint.

However, The real-world waypoint and the Virtual-world path had the same path characteristics, the real world waypoints were more uneven than the virtual world paths because the real world waypoints were manual driving in which the control system of the car with a time delay, but the path of the virtual world was a simulation which is an ideological movement. The data was shown in Fig. 19.

The real-world waypoint and real-world path had the same trend line, but it was indented to the right side of the real-world waypoint, with the maximum distance of 0.478 meters. Because the reality control system had a problem with the steering system and was disturbed by the roughness of the road. The data is shown in Fig. 19.

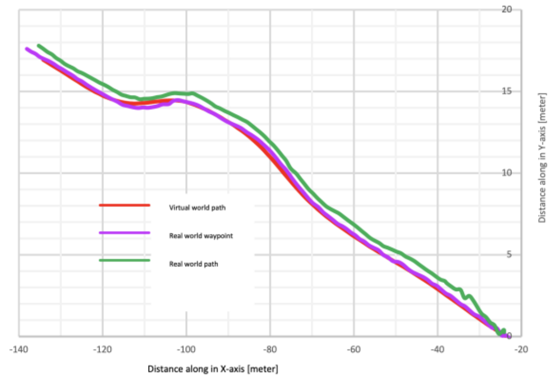


Fig. 19 Real-World Waypoint, Real-World Path and Virtual-world path Graph

6. Conclusion

In conclusion, it is undeniable that virtual driving tests play a fundamental role in aspects of software development. Therefore, this study aims to simulate a virtual autonomous vehicle at low-speed testing in a virtual map which is simulated the environment of Chulalongkorn university using Carla-Autoware integration.

The main findings are as follows: The simulated world map can be used to test simulated automated vehicles. This is because the response of an autonomous vehicle in the virtual world corresponds to the characteristics of the waypoints ordered.

An implication of this study is that before creating a waypoint in the virtual world to be utilized in the Real-world, the waypoint should be transformed using an angle of 0.96 degrees clockwise.

In addition, after the CU Toyota Ha:mo is tested in the virtual Chulalongkorn university map, the distance between the car and the roadside should be set to at least 0.478 meters to prevent accidents in the Real-world testing. Another autonomous vehicle should be tested in this virtual map before having been tested in Real-world to find the specific offset distance every time.

However, the system accomplished the study's objectives and also led to the design of additional experiments in the future by using links between the software of the autonomous algorithm, automobile models, and the custom map in the campus area.

7. Acknowledgement

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SESSION 3.1: AYRF 2022 RESEARCH PAPER PRESENTATION

From Paper ID: 017-2022, 018-2022, 019-2022, 020-2022

PAPER ID/ Page No.	Paper entitled	Presented by
017-2022 p.145-156	"Proposal on Indicators and Methods to Assess Sustainable Development of Urban Public Transport in Vietnam"	**Mr.NGUYEN QUANG THANH** University of Transport and Communications, Vietnam
018-2022 p.157-167	"Management of Public Transport in Hai Phong city, Vietnam: A Serious Improvement to Success"	**Ms.VU KHANH LINH** Binh An Construction Company, Ho Chi Minh City, Vietnam
019-2022 p.168-178	"Low-Carbon Urban Transport: Policy Context in Vietnam and Development Orientation in Hai Phong City"	**Mr.NGUYEN HUU HA** University of Transport and Communications, Vietnam
020-2022 p.179-186	"Analysis of Efficiency of Urban Public Bus Transport: A Case Study in Hai Phong City, Vietnam"	**Mrs.VU THI PHUONG HOA** Department of Natural Resources and Environment, Hai Phong People's Committee, Vietnam

Proposal on Indicators and Methods to Assess Sustainable Development of Urban Public Transport in Vietnam

Topic number: 3 Paper Identification number: AYRF 017-2022
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Abstract

The increase in motorcycles and cars in developing countries has caused serious air pollution, congestion and accident, especially in urban areas. In this context, development of public transport has become one of the top priority targets in order to serve the increasing transport demand and thus contributing to the sustainable development of the cities. This is also indicated in the development strategy of public transport services in the big cities of Vietnam. However, recent studies showed that quality of public transport is not adequately attended during operation process. The public transport system exhibits significant limitations that make it unsustainable. The main reason is due to limitation of development and management. Constantly improving quality of public transport are one of the most important goals to ensure the sustainable development of public transport.

The main objective of the study is to review the current situation of public transport in the big cities of Vietnam. Then, a list of indicators and an assessment method would be proposed to analyze the main factors affecting public transport. The results could be useful in measuring efficient solutions to improve public transport towards sustainable development.

Keywords: Vietnam, Indicators, Quality, Public transport, Sustainable development.

1. General Introduction

Public bus transport operated on 60/63 provinces and cities nationwide with nearly 10,000 vehicles and 280 service providers; in which concentrated mainly in big cities of Vietnam, such as Hanoi, Ho Chi Minh city (HCMC), Da Nang, Hai Phong and Can Tho. Public bus transport strongly operated in Hanoi and HCMC. Specifically, Hanoi has 124 routes, 1,200 buses, carrying over 400 million passengers/year; Ho Chi Minh City has 128 routes, over 2,200 buses, carrying 350 million passengers/year. In addition, urban railway projects such as: Cat Linh - Ha Dong route, Nhon - Hanoi station route (in Hanoi); metro line 1 (Ben Thanh - Suoi Tien), line 2 (Ben Thanh - Tham Luong) in HCMC have been building and completing. (MOT, 2016) Actually, looking at the potential of public transport from now to 2030, development will still focus on the bus system. After the urban railway projects are completed and put into use, the bus system will play the connecting system to mass rapid transit (MRT).

Up to now, although the public transport network has been appropriately adjusted and expanded, development of urban public transport in Vietnam has only achieved initial results, improvement of quality is still limited. In particular, there is only one type of public transport by bus and one route bus rapid transit (BRT) in Hanoi. The system with weak infrastructure and network is not synchronous and does not cover the whole urban area. Especially the quality of public bus transport is not up-to-date and lags behind in comparison with the increasing quality of services in other sectors (e.g., freight forwarding, logistics, shops and banks). Urban public transport also have to face a series of challenges regarding the number of users, providing them with the necessary mobility, quality at the highest level and the system reaction time as low as possible. These are the reasons leading to the situation of personal vehicles is constantly increasing.

Currently, urban transportation in the cities mainly is private vehicles, equivalent to approximately 70% of the trips while the bus only meets less 10% of the city's travel needs. Currently, Hanoi's bus system contributes about 8-10% travel need, HCMC about 7-8% and others cities only contribute less 5%. The share of public bus transport in Hanoi, Ho Chi Minh City and other big cities are not still as expected and not meeting according to the master plan. These limitations are due to the lack of linkage between urban and transport planning and the conditions for public transport do not meet the requirements for sustainable development. Besides, the problem of encouraging people to ride bus is not only in fare structure but also in capacity and quality. The current fare is quite suitable for low-income people such as the elder, students, workers...However, bus riders are mainly people who do not own a personal vehicle or cannot control individual vehicle without including other objects. The Transport Development Strategy of Vietnam vision to 2030 also defined the basic requirements for development of public transport. The goal is Transit-oriented development with quickly develop bus and mass rapid trasit systems in big cities, ensure share of public passenger transport from 15-20% by 2025, 25-30% by 2030; increasing control of personal vehicles and environmental protection (MOT, 2016). Although not impossible, it can be doubted if it is realistic. There seems to be a large gap between policy targets and implementation. This contradiction between planning and reality indicates that an improvement is needed for sustainable development.

2. Theoretical Foundation

2.1 Sustainable Development of Public Transport

One such definition, from the European Union Council of Ministers of Transport, EUCMT (2003) defined a sustainable transportation system as a transportation system must provide optimal transportation capacity and ensure affordable cost for both supplier and user. In addition, the transportation system must positively impact on the environment, save fuel and gradually reduce participation of personal vehicles.

Public transport system is an integral part of urban transportation system. It includes all related services with the entire infrastructure for operation of vehicle to serve travel needs. The system organization must be complete with a combination of five elements: route network; infrastructure; means of transport; service system; transport management and operation system. Organization and management of public transport system in urban area as in Figure 1 below:

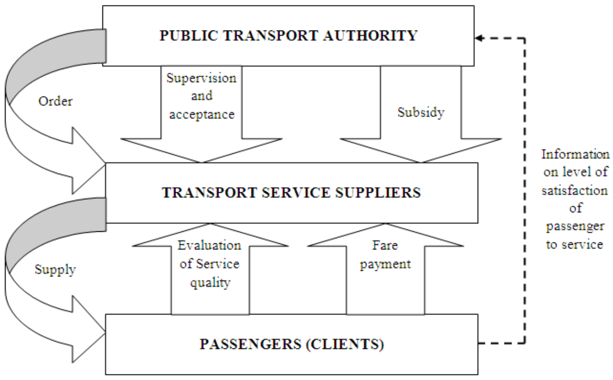

Fig. 1 Organization of public transport system in urban area

For operation of public transport, in addition to above directly affect factors to conditions of operation, it is also influenced by many other socio-economic factors, such as: natural conditions and economic growth of the urban, scale of population, urbanization, development of science and technology, investment, institution and policies, impact of natural disasters and epidemics...These factors affect the user's needs and travel habits. They can also positively or negatively affect the trend in the development of transport modes and the formation of transport routes.

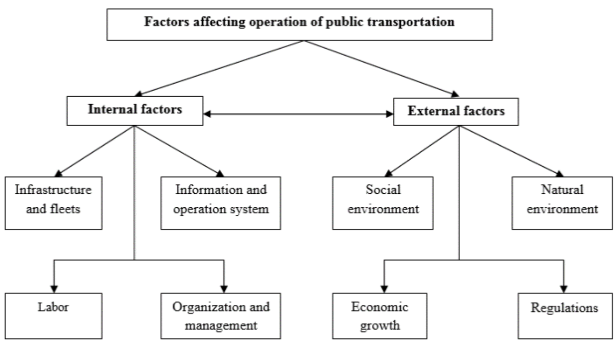

Fig. 2 Factors affecting operation of public transport system

Public transport is regarded as one type of common public services in urban areas in the world. Notwithstanding, the popularity of public transport in almost all big cities does not mean that it can meet user expectations, in other words its quality needs to be enhanced progressively. Therefore, development of public transport is a transformation, increasing in a positive direction in the size and quality of public transport system (route network, infrastructure, vehicles and technology) and executive management capacity to meet the increasing travel demand. The development process must be done synchronously and in accordance with long-term planning and strategy.

The author said that the concept of sustainable development of public transport can be defined as: *"the development of public transport is continuous, stable,long-term that maximizes the current travel needs without compromising the ability of future generations to meet that travel needs".* The development of public transport must ensure 5 goals, namely economic (economic efficiency), society (equity - social welfare), environment (environmental protection), institution (institution politics - executive management capacity) and finance (ensure financial resources). At the same time, it must also ensure a balance of benefits between the subjects who play in the process of providing public transport service, namely the State (Public Transport Authority - PTA), the Operators and the users (passengers).

2.2 Assessment of Sustainable Development of Public Transport

To evaluate the public transport system, a system of criteria or indicators related to public transport is often used. Approach towards standardization, service quality in public transport in Europe was developed according to the requirements of the EN 13816 standards (2002) and EN 15140 standards (2006) with a complex system of indicators (based on the three-level structure with 8 criteria: Availability, Accessibility, Information, Time, Customer care, Comfort, Security, Environmental Impact and 103 indicators). These are the guiding framework for managing public transport activities in Europe. Enny Karlsson (2010) used indicators in EN 13816 standard (2002) to assess the suitability of facilities in public transport service and propose measures in order to increase utilities in accordance with expectation of users in Gothenburg city (Sweden).

Research on efficience of public transsport, Chhavi dhingra (2011) developed principles to select the appropriate criterias and indicators to evaluate the performance. At the same time, the author set out steps to measure the effectiveness of public transport system according to the identified objectives. Research on sustainability of public transsport, Miller, P. and colleagues (2014) proposed a set of indicators to evaluate a sustainable public transport system based on 4 criterias: economy, society, environment and efficiency of system with 29 specific indicators. Although these indicators are highly quantitative, the determination of the indicators is relatively complicated. Therefore, the authors introduced a system of scientific arguments and a series of technical tools to clarify relevant problems based on the qualitative approach rather than the quantitative indicators. Chris De Gruyter, Graham Currie and Geoff Rose (2017) selected 15/29 indicators in the study of Miller, P. and colleagues to assess sustainable public transport in cities of the Asia/Middle East Region. Graham Currie and Chris De Gruyter (2018) reused 15 indicators in the study of the authors Chris De Gruyter, Graham Currie and Geoff Rose to analyze and compare in different regions and focus on affect of urban land use to sustainability of public transport. The authors A.M.Ngoc, K.V.Hung, V.A.Tuan (2017) considered customer's behavioural aspects while attempting to develop a set of quality standards for public transport services in developing countries and addressing the applicability of various criteria under those specific conditions. According to the research direction to evaluate performance of public transport service from supplier's viewpoint, An Minh NGOC (2017) assessed the satisfaction level of passengers for service quality according to 8 criterias of the EN 15140 standards (2006) with a number of performance indicators.

In Vietnam, there are no specific studies on sustainability indicators for public transport. There are many researches on public transport but mainly focusing on service quality assessment and customer satisfaction. From the perspective of state management, the Ministry of Transport (2017) has issued a System of Statistical Indicators in transport sector with 32 indicators belonging to 7 groups of criterias: infrastructure, investment capital, means, fuel consumption in transport industry, results of transport activities, labor, and results of enterprises. However, they are only of statistical indicators to serve specialized state management.

3. Proposal on Criterias and Indicators to Assess Sustainable Development of Urban Public Transport in Vietnam

3.1 Content and Requirements of Sustainable Development of Public Transport

Toward sustainability, development of public transport must ensure the following content and requirements:

- Ensure economic efficiency, meet urban development requirements, satisfy travel needs with good quality, connect transport modes throughout the network, contribute to save travel costs and the overall cost of whole society.
- Ensure fairness and meet the travel needs of all people. The system must increase accessibility and contribute to reducing traffic congestion and attracting users.
- Ensure friendliness and environmental protection, rational use of resources, using clean fuel vehicles.
- Based on long-term master plans and appropriate mechanisms and policies, enhancing connection between the State and transport enterprises.
- Ensure sustainable financial resources, especially stable, continuous and long-term investment capital, balancing between investment and maintenance capital of public transport system.

3.2 Proposal on Criterias and Indicators

In Vietnam, the standard regulations on statistical indicators have not still established (including concept, calculation method, main disaggregation, release period and data sources, organizations in charge of collecting and aggregating) for the overseeing, monitoring and evaluation of implement. It is necessary to establish the sustainability indicators of public transport. This enables the recognition of the deficiencies in the operation of the system as well as support in the decision making of City government in supporting public bus transport. However, making the future operating threshold and sustainability indicators is not a simple job because the bus transport system has been undeveloped, not yet professional operated, the financial investment is limited and small. Requirement of overestimating is unrealistic. Most current assessment is based on the guidance in law, national and international experience.

The criterias and indicators should be established according to "the SMART principle" as below:

- Specific: target a specific area for improvement.
- Measurable: quantify or at least suggest an indicator of progress.
- Assignable: specify who will do it.
- Realistic: state what results can realistically be achieved, given available resources.
- Time-related: specify when the result(s) can be achieved.

Based on analysis of the above problems, so as to make public transport really attractive, it is necessary for calibration and indicators of operations at a minimum level. It will be supplemented and raised to higher level by time. The activity data of public transport should be collected annually to be able to assess and monitor the change of the operation index. Some data may be conducted by interviewing passengers. Some other figures should be collected automatically and continuously by electronic devices including Automatic Vehicle Location System (AVLS); Automatic Passenger Counters System (APC); Automatic Fare Collection System (AFCS); Camera system installed on vehicle.

The sustainability indicators must be compatible with the indicators in the public transport sector. There are a number of indicators that need to be calculated accurately, but there are also indicators that can be estimated relatively. To make an objective assessment, it is necessary to collect sufficient data to compare the situation between cities on the defined standard or score for ranking, and consider the level of sustainable development.

The set of sustainable development indicators for public transport includes 6 groups of general criteria and 35 specific indicators. The indicators in 5 groups of criterias: Economy - finance - society - environment - institution. They show the relationship between socio-economic development and development of urban public transport. Typical group of criterias for the development of public transport system: including indicators which reflect the development status, directly affecting to scale and capacity of the public transport system. The set of indicators include indicators which affect development of public transport by different levels of influence. Indicators with positive effects should tend to increase while indicators with negative effects should tend to decrease. Moreover, indicators should be quantifiable and suitable to the development of urban public transport in Vietnam.

Table 1 Proposal on criterias and indicators to assess sustainable development of urban public transport in Vietnam

Criterias	Performance Indicators	Significance of indicators	Calculation method / Statistics	Responsible subject
1. Group of economic criterias	GDP Per Capita of the urban area (USD/year)	This indicator demonstrates the speed of urban economic growth	Basic statistics	State
	Average GDP growth rate in 5 years (%)	This indicator demonstrates the speed of urban economic growth	Basic statistics	State
	Proportion of service sector in economic sectors (%)	The indicator reflects the level of investment in service sector compared with other economic sectors	Basic statistics	State
	Proportion of transport service in structure of service sector (%)	The indicator reflects the development of transport services compared to other service sectors	Basic statistics	State
2. Group of financial criterias	Proportion of social investment capital of the urban area compared with the whole country (%)	The indicator shows scale of investment in socio-economic development of urban areas	Basic statistics	State
	Proportion of foreign direct investment (FDI) of the city compared to the whole country (%)	The indicator shows scale of investment in socio-economic development of urban areas	Basic statistics	State
	Proportion of transport sector's investment compared to the urban's total social investment capital (%)	The indicator shows scale of investment in socio-economic development of urban areas	Calculated by the transport sector's investment capital /the urban's total social investment capital	State
3. Group of social criterias	Rate of natural population growth (%)	This indicator shows scale of urban development	Basic statistics	State
	Urbanization rate (%)	This indicator shows scale of urban development	Basic statistics	State
	Percentage of trained labor (%)	This indicator shows scale of urban development	Basic statistics	State
	Total length of urban road network (km)	This indicator shows the capacity to serve transportation needs of infrastructure	Basic statistics	State
	Growth rate of road motor vehicles (%)	This indicator shows the capacity to serve transportation needs of infrastructure	Basic statistics	State
4.	Proportion of land use for urban transport works (%)	This indicator demonstrates the ability to meet use of urban space	Calculated by the land area to construct transport works /	State

Criterias	Performance Indicators	Significance of indicators	Calculation method / Statistics	Responsible subject
Group of environmental criterias			Total land area of urban	
	Growth rate of land use for urban transport (%)	This indicator demonstrates the ability to meet use of urban space	Calculated by average land use growth rate in 5 years (%)	State
	Rate of pollution caused by urban transportation (%)	The indicator shows the level of environmental impact of transportation activities	% level of fare/average income of 1 month	State
	Rate of GHG emissions from urban transportation activities (%)	The indicator shows the level of environmental impact of transportation activities	Calculated by the amount of CO_2 emissions due to transportation activities / Total CO_2 emissions in the urban area	State
5. Group of institutional criterias	Provincial Competitiveness Index of Vietnam (PCI)	PCI INDEX is designed to assess and rank the performance, capacity and willingness of provincial governments to develop business-friendly regulatory environments for private sector development	Calculated according to the average index of 3 consecutive years	State
	Public Administration Reform Index of Vietnam (PAR)	PAR INDEX is a set of indicators for evaluating the administrative reform of ministries, agencies and localities with the expectation that the PAR will be assessed in a quantitative way	Calculated according to the average index of 3 consecutive years	State
	Provincial Governance and Public Administration Performance Index of Vietnam (PAPI)	PAPI measures and benchmarks citizens' experiences and perception on the performance and quality of policy implementation and services delivery of all 63 provincial governments in Vietnam to advocate for effective and responsive governance.	Calculated according to the average index of 3 consecutive years	State
	Information and Communication Technology Index of Vietnam (ICT)	ICT INDEX is a set of indicators to assess level of the readiness for information technology development and application of provinces or cities	Calculated according to the average index of 3 consecutive years	State
6. Typical group of criterias for	Rate of investment capital for development of public transport in the total	The indicator shows the level of investment for development of urban public transport.	Calculated by investment capital for public transport / Total investment	State and Operators

Criterias	Performance Indicators	Significance of indicators	Calculation method / Statistics	Responsible subject
development of public transport system	investment capital for urban transport (%)		capital for urban transportation	
	Subsidy for urban public transport (billion VND / year)	The indicator demonstrates the state's ability to support for public transport	The calculation is based on the formula: Subsidy = Cost – Revenue The Cost and Revenue will be calculated by result of demand forecast and necessary assumptions are referred to the current situation public transport of cities.	State and Operators
	Length of public transport network (km)	The indicator shows scale of the urban bus network	Basic statistics	State and Operators
	Coefficient of length public transport network (km / km^2)	The indicator shows scale of the urban bus network	Calculated by route network length / Total urban population (ratio / 1000 population)	State and Operators
	Proportion of stations (stops) meet the design standards on the network (%)	The indicator shows scale of the urban bus network	Calculated by number of stations (stops) meet the design standards / Total of stations (stops) on the whole network	State and Operators
	Ratio of public transport vehicle / 1000 people (%)	The indicator shows the ability to serve travel needs of public transport vehicles compared to other vehicles	Calculated by number of public transport vehicles / Total of public transport vehicles on the whole network (ratio / 1000 population)	State and Operators
	Volume of public passenger transport (million passengers / year)	The indicator shows the operation results of urban public transport	Basic statistics	State and Operators
	Average speed of public transport vehicle (km/h)	The indicator shows capacity of the fleets to operate	Data survey	State and Operators
	Operating frequency of public transport vehicle (min / trip)	The indicator shows capacity of the fleets to operate	Data survey	State and Operators
	Ratio of the fare to the average income per capita per month (%)	The indicator shows level of expenses for people's travel by public transport vehicles	Calculated by travel costs by public transport vehicles / Average income per person per month	State and Operators

Criterias	Performance Indicators	Significance of indicators	Calculation method / Statistics	Responsible subject
	Share of public transport (%)	The indicator shows responsiveness of public transport vehicles compared to other vehicles	Basic statistics	State /Operators/ Users
	Rate of land use for public transportation system (%)	This indicator demonstrates the ability to meet use of urban space for public transport	Calculated by the land area to set public transport network / Total land area of urban	State and Operators
	Proportion of public transport vehicle using clean fuels (%)	The indicator shows responsiveness of public transport vehicles	Calculated by number of public transport vehicles using clean fuels / Total of public transport vehicles	State and Operators
	Percentage of trained managers and operators (%)	The indicator shows quality of human resources for developing public transport	Calculated by number of trained managers and operators / Total of managers and operators	State and Operators
	Percentage of trained drivers and service staffs (%)	The indicator shows quality of human resources for developing public transport	Calculated by number of trained drivers and service staffs / Total of drivers and service staffs	State and Operators

4. Proposal on a Method to Assess Criterias and Indicators of Sustainability of Public Transport

4.1 Proposal on Assessing Method

It is necessary to evaluate the set of indicators according to each period of implementation. The purpose is to examine level of its impact on sustainability of each group of sustainable development criterias and on sustainability of the whole system. Thus, managers can identify the prioritized solutions and ensure effectiveness. For example, at the time of the assessment, if the achieved indicators of the group of economy criterias reach the sustainable level, it is necessary to prioritize the implementation of solutions to others and opposite.

The author uses the weighted criterial method to evaluate level of sustainable development of public transportation system:

Step 1: Scoring each indicator and each group of criteria on a selected scale with weight (coefficient) adjustment (value of the weight represents the relative importance level of that group of criteria). Before adding scores, the score must be multiplied by the coefficient (short by Cof) representing importance level of each criteria.

Step 2: Analyzing the importance level of each group of criteria to multiply the coefficient

The author temporarily considers the economic, social, environmental criterias and typical group of criterias for development of public transport system to be more important than the institutional and financial criterias. The level of each group of criteria would be changed in increase or decrease of specific indicators as well as the situation of developmet of public transport.

The weight of criteria is as follows:

- Group of economic criteria: Cof 2
- Group of social criteria: Cof 2
- Group of environmental criteria: Cof 2

-Typical group of criterias for development of public transport system: Cof 2

- Group of institutional criteria: Cof 1
- Group of financial criteria: Cof 1

Step 3: Scoring and determining the total score that shows sustainability level of each criteria. There are 4 levels to evaluate sustainability of public transport: Indestructible, sustainable, less sustainable and unsustainable.

- Level A: Indestructible, 4 scores
- Level B: Sustainable, 3 scores
- Level C: Less sustainable, 2 scores
- Level D: Unsustainable, 1 score

Formula for determining the total score of criterias: $T = \sum_{i=1}^{n} M_i \times W_i$ Inside:

T is the total score representing sustainability of the criteria;

M_i is the score representing sustainability of the i^{th} criteria;

W_i is the weight of the i^{th} criteria;

n is number of the criterias.

Step 4: Developing a synthetic score to assess sustainability of criterias

Table 2 Synthetic score to assess sustainability of criterias

Group of criterias	Level and Score			
	A	B	C	D
Economic	8	6	4	2
Social	8	6	4	2
Environmental	8	6	4	2
Development of public transport system	8	6	4	2
Institutional	4	3	2	1
Financial	4	3	2	1
Total score (T)	**40**	**30**	**20**	**10**

Step 5: Determine the sustainability level of each criteria

In each group of criteria, there are many indicators that specifically reflect the impact on the sustainability of that group of criteria. Therefore, the sustainability level of each criteria needs to be determined by the calculated indicators, in combination with the following conditions:

Table 3 Conditions for evaluating the sustainability level of each criteria

Sustainability level of each criteria	Achieved conditions
Indestructible	All indicators must reach the maximum score
Sustainable	Least 2/3 of the indicators achieved the maximum score and none of the indicators achieved the lowest score
Less sustainable	Least half of the indicators did not reach the maximum score and none of the indicators achieved the lowest score
Unsustainable	There is no indicator with the maximum score or one of the indicators with the lowest score

Step 6: Applying the synthetic core of each criteria to assess sustainability level of the whole public transport system

From the above synthetic core, the minimum score for the public transport system to achieve the sustainable level is 30 scores. Sustainability level of the whole public transport system is determined as follows:

Table 4 The synthetic core to assess sustainability level of the public transport system

No.	Sustainability level	Synthetic core	Achieved conditions
1	Indestructible	$36 \leq T \leq 40$	Least 3 weighted criteria should be indestructible and others must be sustainable.
2	Sustainable	$30 \leq T \leq 35$	All criterias must be sustainable or 4 weighted criterias should be indestructible. The remaining criterias may be unsustainable and no criteria is unsustainable.
3	Less sustainable	$18 \leq T \leq 29$	Least 4 weighted criterias do not reach the

No.	Sustainability level	Synthetic core	Achieved conditions
			sustainable level.
4	Unsustainable	T < 18	There are no criteria to achieve the sustainable level

4.2 Applying the method to assess

With the 35 indicators of sustainable development as proposed above, setting an synthetic score by scoring corresponding scores on a scale of 0 - 4 with each indicator. Then, quantifying each indicator into value ranges corresponding to the identified score. Maximum of achieved total score of 35 indicators is 200 scores. In which, the important indicators are multiplied by the coefficient 2. Among the indicators, there are indicators with higher value, higher score (Indicators with positive effects to the system) and vice versa, there are some indicators with higher value, lower score (Indicators with negative effects to the system). Each indicator shows a certain influence on sustainable development of public transport system. Finally, determining the achieved total score of the system to assess level of sustainability. So, it is possible to identify tasks and solutions for adjustment in the future.

In case of the above sustainbility indicators are considered equally important, sustainability level of the public transport system would be evaluated according to the achieved total score. Conditions for evaluating the sustainability level is determined as follows:

Table 5 Conditions for evaluating the sustainability level of the public transport system according to the achieved total score of indicators

Sustainability level	Achieved total score of sustainability indicators
Indestructible	$180 \leq T_s \leq 200$
Sustainable	$140 \leq T_s < 180$
Less sustainable	$100 \leq T_s < 140$
Unsustainable	$T_s < 100$

4.3 Proposal on assessment mechanism

** Process:*

4-step process is recommended to implement sustainability indicators.

- Step 1: Developing a plan to implement the indicators

Determining requirements of resources, institutional framework and human resources to implement the indicators.

- Step 2: Forecasting impacts of the indicators on the system

Forecasting development trends and impacts of the implementation indicators on both positive and negative angles to ensure objectivity.

- Step 3: Implementing and evaluating results and effectiveness

It is necessary to analyze and evaluate effectiveness of indicators on both the perspective state management and operation of the operator to consider suitability of the indicators with the goals of developing public transport.

- Step 4: Adjusting and completing the solutions

In order to perform the indicators, it is necessary to build and adjust appropriate solutions, contributing to sustainability in the long term.

The 4-step process is recommended to implement sustainability indicators as in Figure 3.

** Assessment mechanism:*

Assessment should be carried out by Public Transport Authority (PTA) of the cities. It is the operator's responsibility to provide the operating data of public transport for the worthwhile time. PTA may cooperate with other agencies to conduct investigations, survey, collect data. Besides, the experts in transport sector, scientists, resident community representatives, etc., should also be invited to interview according to many different criterias. The clollected opinions would be useful to ensure objectivity of assessment results.

The assessment period should be based on duration and quality requirements of the service contract. Assessment results contribute to the regular monitoring of performance. It also helps the PTA realize the necessary tasks to develop the public transport system. Moreover, it is taken as a basis to select good operators to provide high quality service. Operators with high assessment results will receive incentives in tendering. In contrast, operators with low assessment results will face disadvantages. Finally, the asssessment results allows to propose expectations and the best solutions to enhance quality of public transport and attract users.

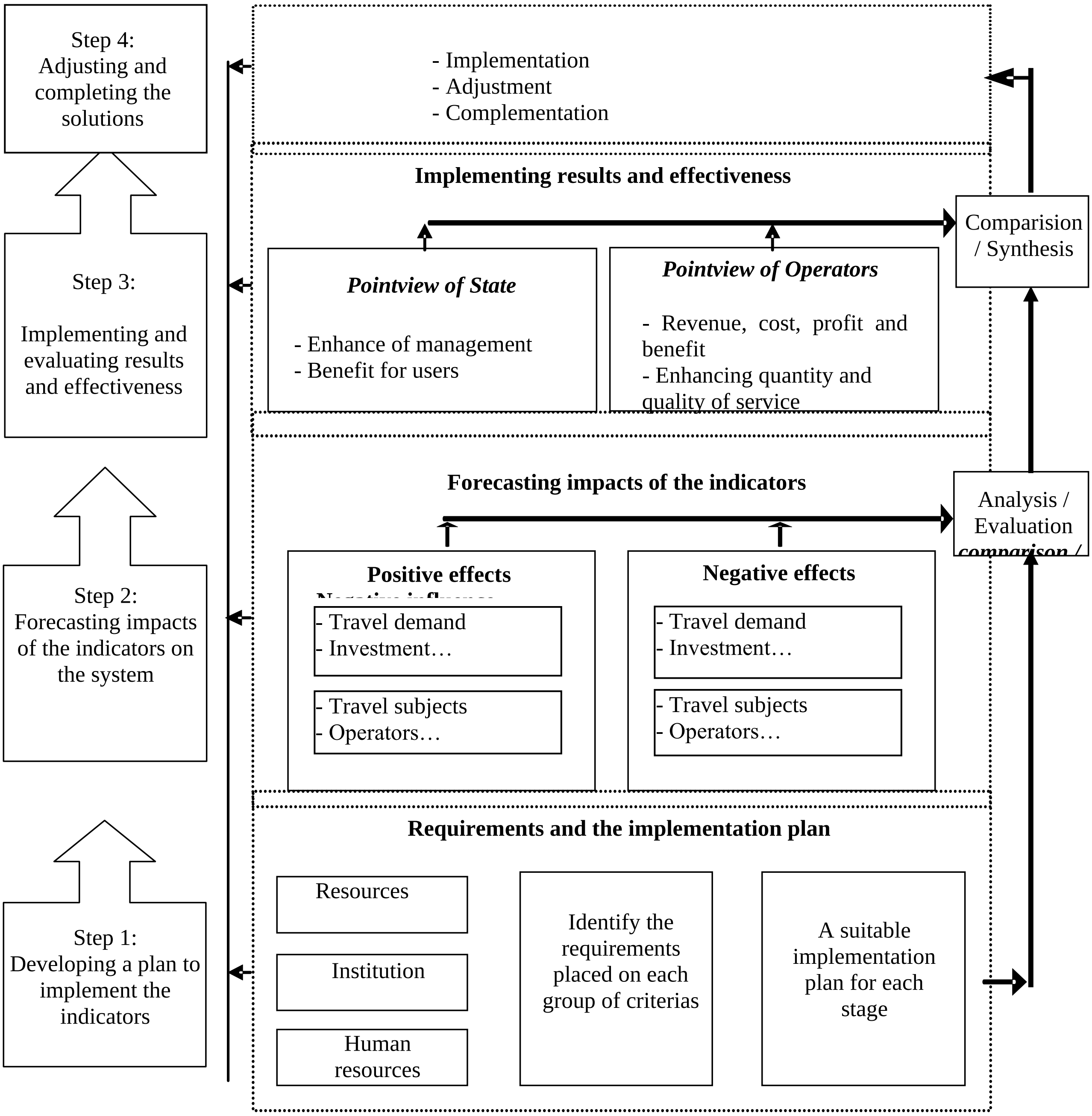

Fig. 3 The process to implement sustainability indicators of public transport

5. Conclusions and recommendations

To overcome the current limits in management and operation of urban public transport, managers need to implement many different solutions. In the framework of this study, the author focused on asssessment of urban public transport baased on criterias and indicators of sustainable development. This is a basic tool to standardize and improve operation capacity of the system. Describing the present public transport and finding out the main factors affecting sustainable development, the results contributed to propose a set of indicators and assessing method on sustainability. Understanding and assessing the actual needs are the important factors for sustainable development of public bus transport.

This study recommended the most suitable sustainable development criterias and indicators on public transport for cities of Vietnam. In order to develop indicators, there were raised descriptions, and the threshold of acceptance for each criterion. This paper also provides a proper measurement methods as well as the guidance for assessing the indicators. The implementation of sustainable development indicators in reality needs sufficient protection of regulations and good awareness of transport authorities and operators. Constantly Improving quality always presented as the fundamental requirementt to offer sustainability of urban public transport in the developing countries. Implementation of criteries and indicators for sustainable public transport always go hand in hand with development solutions. They set the stage for developing and managing successful and sustainable.

Response of quality public transport under scenarios is the future ridership per route and of the whole network. Such information is a base for proposing options that suit different needs of development. To reach the target of bus share 30% in 2030, and get further beyond it, the comprehensive improvements are very important. However, building up a share of 30% while the starting point is less than 10%, may take many years. Improvements should be made step-by-step to the extent that is affordable to the cities.

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Management of Public Transport in Hai Phong city, Vietnam: A Serious Improvement to Success

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Abstract

Hai Phong is one of the 5 largest cities in Vietnam. In more recent years, traffic jams and pollutions due to the increase in motorcycles and cars are a pressing issue in the city, cause a lot of impacts on society and economic development in urban areas. In the development strategy of urban transport, encouraging people to use public transport (PT) concerned Hai Phong City Government. The city government and enterprises are making efforts to increase the number of people using PT. However, recent reports showed that quality of PT is not adequately attented during operation process. The PT system exhibits significant limitations that make it unsustainable. The main reason is due to limitation of management. Constantly enhancing of PT management are one of the most important goals to ensure the sustainable development of PT. The main objective of the study is to review the current situation of PT in Hai Phong. Then, policy recommendations for effectively reaching the goal involve improvements on PT management, encouraging the use of PT and discouraging the use of private vehicles.

Keywords: Hai Phong, Public transport, Management, Sustainable development.

1. General Introduction

Hai Phong is a major industrial city and third largest city overall in Vietnam. The development of the city is facing many difficulties and challenges to be able to reach the worthy position with the potential of resource. The city is also experiencing rapid urbanization with these came motorization, mostly motorcycle-led, and its accompanying problems of street congestion, road accidents, and emissions. This has placed the city in front of the challenge of long- term sustainable growth with the desire is to become a modern and smart city.

In this context, public transport (PT) is expected as the key measure to deal with the transport consequences. However, the PT network with single bus type only meets less than 2% of the city's travel needs while that motorcycle takes up 80% number of trips in the city.[2] Besides, the quality of public bus service is getting worse and worse, making it less attractive to users. One among urgent matters for Hai Phong is to develop transport infrastructure and improve PT toward smart mobility city. The objective is to provide a good quality and smarter PT service. This should attract urban citizens to use PT thus reducing the traffic pressure caused by private vehicles.

According to the Master Plan of public bus transport orientation to 2030, Hai Phong will continue to maintain current bus route and open more routes linking the city center to districts and adjacent provinces. The city has plan to increase the number of passengers using PT from 31.6 to 63.2 million, meeting people's demands for travelling from 10 to 15%. Especially, the plan was also envisaged to introduce Bus Rapid Transit (BRT) for which 4 lines were proposed in 2030. At the same time, one Metro route would be implemented in the period after 2030.[2] The goals were proposed clearly and toward sustainable development. Although not impossible, it does not seem very likely unless political will and ensure sufficient budget.

The paper attempts to cover various aspects of PT management particularly in the context of Hai Phong city of Vietnam as a typical example.

2. Theoretical Foundation

2.1 Types of PT

Urbanization creates concentrated travel with high density. To meet the travel demand, it is necessary to associate the development of the road network with PT system. So PT has been developing in most of cities in the world. Development of PT has become one of the top priority targets of cities in order to serve the increasing transport demand and thus contributing to the sustainable development of the cities. Each type of PT has its own advantages and disadvantages, so depending on the specific conditions of each city, each country, to apply all or part of the types of PT.

Table 1 Urban scale and major types of transport

Type of urban	Population (million people)	Number of trips/ year	Main means of transport
Mega city	>10	900 - 1,200	Metro, tramway, monorail, urban railway, BRT, bus, taxi, motorbike, bicycle
Level I	> 1	850 - 950	
Level II	0.5 - 1	650 - 850	Tramway, monorail, urban railway, BRT, bus, taxi, motorbike, bicycle
Level III	0.25 - 0.5	400 - 600	Tramway, monorail, urban railway, bus, taxi, motorbike, bicycle
Level IV	0.1 - 0.25	300 - 450	Tramway, monorail, bus, taxi, motorbike, bicycle
Level V	0.05 - 0.1	250 - 380	Bus, taxi, motorbike, bicycle

Source: Tu Sy Sua

2.2 PT Management

Available studies focused on various aspects of PT management:

PT management should strive to meet environmental targets, support environmentally friendly solutions, and manage transport reduction programs. Solutions should be to meet sustainability and quality of life expectations more effectively to shift transport to sustainable forms through system changes (Sveinn Vidar Gudmundsson, 2010).

PT manager would deal with closer integration of design, planning, and management of the PT infrastructure, the increased emphasis on issues related to the environment (APTA, 2004).

PT management should deal with transport reduction and replacement with alternatives such as communication technologies, or 'virtual mobility' as it was termed by Crowley (1998).

An important aspect that should be incorporated into Public Transport Management is the distinction between healthy public policy and public health policy (Davies, 1997).

The study of Le Thi Minh Huyen (2020) indicated that many cities in Europe, America, Asia such as London, Paris, New York, Curitiba, Seoul, Beijing, Bangkok, Singapore, Kuala Lumpur…are developing modern PT systems along the direction integration of multimodal PT. PT is managed according to the main functions of planning, construction investment and exploitation. Types of PT is integrated in the Master Plan to establish an unified PT network: on planning, investment in infrastructure construction, public transport techniques, operation and exploitation such as map integration, field and network integration, fare – ticket.

The author believes that an advanced PT system should provide users with exactly the same level of comfort, safety and convenience. PT management which can be seen as the planning management, the strategic management of supply and demand of transport for a sustainable future as well as the management of stakeholder cooperation and infrastructure integration. It is a suite of solutions that help make PT Services more efficient for operators, drivers and passengers.

Thus, PT management should be accommodated management according to the main functions: network planning; fleets, infrastructure and technology; service quality; operators and exploitation; subsidy and financial resources.

2.3 PT Management Model

To manage integrated PT, the cities' government established a specialized agency. A public transport authority or PTA is an authority which regulates or administers transportation related matters. In general, urban transport agencies are often responsible for the organization of urban transport services. Other relevant agencies formulate urban transport policies. Most transportation authorities in countries are state-owned and under the direction of elected officials. It manage all modes including buses and rapid transit in metropolitan areas such as BRT, LRT, MRT, subway. It is responsible for infrastructure, means, regulating, planning, operating and safety relating to PT. PTA is an authority of financial and administrative independence. It is usually a high level of authority within structure of the municipal government. In addition, for some cities it is also given the authority to impose "traffic taxes" or "excise taxes" (fuel taxes) on gasoline, diesel fuel, and other motor fuels with revenues to redevelop urban transport systems.

Today, PTA is the most popular model to effectively manage and operate the PT systems in a certain locality or territory. This model often appears when the PT system has many different modes such as buses, high-volume transport: metro, tramway, monorail, BRT. The purpose of this model is to uniformly manage transport modes. At the same time, connecting all activities of different modes of transport: from route network, stops and stations, fare and ticketing system, revenue distribution, sharing passengers and travel information.

On the basis of the common model of PTA, the cities can apply it differently. However, its functions and tasks are as follows:

- Urban public transport planning;
- Design, build and maintain the state's transport infrastructure.
- Responsible for the development of PT services;
- Determine the levels of transport service quality;
- Manage operators;
- Mobilize the necessary financial resources to develop transportation systems;
- Issue regulations on transport activities.

3. Accurate Understanding of the Current Situation of PT in Hai Phong City

3.1 Overview of Hai Phong Socio-economic Development

Hai Phong city's population is 2,022,000 (2019), of which urban population makes up 46.7%. The urban population of the city is forecasted to reach approximately 2.2 million in 2025. The economic growth is expected to be around 15% per year. Urbanization of Hai Phong has increased rapidly. In 15 years, the number of inner urban districts has increased from 4 to 7 districts, resulting in an increase of travel demands in the inner part of the city. In the current situation of urban transport, most trips are made using private individual vehicles, leading to increase of pressure on infrastructure and the urban traffic network. The city is encountering the problem of traffic congestion and pollution.

3.2 Issues on PT Network Planning

In Hai Phong, PT has only 1 type of bus. Bus appeared in Hai Phong city since the 1970s but it was stopped for a long time due to not ensure operating conditions. Bus network in Hai Phong was reset in 2004. Bus within the urban area has not depveloped properly with 7 routes (Reduce 7 routes compared to 2010) are available at the moment, equivalent to less 2% of the transport demand. Total length of route is over 224 km (Reduce more than 100 km compared to 2010), the average length of each line is about 26 km. Operating time of bus from 5:00 to 21:00 everyday, operating frequency is maintained from 15 to 40 minutes/bus trip.[2] Most of the bus routes are link the inner city with neighboring districts and towns. However, the route network has not been distributed all over the urban areas to the road routes with huge travel demand, there are still many limitations in connectivity of routes; leading to the ineffective operation.

Currently, the city has approved plans in the urban transport sector including: Road planning; network of parking points and stations; public bus transport (including BRT lines) and taxi. A public transport master plan has not studied to include types of mass rapit transit. These plans have only been implemented in a period of 5 years.

The development planning of public bus transport can be divided into 2 phases:

- Period 2007 - 2017: Formulating and implementing the public bus transport planning until 2020.
- Period 2018 - present: Adjusting and implementing the master plan of public bus transport network to 2025, orientation to 2030.

At present, many planning targets have not reached and will have to be adjusted in the coming time. The main reason for the planning's failure to meet its objectives lies in the management of plan. In Vietnam, there is still a lack of detailed regulations and standards on planning and design in urban transport planning in general and PT in particular.

Table 2 Some main objectives in the public bus transport plannings 2007 and 2018

Main objectives	Based on the planning 2007		Based on the planning 2018	
	Need to be achieved by 2020	Done until 2017	Need to be achieved by 2020	Done until 2020
Length of bus network (Km)	650	380.5	600 - 800	224
Routes	30	14	22	10
Vehicles	450	107	258	79
Land fund for PT	-	3.7 ha	3.27 ha	3.7 ha
Depots	-	24	26	18
Transit points	-	1	3	1
Stops	-	300	499	590
Seats/1000 persons	16.2	2.5	5.8	1.85
Number of passengers (Mil.per/year)	359	7	31.6-41.2	2
Bus share	15% - 25%	1,3%	5% - 7%	1.1%
Development of mass rapid transit	Proposal on BRT routes	Not yet	1 BRT route	Not yet

Source: Author

The Department of Transport (DOT) is the agency responsible for submitting the formulation and adjustment of the Master Plan to the City Government for approval, and at the same time organizes the implementation of the Master Plan. However, in the current urban development planning, there is a lack of synchronization, lack of consistency, lack of linkages and overlaps, conflicts between the transport planning due to management of DOT with construction planning and land use planning due to management of others. The plans lack vision, are not tied to resources and development goals, even stemming from subjective desires rather than from requirements of market and available resources.

3.3 Issues on Fleets, Infrastructure and Technology

Bus fleet:

Total vehicles is 72 (Reduce 30 vehicles compared to 2010). Types of vehicles B40, B50, B55 account for the largest share as about 53.0%. The bus fleet is 7 - 10 years old and has low emission standard. Currently, many vehicles are too old, producing black smoke when running. It is one of causes of environmental pollution in urban area. In 2016, the city put into 20 new buses to upgrade the fleet to types of vehicles B60. However, the quantity and quality are still not enough to meet the requirements of bus operation.

Infrastructure:

Total area of stations is 3.7 ha, in which the area itself is 0.3 ha, an area of 3.0 ha is from the city and an area of 0.43 hectares is rented. Location of stations are distributed irrationally and it's a major reason that affects service quality, raises the cost of operation and reduces business efficiency of bus transport enterprises. There are 5 garages for bus. The garage in An Lao car park is managed by the city, The remaining garages are managed by the operators. There are 520 bus stops, of which there are 103 bus stops with shelters, 405 bus stops with sign boards and 12 bus stops with painted lines.

Bus system has been hindered by the existing poor urban transport infrastructure due to land fund for transport is very limited. Currently most streets and roads have only two traffic lanes. Many roads have a low quality of the road surface, much damaged and poor drainage. Stops and shelters are unroofed and have inconvenient layout and the distances are too far. Many streets have narrow cross section (7 - 12m), often alleys have width of less than 5 m that makes it difficult for the safe and smooth operation of bus. Consequently buses cannot compete with motorbikes in meeting people's demand for city travel. With crowded and narrow streets, buses have to run together with other vehicles that has resulted in the small average operating rate of 15-20 km/h in peak hours.

Fare structure:

There are 2 types of curent bus fares: single ticket, monthly ticket which are given by bus enterprises themselves after registering with the state agencies. The single ticket is not fixed on the network, it is change by the length of bus trip and by the operation companies. The existing fare structure is not decided by the City government but by each operator. So, the present fare structure has a few disadvantages:

- Fares differ per line;
- Number of trips of users, who have monthly ticket, are not collected;
- Number of trips of riders, who buy single ticket depends on staff behavior;

- In case of a transfer, not uncommon in urban transport, the customer pays twice;
- The fare level is relatively high for people with a low income.
- The present fares seem to be a compromise of trying to keep the fare affordable while generating enough revenues to cover the operating costs.

Passenger information and operation technology:

Currently, the application of technology in bus management is lacking with a limited passenger information system on bus stops and shelters. Available information for customers is very limited. Stops signs indicate the route but do not mention the frequency or the times of the first and last trip. There are a limited number of stops which provided the route map. Unfortunately the route map is not up-to-date anymore. In the future, real-time information is to be based on GPS (Global Positioning System). At present, only part of the fleet is provided with GPS. There is no control system of the vehicle punctuality.

The city issued paper tickets and no integrated tickets as well as fare reduction. A trip based fare system where customers pay a flat fare per ride. An Automatic Fare Collection System (AFCS) hasnot been set up to control ticket and revenue. Besides, the system s Automatic Vehicle Location System (AVLS) and Automatic Passenger Counters System (APC) hasnot been implemented to manage and monitor bus operation.

Fig. 1 Fleets, infrastructure and technology for bus operation in Hai Phong

3.4 Issues on service quality

A survey of DOT on bus network and factors of mode transport choice was conducted in 2020.[3] The survey conducted along all the existing bus lines and over all the defined zones that include both urban area and suburban area of the city. The main issues related to bus choice including bus fare, punctuality (fast and convenient, runningon time, on schedule), safety and security (no burglary, no sexual harassment), mooth running.

As survey results, many bus-routes have almost ceased operation or operate intermittently there the quality of bus services is very poor. Vehicles are equipped at low-level, no air condition, no support system for disable and old people. High fares and lack of inter-routes. There is no control system of the vehicle punctuality. The schedule is not fixed but depends on the number of available buses and information on routes, frequencies and fares is lacking, incomplete and sometimes incorrect. Therefore, the bus operators have to try to ensure as well as improve the bus service quality for the rise in the number of passengers.

Totally 500 bus passengers and private mode users were asked to reveal their responses. Among our respondents, only 20% told us they used PT service. From these 20% of PT users, 55% are satisfied with their experience, 35% stand neutral and only 10% is dissatisfied. Some customers answer that the main reasons for using bus service are:

- The bus is safer than motorcycle and bicycle;
- Suitable route and frequency;
- Does not possess a private vehicle.

Remaining, the most common answer from customers who were asked is lack of familiarity with them, most likely due to their traditional preference of privileging personal modes of transport such as their motorbikes or cars (51%). 40% of them consider there is also a lack of bus stops which are not covering the areas where most of the people live. Moreover, the poor conditions of the vehicle (considered too old and uncomfortable) and the careless driving make up 45% of the answers. Finally, 20% of the respondents said the dangerous encounters and the unsafety (pickpocketing) is also a big issue, restraining them from using bus.

The reasons making people not use PT:

- Inconvenience;
- Quality of vehicle and service is too low;
- Fare is too high;
- Not enough bus stops;
- Poor conditions of fleets;
- Unsafety (eg. pickpocket);
- Careless driving.

Customers also demanded significant improvements on service quality:

- Driver should drive carefully;
- Vehicles should be cleaner;

- More suitable travel route and bus stops should be created more;
- Equipment should be reviewed.

Customers want to experience the transport service, not the technology behind. Price, travel time, reliability, safety and comfort are the most important aspects. Safety is certainly a good selling point, but the high price, low quality and limited availability disqualifies the bus as a serious alternative. In addition, the bus network does not cover the entire city. So, bus cannot be expected to offer any combination of origin and destination so it is common in urban transport that people need to transfer for certain journeys. However, without fare integration every transfer means buying a new ticket. That makes the fares unattractive.

3.5 Issues on Operators and Exploitation

Currently, there are 3 bus operators in Hai Phong city (Reduce 2 operators compared to 2010). Bus routes 1 and 2 are operated by Hai Phong Road Company, owned by the City of Hai Phong, and the other routes are operated by private operators.

At present, the opening of new bus lines depends on the initiative of the operators. They can present a proposal for a new line that is subject to approval by the City Government. Ror subsidized routes, the city government subsequently chose a route by route gross cost contract i.e., operators will not bear revenue risks and will be compensated based on service provided as the basis for involving the private sector in bus services. At the same time, the city has little or no influence on the performance of the private operators. Not because they are private but because they do not receive any subsidy. Bus operations and operators are arranged under direct concessionaire contracts. The operator obtains a concession to operate the line for an indefinite period. However, he has no obligation to operate a certain time table and by absence of any financial compensation the authority has no means of enforcement. In general, the service capacity of bus operators is still low and inconsistent. Bus operators, which originate from intercity transport, lack experience in PT services, lack of financial resources, leading to an incomplete process of providing PT services, and lack of technological and equipments. So it is difficult to keep up the needs of the current transport market.

3.6 Issues on Subsidy and Finanical Resources

The unprofitability feature of PT provided as public services in the majority of cities worldwide including Vietnam. Therefore, the efficient operation of PT (as public services) requires subsidy. Subsidies for PT affect the price and scope of provided services. Therefore, thanks to public funds PT services can be rendered for the public at a lower price.

Hai Phong city is supporting the cost of operation on 3/7 bus routes for only 1 operator. The public operator, Hai Phong Road Company (HPRC), receives subsidy covering 30-40% of operating costs. In contrast, the 2 private operators have no access to subsidy and seem to have difficulty to survive commercially. Losses made on urban public transport are compensated by profit made in intercity transport or commercial side activities. Private operators indicate that they are not in the position to renew their fleet, given the present fare level and the lack of financial support.

Investment for PT projects is very limited and small in scale, heavily dependent on investment projects from the state budget and development assistance (ODA, IDA) from foreign organizations.

3.7 Issues on Institutional Framework and Management Model of PT

At present, the City Governmental management for all modalities of PT, as well as inter-provincial PT, is at responsibility of DOT which is under the City Government. DOT is responsible for organizing the route structures, network for PT services and manage all bus operations in accordance with the provisions of law. In which, a specialized agency under the DOT was established to directly manage operation of PT system (PTA). A common feature for cities in Vietnam, and Hai Phong is not exception, is that the bus operation runs by an state enterprise under the DOT. Management is limited to administrative procedures such as registration and licensing. The PTA lacks the required authorities for PT network establishment and operation. PTA has little influence on the level of service (scheduling and frequency), fare setting, or compliance with relevant regulations in the operation of PT, instead, the routes, the bus scheduling and frequency, fare setting are calculated and then proposed by the very operators/investors and consequently approved by the DOT, on behalf of the City Government.

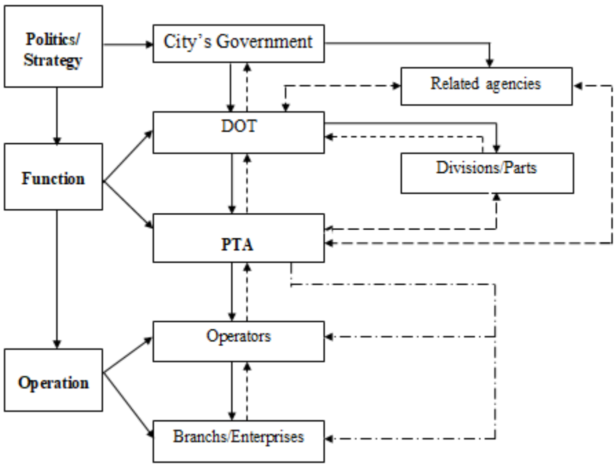

Fig. 2 The current PTA model in Hai Phong

4. Challengies and the Way Forward

The bus transport system in Hai Phong has been undeveloped, not yet professional operated, the financial investment is limited and small. Quality of bus service has not met user expectations. The development of PT has been hindered by the existing poor urban transport infrastructure and institutional framework.

In PT management, PTA is only on behalf of the DOT to manage bus operations, but fares and revenue are actively counted and managed by operators, leading to a lack of transparency in information about output and revenue. This will lead to operators not putting the community's interests first, but only operating independently, focusing on increasing profits, minimizing investment costs instead of improving service quality. Thus, application of subsidy mechanism is ineffective and not for the original goals. Moreover, one of the main conditions for good quality PT is proper funding and this is still unresolved. Adequate funding is the key to successful urban public transport.

Providing and developing public bus service which is adequate and appropriate is the challenges that encountered in almost all cities in the world. A breakthrough is needed to make public transport an attractive alternative for the motorcycle or car.

5. Improvements

5.1 Development of the PTA Model

PTA model should be organized in accordance with institutional framework and regulations of Vietnam. Therefore, PTA should be become an authorized agency under the City Government to conduct detailed tasks. The public transport policy is prepared by the PTA and approved by Hai Phong's City Government. The role of the PTA is to implement that policy by organizing and managing the public transport. The operation is in hands of one or more public or private operators. It is imperative that a Steering Committee or Executive Board be established, made up of the most responsible people in the city such as Leader and Council Chairman of city, Director of important departments: Transport, Planning, Finance, Investment…, representatives of businesses and the residential community. This agency serves as the city's PT development policy oversight and adviser.

Operations of PTA will be included in the 5 main functions and tasks:

- Planning and developing the network;
- Transport and financial planning;
- Tendering, contracting and monitoring contracts;
- Communicating and providing adequate information to users;
- Management and development of services.

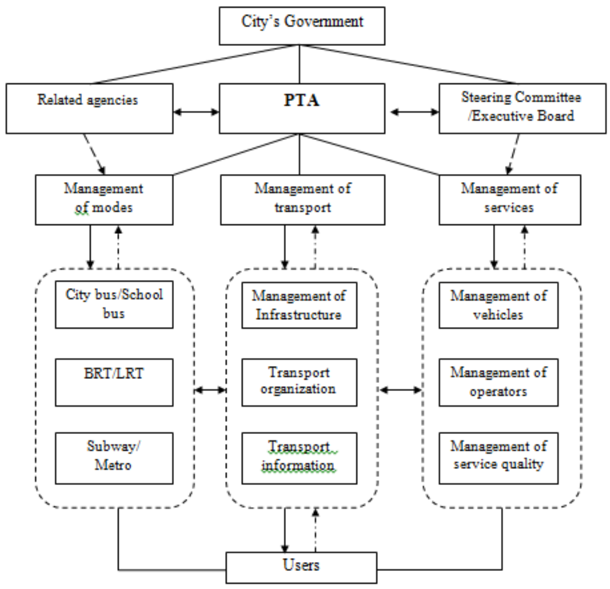

Fig. 5 Proposal on development of PTA model

5.2 Management of an Integrated Public Transport Network

Due to increase of urban traffic density and to solve travel needs in the future, it is necessary to develop diversified types of transsport such as bus, BRT or metro. The city should introduce a diverse, integrated and balanced PT system that meets the transportation needs in the city. Improving the necessary infrastructure and facilities (road network, stops, stations, means) to extend the coverage of the system in the city. The network should be extended in order to cover the city in such a way that people have a bus stop within 500 meter distance. The plans should present a step-wise extension of the bus network, including bus terminals, interchange points, parking area arrangement and transport infrastructure accessible (priority lane for elders, children and disable people).to residential areas in order to increases bus transport capacity.

The first step should be focused on improving coverage and integration on whole bus network. Providing bus service to attraction points allows residents a transport alternative to personal vehicles. Besides, the city should attempt to attract commuters away from personal vehicles by increasing the number of buses within the city, creating new routes to service more attraction points, sush as: school, hospital, shopping mall...The Master Plan of PT of the city was also envisaged to introduce BRT for which 4 lines were proposed. The plan calls for 4 BRT routes by 2030. At the same time, from 2025, the city will study and deploy the urban railway lines to connect the central area to the suburban areas and the ring roads of the city. Thus, the PT network must be decentralized on the basis of the supply capacity of the transport vehicles. The following requirements must be attented:

- Adjust the network according to the principle of covering the city, taking the mass rapid trasit (MRT) routes as the main trunk routes of the city. New bus routes should be only opened outside the ring roads 2 and 3, minimizing new routes within the ring roads 2 and 3.
- Arranging bus routes on main corridors including buses with large capacity (B80). These lines will play the role as the main lines for the route network without BRT or urban railway.
- Branch bus routes including buses with average capacity of B40-B60 on radial routes are responsible for attracting passenger in the central areas.
- The remaining routes with a capacity of B17-B40 will play the role as the collection routes to transfer passenger to main routes and branch routes.
- Planning bus routes to serve specific travel needs (connecting airports, stations, seaports, inland waterways terminals, school bus, bus for workers in industrial zones, tourist bus ...)
- Constructing the transfer stations in the whole network according to the approved plan and planning the backup bus route for the railway lines.

The second step, it is necessary to integrate urban planning based on the PT system planning (TOD model) with the integrating plannings: Socio-economic development planning, land use planning, construction planning and PT lanning to ensure that urban development must likewise be integrated with PT development to enhance accessibility, safety, and environment.

5.3 Management of Infrastructure and Technology

** Infrastructure priority for PT:*

The overall performance of the bus service is constrained by the external environment, in terms of the traffic conditions on urban streets. Various infrastructure improvements can allow buses to move faster and more efficiently through the city. This can be accomplished creating Traffic Signal Priority (TSP) for public transportation vehicles.

Roads will be more congested due to increases in motorcycle and car use. It is assumed that road traffic speeds will be decreased by 30% and this will cause reductions in bus speed as well. To keep buses running at the current speeds (20 km/h in urban area and 35 km/h in suburban area), it will require an installation of bus priority signal system and introduce bus priority lanes along the bus lines in future, allowing for faster commuting times for users. This is the form of prioritization and specialization in order to increase efficiency and quality of service. With the adoption of bus-only median lanes, buses could be faster and more convenient than cars.

** Development of an intergrated technology in bus operation:*

The success of the bus service comes from advanced operating technologies to provide optimal management tools and to attract passengers. These technologies must be integrated into a system that can control the entire operation of buses, passengers as well as drivers and service staffs. In which, Automated Fare Collection System (AFCS) is one of important key for improvement of Hai Phong bus system. This will be done as fast as possible for move smoothly, no congestions at the validator place. Without an AFCS, types of the current fare systems become complicated to manage for the operator and navigate for the customer. An AFCS includes with contactless smartcards, validators, vending machines, and the servers with the management softwaret to record all transactions. Thus, it is possible to control the number of passengers at each bus station, the flow of passengers from one station to another as well as information of the riders. Besides, an AFCS provides passengers with a flexible, convenient method of payment and easy application of multiple payment options such as discounts for different user groups (students, pensioners, disabled, etc.) and period based fares (monthly passes, daily pass, etc.). An AFC system also has the potential to reduce fraud and cut operation costs due to the reduced need for ticketing staff, efficient accounting and data collection.

Currently, database on public transport in the city is relatively simple and sporadic with collecting information from operators and related agencies. Information is not fully provided and integrated in the entire route network. Therefore, it is necessary to set up an integrated database system for public transport such as Information and Operation Center under the PTA. The data is collected to exploit and process, serving management and making decision. Moreover, the system must be connected and shared information to coordinate implementation with related agencies.

The main data sources should be collected as below:

- Digital map of puclic transport network using GIS and GPS technology;
- Database on infrastructure and vehicles;
- Fare, passenger information and other relevant service;
- Information on organization and management.

The more passenger information options that are provided, the more accessible public transportation becomes. A intergrated information system is very necessary to to attract users as well as to issue decision improve services quality. There are two levels of information with regard to timeliness of information, fixed information and real time information. The fixed informations provide passengers with planned service information, such as stations and stops, routes, service numbers, times, trip durations, and fares. It can be provided direct to the customer, at stations and stops and on vehicles. It is available to allow customers to plan their trip before leaving home and in moving. The real time information changes to update passengers regarding current information based on facts on the ground. This includes service updates, real-time vehicle arrivals, real-location stop announcements and station-to-station or origin to destination directions. It can be also provided direct to the customer, at stations and stops and on vehicles.

Direct to customer:

- Computer information provided over the internet in an interactive format: online ticketing software, trip planners, real-time vehicle arrivals to stations, changed or updated service.
- Mobile information on a smart phone or in SMS form, on interactive applications facebook, zalo...

At Stops and Stations:

- Electric signage, which are visual notifications using LED screens;
- Public address systems, which are audio announcements;
- Information Kios, which are centers that provide interactive information.

On vehicles:

- Electric signage, which are visual notifications using overhead LED screens;
- Public address systems, which are audio announcements;
- Dynamic screens provide additional information beyond the electric signage.

5.4 Management of Service Quality

** Changing in fare structure and introducing attractive fares:*

Change fare through integrated fare scheme using electronic ticketing system which provides multiple discount options to encourage public transport usage. At present, there seems to be little room for a further increase of the general fare level. The affordability analysis shows that present bus fares are relatively expensive for people with the lowest incomes. Thus, any improvement of the fare structure should focus on:

- The fare does not exceed 10% of the average income (the average level in a month);
- Fare integration: paying per journey instead of paying per trip (removing the penalty of changing lines);
- Fare differentiation: Building exemption policies on fare for preferential subjects such as War Invalids, sick soldiers, the disabled, pupils, students...;
- Better the service quality, the higher the ticket price and vice versa;

- The city government decides fare structure based on the rules and the specific situation of operators.
- All these types of tickets need to use and valid for all bus route of operators in Haiphong. Proposal of the alternative fare structure includes:
- Uniform fares, applicable to all bus lines;
- 50% reduction applicable to students and pensioners;

Moreover, by introducing a full scale integrated-automated and electronic ticketing system, but maintaining the option to pay cash on board at a higher fare, the Haiphong system can be fully integrated with seamless transportation, provide a wider set of fare options and reduce operational costs.

** Supplying a convenient and modern transport service:*

Today, some corporations in transport sector introduced transport services "door" to "door" (same as a type of Park and Ride). This is a useful service which will pick up passenger from their location and taking them to destination, is the reason why passenger selected bus services. To implement this transport services we have to understand the passenger's demand as well as set up travelling schedules and supply the service for each stages. Such service arrangement shall create the good condition for passengers, reduce the waiting time for the ticket purchasing, saving time for travelling. To achieve this, fleets should be renewed with modern and environmeaZntally friendly means. Many types of supporting vehicles for visually impaired people or people with disabilities shoud be also fully equipped to meet needs of passenger.

Besides, safety and security are the top subjects in the transport services in general and in bus service in particular. The safety must be guaranteed for passengers in the whole journey. Passengers have to be taken care, healthy guaranteed during travelling. This travelling time can be estimated from the moment a passenger leaves home to arrive destination, to be insurance immensity for all risks or bad service quality.

** Promoting communication on benefits of public transport:*

The communication strategy presents 4 major issues: Branding strategy, key message, creative strategy and sources of communication and focusing on bus service.

Branding strategy: As the bus system has no name or brand at present, itt is suggested to build a brand name with identity for it. This will help to get attention easier and position bus in customers' mind.

Key message: Approaches to the target audiences in both practical and psychological. Manner for example: The key message is "Hai Phong Bus - safe, friendliness and civilization".

Creative strategy: Building the images to influence the target audiences. The overall of the communication should give the atmosphere of safe, secured, modern and friendly.

Sources of communication: Selecting the sources with mass covering and high influencing to target audiences: Press, radio, influencers, authorities and social media to get word of mouth.

Approaches to communication channels: Using the most effective channels to communicate with target audiences in 2 categories with detailed objectives & activities in each channel.

Owned channels: Website, social media pages, mobile application, Google Transit…

Media channels: PR, advertising (Online & OOH), social media, and promotional.

5.5 Management of Subsidy and Financial Resource

It is recommended to introduce integrated subsidy mechanism for bus operation and fleet that compensates for the gap between fare revenues and the costs of fleet, operation and maintenance. Subsidy calculation must be based on actual conditions and demand forecast in future.

The calculation is based on the formula: Subsidy = Cost – Revenue

The Cost and Revenue will be calculated by result of demand forecast and necessary assumptions are referred to the current situation of Haiphong City and other similar cities.

In which:

- The average revenue per passenger trip is taken from existing fare/ proposed fare structure;
- From the number of passenger, the number of bus trip by route is calculated basing on average vehicle working hour, average vehicle speed and average occupancy rate of passenger/trip by route;
- The amount of km running is calculated from number of bus trip and length of each bus route;
- The operating cost per km calculated basing on the real price, referring to operating cost per km by bus operator and norm for bus operation in Hai Phong city.

By introducing subsidies to all operators, combined with the introduction of service contracts that define the required performance, bus service can be controlled effectively. Competitive tendering have proven to be an effective method for procuring transport services with a good balance of quality and price. Route service contracts were awarded based on technical and operating capacity and lowest subsidy requirement. Contracting and monitoring are the main tools to manage the selected transport operators.

At the moment, subsidies for PT in Hai Phong can only be funded from the state budget, as is also the case in Hanoi, Danang or Ho Chi Minh City. The funding limitations can be overcome with a funding mechanism that involves many sectors so as not to overburden the state budget. Thus, the city should have its other revenues without state budget and plans to develop revenue to reduce the dependence on the city budget throughing possible revenue sources as below:

- Parking fee in urban areas (including cars, motorcycles and other vehicles);
- Fee for managing and exploiting infrastructure;
- Fee for managing subsidies;
- Advertisement on bus stops, shelters and stations;
- Revenues from penalties (specified in the service contract);
- Other allowed revenues.

6. Conclusions and Recommendations

This study recommended serious improvements on PT management in Hai Phong city. The implementation in reality needs sufficient protection of regulations and good awareness of transport authorities and operators. In addition, support is indispensable for PT. To promote PT, it is needed to adjust the viewpoint of the City government on supporting bus operation including subsidy for fare and support for interest on capital expenditures (in particular fleet). It is recommended to introduce integrated subsidy mechanism for PT.

The bus, BRT and urban railway represents today most common means of public transit-worldwide. However, providing and developing PT which is adequate and appropriate is the challenges that encountered in almost all cities in the world. As it can be seen, each mode of transport has its specific advantages and drawbacks directly influencing decisions of users. The first priority is related to efficient management of the PT system, and the second priority is related to effectively control the ownership percentage and use of personal vehicles, especially motorcycles and cars through radically collecting road fee; increasing registration fee and premium and environmental protection fee with personal vehicles. In many cities elsewhere in the world paid parking is a sizable source of revenues. It facilitates PT and contributes to restrict private mode. Parking fees were also introduced in other cities as Hanoi, Da Nang or Ho Chi Minh City. So, revenues from parking fees might revenue of interest and partly fund the subsidy needed for PT in Hai Phong.

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Low-Carbon Urban Transport: Policy Context in Vietnam and Development Orientation in Hai Phong City

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Abstract

Hai Phong is known as the third largest city of Vietnam and a largest ocean port in the North. In recent years, the city's rapid economic growth leads to a series of industry, energy, transport and environmental challenges. Especially, the urban transport activity (including freight and passenger transport) is one of the main pollutant sources in the big cities in Vietnam including Hai Phong city. It also leads to increase of greenhouse gases (GHGs) and the serious problems of climate change. Besides, the explosion of individual motorized vehicles due to urbanization process has placed the city in front of the challenges of sustainable development. The increase in private vehicles has caused congestion and serious air pollution, especially in urban areas. According to nearly statistics, in Hai Phong every day more than 4 million people travel, in which private vehicles accounted approximately 80% of the trips and public transport only responded less than 2% of travel needs. In this context, low-carbon transport is expected as the key goal to deal with the consequences. Policies and actions recommendation for effectively reaching the goal involve to reduce the environmental consequences and other negative externalities of transport systems. The paper presents an analysis of current policy context in Vietnam, and to focus on the case study in Haiphong city. Then, the study proposes the way to create efficient and low-carbon transport for Hai Phong city.

Keywords: Hai Phong, transport, low-carbon, climate change mitigation, sustainable development

1. General Introduction

Vietnam is one of the most vulnerable countries in the world to the impacts of climate change. Greenhouse gas (GHG) is a factor behind climate change. Moreover, the cities of Vietnam are facing various environmental problems, including issues with waste, air and noise pollution, pollution of public waters, and traffic congestion. According to JICA and the Ministry of Transport (MOT), up to 45% of emissions are generated by transport activities (nearly 18 million tons of CO2/year). Transport is becoming one of the major sources of GHG emissions in the city, an overwhelming proportion over other segments. The CO2 emission volume in the transport sector is expected to reach 65 million tons by 2025 and 89 million tons by 2030. Road transport is the biggest source of emissions as it generates 85% of total emissions, followed by internal waterway transport with 8% which remains unchanged in 2020-2030, airways 5%, and sea transport 2%. Railway generate the smallest volume of emissions. This is an alarming situation and big challenge for sustainable development. It needs to execute policies and measures that are both environmentally-friendly and allow socio-economic development.

Hai Phong City, a major harbor city and the large urban in North of Vietnam, has played an important, strategic role in the socio-economic development of the region and Vietnam. As Hai Phong's economy grows, the city is becoming a significant emitter of GHGs. In which there is a significant contribution from the transport sector. Hai Phong's development of transport plays an important role in its socioeconomic development. In the last 5 years, transport sector has progressed significantly, resulting in rapid growth. However, with the increase of urban residents especially in the central area of the city drag along with increasing motorization and push more pressure on transport system. The large share of personal vehicle is a main reason which leads into serious problems of congestion, environmental pollution, economic burdenand and a low quality of life. Public transport modal share remains persistently low, partly due to the low level of network development and partly to the convenience and affordability of two-wheeler based mobility. Public transport system is facing a series of challenges regarding the number of users, providing them with the necessary mobility, quality at the highest level and the system reaction time as low as possible.

The transport plan demonstrates the city's ambitions to develop a optimal transport system. However, a number of barriers affect the exploitation of these potentials. One of the main conditions for good quality urban transport is proper funding and this is still unresolved. Adequate funding is one of important conditions to successful urban transport. A large gap between planning and reality indicates that a different approach is needed. A efficient transport plan can help to achieve a transport system that is enough attractive and environmentally friendly the sustainable goals. These include developing public transport, managing traffic, controlling vehicle emission and fuel quality.

Hai Phong is taking the lead in awareness raising and taking action to become the first "Green and smart port city" in Vietnam. The objectives of this study are to design a low-carbon transport system and to support the vision of building Hai Phong as a green urban. The study provides the analysis of current transportation situations in Hai Phong city, a compilation of these decisions and results. Such analysis will enable and contribute to the assessment of feasibility of low-carbon transport policies. And then, it recommends the different measures in each sector which are included in the action plan and a roadmap to achieve the goal of low-carbon transport. It is the way to exploit potential climate change mitigation opportunuities in urban transport.

2. Research Work and Methodology

2.1 Methodology

Approach to addressing environmental impacts of transport can be done by the Avoid – Shift – Improve (ASI) framework. The model gained wide international acceptance as a guiding principle, focusing on the demand side and offers a holistic approach for a low-carbon and sustainable transport system design. It offers comprehensive tools and measures as identified in Figure 1 below:

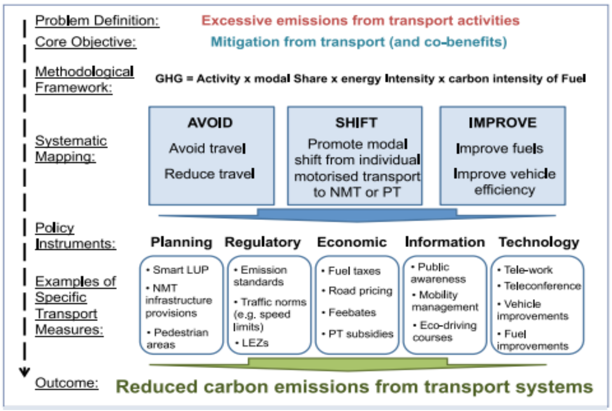

Fig. 1 ASI framework

*Note: *LUP = Land use planning.*
NMT = Non motorised transport.
PT = public transport. LEZs = Low-emission zones.

GHG emissions from transport sector show an upward trend. The main reasons for this are:

(i) increased transport activities (larger numbers of vehicles and greater traffic volume);

(ii) dominance of road transport in the modal structure (road transport produces higher GHG emissions per passenger or freight transported compared with other modes of transport);

(iii) increased transportation mode share of gasoline-powered motorcycles, the vehicle with the most intensive per-person per-kilometer fuel use;

(iv) the high age of the transport vehicle fleet, leading to higher fuel consumption per distance driven or per unit transported.

Vehicle fuel combustion is the main source of GHG emissions from the transport sector. Key factors affecting GHG emissions are:

(i) the total volume of passenger travel and freight traffic,

(ii) the modal split of this travel and traffic,

(iii) the energy efficiency and intensity of each transport mode, and

(iv) the GHG content of the energy used in each mode.

Consequently, reducing consumption of fuels per distance driven or per unit of passenger or freight transported, switching from high- to low-carbon fuels, and improving the energy and operating efficiencies of the traffic fleets can all mitigate GHG emissions in the transport sector.

The ASI framework is one such people-centered approach, including three strategies:

Avoid: reduce the need for motorized transport or the distance traveled by motorized transport. It entails reducing the length and number of trips through measures such as promoting work-from-home schemes, smarter land use, intergrating transport and logistics planning to creat local cluster of economic activity require less mobility.

Shift: enable and incentivize the shift from higher-emitting transport modes to cleaner transport modes. It entails moving toward environmentally friendly modes of transport, such as walking, cycling, or using public transport. The strategy also requires infrastructure improvements for the provision of public and nonmotorized transport options to address the continuing demand for transport mobility.

Improve: reduce emissions of transport and can include measures such as improvement in vehicle fuel economy and the introduction and switching towards lower carbon fuels. It entails promoting efficient fuel and vehicle technology in transport, such as using clean fuels and clean technology.

2.2 Research Work

The research work is based on qualitative method combining with professional solution by collecting opinions of experts in the transport sector and relevant agencies. Data of the status of transport and GHGs emission in Hai Phong were collected from specialized reports, prevailing publications, official statistics, and from related agencies' documents. Data of the base year (2013) was collected and analyzed in order to estmate current carbon emissions. Others is collected until the end of 2020. This paper aims to establish low-carbon strategies which are needed to ensure sustainability of transport. In order to gain its objective, the research makes qualitatively an consideration of policy context in Vietnam. Through researching on experience in the world and referring the studies of authors in transport sector, the author recommends to efficient measures for Hai Phong based on low-carbon transport strategies up to 2030.

3. Accurate Understanding of the Current Transport Situations in Hai Phong City

3.1 A Review of the Current Status of Transport

Hai Phong is a transportation hub linking North Vietnam and regional countries and others in the world. The city has numerous large industrial, commercial zones and big centers of services, tourism, education, healthcare in the northern coastal area. The city's population is 2,022,000 (2019), of which urban population makes up 46.7%. The urban population of the city is forecasted to reach approximately 2.2 million in 2025. The economic growth is expected to be around 15% per year. Urbanization of Hai Phong has increased rapidly.[4] In 15 years, the number of inner urban districts has increased from 4 to 7 districts, resulting in an increase of travel demands in the inner part of the city. According to the forecast, the transport demand up to 2030 (Business as Usual - BaU) will increase dramatcally from 10,236 to 22,490 million person per kilometer (mil.per.km) of passenger transport and 8,470 to 48,158 million ton per kilometer (mil.ton.km) of freight transport compared to 2013. Freight transport relies predominantly on roads and followed by waterway, in which road is stll dominates and contributes to 91%. Regarding to passenger transport, there is a rapid increase of demand on car to 8.25 times, transport demand of car and motorbike is similar. [5]

Table 1 Number of vehicle in the big cities of Vietnam in 2017 [4]

No.	City	Number of vehicle		
		Car	Motor	Bus
1	Hai Phong	98,094	1,025,082	107
2	Ha Noi	554,325	5,439,179	1,404
3	Ho Chi Minh city	516,956	7,267,487	2,785
4	Da Nang	60,799	706,934	91
5	Total in Vietnam	2,902,623	46,097,000	10,000

Source: *Author, 2018*

Alternatively, the explosion of individual motorized vehicles, including motorcycles and cars has placed the city in front of the challenge of long-term sustainable growth. Currently, the preferred mode of transport in Hai Phong city is the motorcycle. The number of motorcycles reached approximately 1,025,082 and the number of cars is 98,094 in the last of 2017. Motorcycle ownership rate is 496 motorcycles per 1,000 inhabitants.

An issue that especially needs attention is public transport which has not yet contributed much to a low-carbon transport system. In developed countries, with an urban population of 1 million or more, public transport becomes a major means of transport. Meanwhile, in Hai Phong, there are more than 2 million people but not have mass transit types except buses. The current bus network has not been distributed all over the urban areas to the road routes with huge travel demand, there are still many limitations in connectivity of routes; leading to the ineffective operation. Moreover, quality of public transport are not often up-to-date. Bus service does not attract users. So most of people have to spend their own transportation to travel. Safety is certainly a good selling point, but the high price, low quality and limited availability disqualifies the bus as a serious alternative. Currently, many buses are too old and produce black smoke when running.

The Development Plan of Hai Phong Public Transport of the City Government (2018) proposes for 2025 a network and bus fleet more than three times the size of the current bus network while the share of the bus in the total transport should increase from less than 2% to more than 10%.[2] Although not impossible, it can be doubted if it is realistic. This contradiction between planning and reality indicates that a improvement of the operational efficiency of bus fleets and the ridership of the public transport system is really needed.

3.2 The Impact of Transport on the Environment

In Hai Phong, transport is the largest energy use sector in all economic sectors. It is forecasted that by 2030, the level of energy use for transport will increase 4 times compared to 2013.

Transport sector is also the second main sources of GHG emissions in Hai Phong. Total GHG emission in 2030BaU is forecasted about 33.5 MtCO2eq, accounting for five folds higher than base year 2013 (6.7 MtCO2eq). Main contributors to GHG emissions in the 2030BaU are industrial sector (15.7 MtCO2eq), followed by transport, residental and commercial sectors which account for 13.4, 2.7 and 1.5 MtCO2eq, respectvely. Besides, in Vietnam in general and in Hai Phong in particular, fuels used for economic sectors, including transport, are mainly gasoline and oil. It leads to increase GHG emissions in urban areas.

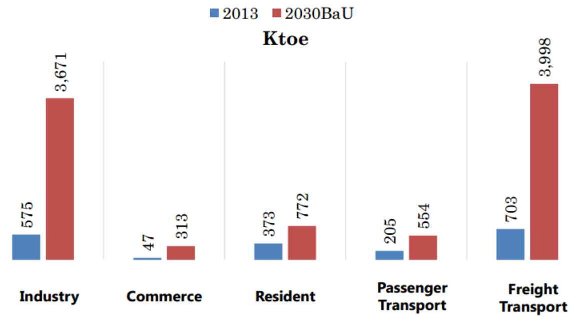

Fig. 2 Forecasting energy demand up to 2030 [17]

Table 2 Forecasting GHG emissions in Hai Phong up to 2030 [13]

Year	Sector	Coal	Oil	Gas	Electricity	Total
2013	Agriculture	1.2	24.5	0.0	17.2	**42.9**
	Industry	1,074.9	126.1	96.8	1,142.2	**2,440.0**
	Commercial	36.8	66.7	0.0	117.9	**221.4**
	Residential	37.2	489.1	0.0	765.2	**1,291.4**
	Passenger transport	0.0	604.3	0.0	0.0	**604.3**
	Freight transport	0.0	2,074.8	0.0	0.0	**2,074.8**
	Total	**1,150.2**	**3,385.4**	**96.8**	**2,042.4**	**6,674.8**
2030 BaU	Agriculture	4.9	97.5	0.0	68.4	**170.8**
	Industry	6,883.0	816.3	603.6	7,446.0	**15,749.0**
	Commercial	244.6	443.1	0.0	782.7	**1,470.3**
	Residential	76.9	1,011.9	0.0	1,583.3	**2,672.1**
	Passenger transport	0.0	1,634.3	0.0	0.0	**1,634.3**
	Freight transport	0.0	11,797.4	0.0	0.0	**11,797.4**
	Total	**7,209.4**	**15,800.5**	**603.6**	**9,880.3**	**33,493.8**

In the current situation of urban transport, most trips are made using individual vehicles, leading to increase of pressure on infrastructure and the urban environment. According to the Vietnam National Environment Report 2016, emissions from road vehicles contribute most of the total pollutant emissions in urban areas. Among road vehicles, motorcycles are the largest source of GHG emissions.

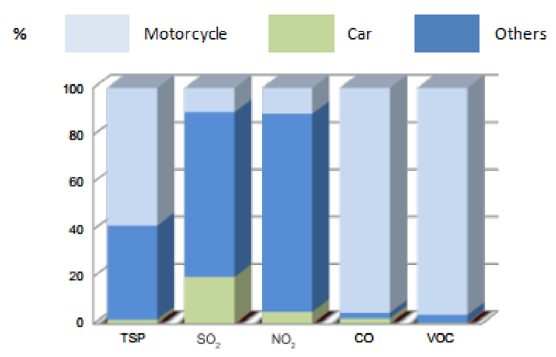

Fig. 3 Rate of air pollutants caused by road vehicles [18]

Hai Phong city is also encountering the problem of traffic congestion and pollution. During rush hour some arterial roads of the city are packed with slowly-moving vehicle traffic, to the threshold of a traffic jam. A forecast has shown that in about next 10 years, the rate of using motorbikes and cars will be still in high level. The period of traffic jam in rush hours will increase to two or three times in comparison with current situation and increase pollution if no actions are taken to relieve the situation.

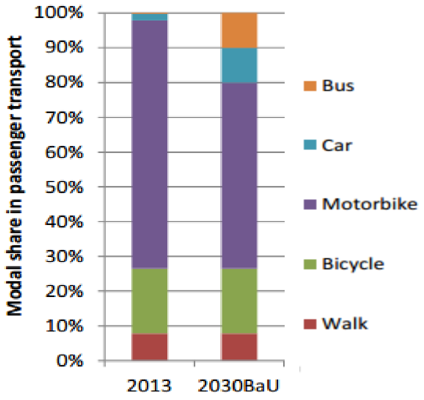

Fig. 4 Modal share of urban transport up to 2030 [13]

4. Policy Context in Vietnam and Hai Phong

Vietnam is committed to addressing climate change, including through signing of the Paris Agreement in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC) and submission of its Intended Nationally Determined Contribution (INDC, or simply NDC). In its NDC, Vietnam set the goal of reducing its GHG emissions by 8% in 2030, compared to business as usual (BAU) using domestic resources, and raised its ambition to 25% emissions reduction against BAU the transport sector, using domestic resources, would be responsible for contributing to the commitment of reducing 8% its GHG emissions against BAU, in 2030.[6] The Vietnam government has issued a series of policies to underscore the commitment to low-carbon development and environmental protection:

- The National Climate Change Strategy (2139/QD-TTg dated 5/12/2011);
- National Green Growth Strategy (1393/QD-TTg) approved by the Prime Minister in September 2012: "Orientation towards 2030: Reduce annual GHG emissions by at least 1.5-2%; reduce GHG in energy activities by 20 to 30% compared to BaU";
- The Management of GHG Emissions and Carbon Credits (1775/QD-TTg dated 21/11/2012);
- The Law on Environmental Protection (2014), in which the particular content responding to climate change;
- Green Growth Acton Plan (403/QD-TTg) approved by the Prime Minister in March 2014;
- The Prime Minister issued Decision No. 2053/QD-TTg, dated 28/10/2016, approving the implementation plan for Paris Agreement on climate change.

The Government has positioned the reduction of GHG emissions in the transport sector as an important national policy. The policy has been developed from low-carbon scenarios for the transport sector in ten ASEAN member countries by 2030. The Ministry of Transport's suggestion on mitigation of GHG emissions in the transport sector is to set three pillars of measures, i.e. modal shift (passenger and freight), energy efficiency (in 5 subsectors: road, railway, inland waterway, maritime and aviation) and fuel switch.[12] Additonal countermeasures are seriously introduced in order to reduce GHG emission. Experts from the World Bank also recommended that the most effective solution to reduce the greenhouse gas emissions by 2030 is applying new standards on fuel efficiency standards for cars and motorcycles. [8,9]

Table 3 GHG mitigation strategies in the transport sector [13]

Strategies	Actions
Fuel shift	Use of biofuels, including ethanol blend (E5/E10)
	Use of natural gas
	Use of electricity
Modal shift	Shift from private vehicles to public transport modes (buses, BRT, and metro)
	Shift freight transport from road to other modes
	Encourage non-motorized transport (NMT)
Energy efficiency	Vehicle maintenance
	Shift to energy efficiency vehicles
	Apply the energy saving technology
	Fuel economy standards

Based on the above strategies and the Green Port City strategy (72-KL/TW) of the Communist Party Politburo (Development of Hai Phong city at the time of industrialization and modernization of the state - Green Port City), Hai Phong formulated the strategies to reduce GHG emission and protect environment against the challenges of climate change:

- Decision No.65/QD-UBND dated 08/01/2014 issued the Climate Change Action Plan up to 2025;
- The Green Growth Strategy Acton Plan of the City of Hai Phong (1463/QD-UBND) in July 2014;
- Decision No.2842/QD-UBND dated on 17/12/2014 established "Steering Committee of Action Plan Responding to Climate Change in Haiphong";
- Decision No. 3002/QD-UBND dated on 01/12/2016 issuance of urgent measures to protect environment in Hai Phong city;
- Decision No. 3337/QD-UBND dated on 06/12/2017 on Plan to implement Decision No. 2053/QD-TTg 28/10/2016.

It appears that the most of countermeasures are being implemented in the sectors such as construction, energy, waste, water…However, the low-carbon transport measures are not yet effectively and fully in place.

5. Development Orientation for Low-carbon Transport in Hai Phong City

5.1 Goals

The study of developing a low-carbon transport system for Hai Phong aims to respond the national target. Two scenarios have developed with the projection of energy consumption and CO2 emission in energy-related categories such as Residental, Commercial, Transportaton, and Industry. They are 2030BaU and 2030CM (CounterMeasures).

Socio-economic information as well as environmental information for the base year (2013) was collected and analyzed in order to estimate current carbon emissions in major sectors. The finding shows that the energy shares of all sectors are expected to increase in future. This is because of continued trends of industrialization and increasing travel demand per person.

Main contributors to GHG emissions in the 2030BaU scenario are industrial sector (15.7 MtCO2eq), followed by transport, residental and commercial sectors which account for 13.4, 2.7 and 1.5 MtCO2eq, respectvely. The 2030CM scenario, which additonal low carbon countermeasures are introduced in order to assess the reduction effects of GHG emissions. GHG emissions in 2030CM, is estmated to reduce by 14% from the 2030BaU emissions. Regarding to GHG emission intensity, in 2013, estmated GHG emission intensity is 62.3 tCO2eq/bil.dongs. In 2030BaU, emission intensity decreased to 58.0 tCO2eq/bil.dongs mainly because of greater share of tertary industry in GDP. In 2030CM scenario, emission intensity is estmated to 49.9 tCO2eq/bil.dongs.

Table 4 GHG mitigation strategies in the transport sector [13]

	2013		2030 BaU		2030 CM
GHG emissions	$ktCO_2eq$	%	$ktCO_2eq$	%	$ktCO_2eq$
Agricultural energy-related	2	0.1	10	0.1	10
Industry	2,483	37.2	15,920	47.5	14,413
Commercial	221	3.3	1,470	4.4	1,170
Residential	1,291	19.3	2,672	8.0	2,291
Passenger transport	604	9.1	1,634	4.9	1,350
Freight transport	2,075	31.1	11,797	35.2	9,626
Total GHG emissions	6,675	100.0	33,494	100.0	28,850
GHG emissions per GDP (tCO_2eq/bil.Dongs)	63.2		58.0		49.9
GHG emissions per capita (tCO_2eq/person)	3.5		11.2		9.6

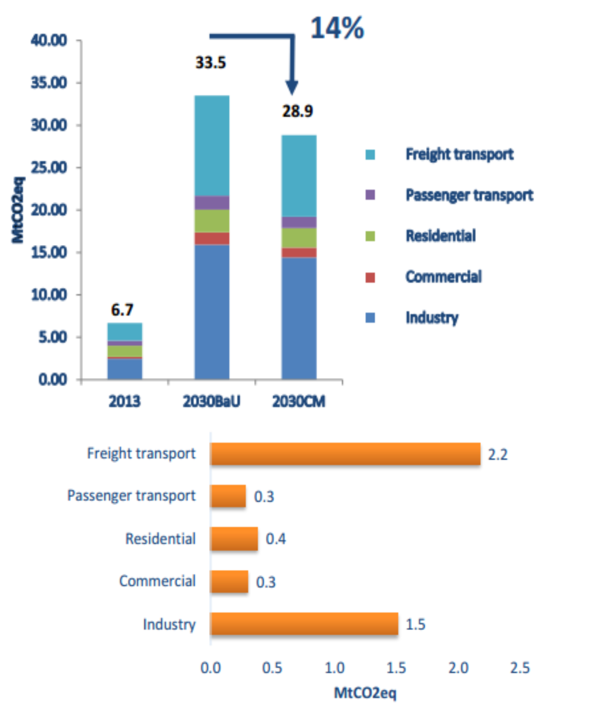

Fig. 5 GHG emissions and breakdown GHG emissions reduction by sector in Hai Phong up to 2030 [13]

In order to achieve sustainable transport, Hai Phong city can follow the ASI Framework. Success of low-carbon, safe, accessible, and affordable transport systems only comes from inclusive, clean, and energy-efficient transport policies. Actions to create low-carbon transport is guided by the ASI framework: integrating land use developments with mobility needs to avoid the need for travel; providing a shift to energy-efficient modes of transport; and seeking to improve vehicle and fuel technologies. While the ASI framework is used as an approach to identify mitigation, actions should be focused on the Shift and Improve components. Modal shift is very important and need to be emphasized, which includes variety of measures regarding both passenger and freight transportn such as improvement of fuel efficiency of vehicles, promoton of modal shift to public transport and control of private vehicles.

5.2 Development Orientation of Low-carbon Transport in Hai Phong City

As it can be seen, potential of GHG emissions reduction in transport sector is the biggest in the mitigation actions. Low-carbon transport strategies are essential, and plays a vital role in promoting sustainability of transport and urban. Low-carbon transport strategies should be developed in more details and local context as well as the timeframe (i.e. short, mid-term and long-term). This covers variety of measures regarding both passenger and freight transport. It is not only improvement of energy efficiency of vehicles but also promotion of transport modal shift. It includes 6 main group of measures with different priority levels as below:

(i) Promotion of public transport

Reducing use of private cars and motorcycles and increasing use of public transport can reduce emissions per passenger or freight transported.

(ii) Shift freight transport

Switching traffic from roads to railways or to inland waterways can reduce emissions per distance transported because these modes are less emission intensive.

(iii) Infrastructure improvement

Measures of this type aim to develop or rehabilitate transport infrastructure to increase carrying capacity of vehicles, giving preference to low-carbon or non-carbon transport modes such as BRT, bus, bicycle and walk.

(iv) Transport management

Transport management measures inlude development of Intelligent Transport System (ITS) for integrated management of transport modes, resulting in improved fuel efficiency and lower GHG emissions and controlling of personal vehicles.

(v) Energy efficiency

Measures related to promotion of using Biofuels/Cleanfuels in the transport sector to reduce GHG emissions and negative environmental effects, at the same time controlling emission standards of vehicles.

(vi) Communication

Measures to propagate and enhance public awareness about the benefits of public transport as well as the use of environmentally friendly vehicles.

Detail measures in the low-carbon transport strategy are shown in the table below:

Table 5 Development orientation of low-carbon transport for Hai Phong City

No.	Strategy	Measures	Period	Priority level
1	Promotion of public transport	Develop the bus route network; Enhance the quality of bus fleets; Improve public bus convenience and services.	Short term	High
		Increase use of public transport; replacing minibuses with larger buses in public transport systems; and introducting of urban railway mass transit systems, BRT and concentration of commercial facilities and housing complexes around stations in the future	Middle term /Long term	High
2	Shift freight transport	Change from roads to railways (including subways, light-duty rail (LDR), trams, or cableways) or from roads to inland waterways	Middle term/Long term	Low
		Increase transport capacity, and railways and feeder vessels which have lower environmental impacts	Middle term /Long term	Low

No.	Strategy	Measures	Period	Priority level
		(shipping and inland waterways) for container cargo being transported by trailers, etc		
		Develop logistics hub for land, sea, and air using the transport and logistics infrastructure of the city	Middle term	Medium
3	Infrastructure improvement	Develop elements of the transport infrastructure such as bridges, fly-overs, intelligent traffic signals, toll roads, and improved road maintenance, ring roads system with access to port facilities and industrial parks without passing through the city, in order to alleviate traffic congestion	Middle term/Long term	High
		Create intersections with overpass/underpass emissions between railways and roads in order to alleviate traffic congestion on roads	Middle term	Medium
		Establish bus-only lanes, improve bus stations, stops and shelters	Short term/ Middle term	High
		Develop parking areas and transfer points, sidewalks and bike lanes	Short term/ Middle term	High
4	Transport management	Establishing Intelligent Transport System (ITS) to optimize road traffic management by developing a system that integrates people, roads, and vehicles, effectively eliminate traffic congestion and accidents	Middle term	Medium
		Priority traffic organization for public transport by traffic signal and lanes priority	Short term/ Middle term	High
		Restrict and control of personal vehicles by application of taxes, fees	Middle term/Long term	High
5	Energy efficiency	Shift use of ossil liquid fuels (gasoline, diesel oil, and fuel oil) to natural fuels: Liquid petroleum gas (LPG), Compressed natural gas (CNG), Electric, Hybrid…	Middle term	High
		Improve current exhaust gas standards from Euro III to Euro IV, V, VI as countermeasures for exhaust gas from motorbikes and vehicles, and promote replacement of old vehicles with expired expiration dates that do not meet regulations and standards for exhaust gas.	Middle term	High
6	Communication	Promote shift from motorbikes and vehicles to public buses	Middle term	Medium
		Promote walking and use of bicycles as alternative to motorbikes and vehicles. Promote the practice of eco-friendly lifestyles to improve health	Middle term	Medium
		Develop publicity and awareness activities to promote eco-driving, including turning off vehicles when stopped ("idling stop").	Middle term	Medium

5.3 Challengies and the Way Forward

The above results show that energy efficiency is the best option to reduce the GHG emissions, following by modal shift to public transport and control of private of vehicles. The other measures contribute less significant impact in short term and middle term. Energy efficiency would be replacement of gasoline- and diesel oil-powered vehicles with vehicles powered by biofuels. Policies to develop biofuels or clean fuels must closely link with the roadmap for application of new technological standards on vehicles, especially regulations on emission control. According to the roadmap for biofuel/cleanfuel development in Vietnam until 2030, this fuels and emission standards based on European Standards (from level IV and up) will be established in the transport sector for all types of vehicles. However, implementation of the measures would be limited by barriers:

- The system of management and plan implementation lack certainty due to lower priority in the national action plan;

- Lack of policy and legal framework for promoting the production and use of biofuels in the transport sector;
- Lack of financing sources and support from the Government to invest in biofuel production and infrastructure development;
- Lack of technical knowledge and studies at the national level on the impact of biofuel production and use in Vietnam;
- Lack of awareness among the population of the benefits of biofuel use.

Low-carbon transport strategies and measures necessary to promote GHG reduction in the transport sector were laid out. However, it takes time before the law/plan is actually implemented. Even if laws and policies are set at the national level as described above, it takes time for proper implementation at the local level in many cases. Implementation a low-carbon strategy also requires large financial capacity, high-tech capabilities, appropriate supporting policies and public awareness. It would be not a small challenge to successful low-carbon implementation in Vietnam. It strongly requires political will, sufficient budget for financial support to the operation and an adequate organization.

As it can be seen, each mode of transport has its specific advantages and drawbacks directly influencing decisions of users. Public transport development is the strategic and important tasks to overcome traffic jam, curb traffic accidents and reduce environmental pollution, contributing to build a civilized, modern urban lifestyle. The Government of Vietnam has also made improving and developing public transport in major and medium cities a priority. However, there are a lot of barriers to the use of public transport: limited bus networks and service quality, other than buses and taxis, unavailability of public transport, motorcycles and cars considered cheaper and more convenient than buses. The Development Plan of Public Transport in Hai Phong set high targets for development of bus network. Especially, it was also envisaged to introduce Bus Rapid Transit (BRT) for which 4 lines were proposed. The plan calls for one BRT route by 2021, which another 3 to be developed by 2030. At the same time, one Metro route would be implemented in the period after 2030.[2] The challenge lies in the implementation of the plans. Up to now, the city has not been any breakthrough strategy for public transport development, consistent with urban development planing in order to ensure suistainable development for the city at the threshold of new opportunities.

GHG emission reduction potential from implementation of public transport systems mainly originate from the following changes:

- Development of bus or BRT, resulting in improved fuel efficiency and lower GHG emissions;
- Increase bus capacity due to larger fleets, thus reducing emissions per passenger-kilometer;
- Use of bus helps to reduce more efficiently fuel consumption and GHG emissions than other vehicles.

Thus, the most effective measures to this end include establishing full bus network and investing in BRTs and rail-based systems. The first priority is related to the strategy of the modernization of the public transport system. The City Government should strongly re-plan public transport in a safe, comfortable and reliable, contributing to change the use of private vehicles. Providing high quality public services enables to foster political decisions in favour of public transport and reconcile individual aspirations and collective will towards the development of sustainable cities. The first step should be focused on improving coverage and integration on whole bus network. Providing bus service to attraction points allows residents a transportation alternative to personal vehicles. Besides, the city should attempt to attract commuters away from personal vehicles by increasing the number of buses within the city, creating new routes to service more attraction points, sush as: school, hospital, shopping mall...

The next steps should be focused on providing multiple discount options to encourage public transport usage. Important improvements on the level of service shoule be focused on main tasks:

- Increase of service frequency;
- Renewal of the vehicle fleets;
- Increase of travel speeds and reliability thanks to infrastructural improvements (e.g., bus lanes, signal priority for bus at intersection);
- Install LED and GPS system on the entire fleet and introduce real-time information system to monitor bus and provide information to users.
- Introduce integrated ticket systems and smart card;
- Communication on the benefits of using public transport.

The second priority is related to private vehicles control plans. The case in Hai Phong city in particular and in the big cities in Vietnam in general is the demand of using private vehicles still far larger than on the using of public transport. Thus it is very necessary to tightly controlled private vehicles and develop public transport service to ensure mobility for people who cannot afford a private vehicle (low-income groups, elderly) and people who are unable to drive (children, handicapped) as well as to keep the city accessible (especially when car ownership and congestion are rising) and the city liveable. So, application of taxes, fees and charges on personal vehicles will not only offer a powerful instrument for influencing people's mode choice and discouraging the use of private vehicles but also is a possible source of revenues for covering expenses on public transport.

6. Conclusions and Recommendations

Vision (Envisioning 2045) Hai Phong aims at the development of a Green Port City that ensures the sustainability of the society, economy, and environment, as a gateway and production base for northern Viet Nam. National policies and international experiences provides cities like Hai Phong with ample examples to guide decision making in order to create a high quality, effective cost and environmental friendliness transport system.

The identification of priority areas to obtain low-carbon or non-carbon transport system requires specific measures, based on both of local and national conditionss. Accordingly, there is a need to develop criteria to identify areas including estimates of potential emission reductions, in-roads institutionally, and methodology and additionality issues. In which to consider the full range of aspects of the potential to reduce GHG emissions, the ability to deploy, the cost and other economic, social and environmental effects. This will not be achieved without a systematic insight to analyze all aspects of transport. It is a process that takes many years, needs a feasible development master plan, a clear roadmap and should perform step by step. The formulation and implementation of policies to reduce GHG emissions need to be considered in a comprehensive manner, which requires close coordination between ministries, departments and locals. It often requires great support financially of the government, including costs such as investment, installation, operation and activities. Besides, efforts should be made to encourage participation and promote the role of stakeholders in the GHG emission reduction activities. This is not only to ensure cooperation with and support of government policies but also can help to raise awareness of environmental protection of the whole society in general.

Mobility is not only one of indispensable human needs, but also promote development of the world. However, mobility also causes enormous negative impacts on people's lives sush as accident, environment pollution and climate change. The COVID-19 crisis has reinforced the importance of a sustainable world, city and transport. The ongoing COVID-19 pandemic is as a catalyst to get cities worldwide to move on the path of sustainability. To continue efforts to make cities efficient, safe and livable in the post-COVID world, sustainable transport is imperative and innovative approaches should be seriously considered by countries.

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Analysis of Efficiency of Urban Public Bus Transport: A Case Study in Hai Phong City, Vietnam

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Abstract

A fact and also a challenge in Vietnam's big cities is that the development of transport infrastructure does not keep up with the growth rate of private vehicles, causing traffic congestion, traffic accidents and environmental pollution tend to increase. In this context, the development of public transport , especially public bus transport is a top priority goal to serve the increasing travel demand and contribute to sustainable development of the city. It is also clearly oriented development in urban transport development planning in general and development planning of public bus transport in particular in the localities. The paper focuses on analyzing some aspects of efficiency of urban bus operation, a case study in Hai Phong city of Vietnam. The research results contribute to affirming the position and role of public bus transpor in the sustainable development of the city.

Keywords: Urban, private vehicles, public bus transport, efficiency, sustainable development

1. Role of Urban Public Bus Transport

With rapid urbanization in big cities of Vietnam, the basic solution in the long term to meet travel demand is to develop public transport to replace private vehicles. In the future, the development of mass rapid transit systems such as bus rapid transit (BRT), urban railway, and subway is possible and within the general development trend of modern and civilized urban. Socially, cost of travel will increase due to rising fuel prices, impact of climate change and epidemics (typically the global Covid-19 pandemic) making users of private vehicles will tend to switch to more cost-effective vehicles. In which, public transport is considered and selected because the prerequisite is cheaper cost. In addition, insecurity due to private vehicles and pollution caused by climate change makes the trend of using public transport increasing to ensure health and not cause adverse impacts on the environment.

With outstanding advantages such as: diversity of types, high mobility and flexibility, suitable for many types of terrain, linking with other types of road transport, capacity is relatively large, the investment cost is relatively low compared to other modern public transport types because it can use the existing road network... bus is the most popular type of public transport in urban areas. It creates great social benefits such as: reducing number of vehicles in circulation, reducing congestion, traffic accidents, limiting environmental pollution, ensuring the health and safety of passengers, creating urban civilized lifestyle...Looking at the potential of public transport in Vietnam by 2030, development will still focus on public bus transport system. After BRT or urban railway development projects are completed and put into operation, the bus system will play the role of connecting the entire public transport network.

2. Overview of Efficiency of Urban Public Bus Transport

Efficiency of public transport is seen from different pointviews, there are many studies on evaluating efficiency of public transport have been carried out by many authors over the years.

Approach on benefit and cost, Richard Layard and Stephen Glaister (1994) studied on benefit and cost analysis (CBA) which mentions assessment of public transport. Benefits and costs considered in addition to economic indicators, including economic and social indicators.

Sampaio et al. (2008) was carried out to analyze and evaluate efficiency of public transport on 12 systems in Europe and 7 systems in Brazil. The author indicated that these systems are characterized by different capacity structure as well as fare structure. A system is considered efficient if capacity allocation is more equitable among population groups as well as establishing a more extensive fare system. Efficiency of public transport is analyzed and evaluated through aspects as follows: Accessibility; Time; Reliability; Frequency; Maximum capacity of vehicle; Technical characteristics of vehicles; Information; Equipment such as shelters, timetables and schedules, instruction of stations and vehicles; Flexibility).

Author Aleksander Purba (2015) indicated that evaluation of efficiency of public transport should be based on a series of performance indicators from different perspectives of transport agency, operators and customers. To enhance efficiency of public transport towards sustainable development, the author focuses on aspects of organization and management.

In Vietnam, according to research [4], efficiency of public transport reflects level of investment into public transport to achieve certain goals related to the socio-economic and environmental aspects. The efficiency of public transport is considered from 3 poinviews: pointview of the state agency towards reducing environmental pollution, promoting social equality and rational land use planning; pointview of operators is to maximize profits or minimize costs; pointview of customers is the best service quality with the lowest cost for the trip.

Approach on service quality aspect, the authors A.M.Ngoc, K.V.Hung, V.A.Tuan (2017) considered customer's behavioural aspects while attempting to develop a set of quality standards for public transport services in developing countries and addressing the applicability of various criteria under those specific conditions. According to the research direction to evaluate performance of public transport service from supplier's viewpoint, An Minh NGOC (2017) assessed the satisfaction level of passengers for service quality according to 8 criterias of the EN 15140 standards (2006) with a number of performance indicators.

In summary, efficiency of public transport is considered from different aspects based on internal factors and capacity structure of the system (route network, infrastructure, fleet, fare, management system, operating technology) and other external factors such as: frequency, accessibility, travel time, reliability, information, etc. From the economic perspective, efficiency of public transport are associated with evaluation of passenger volume (output results of public transport). From the customer's perspective, efficiency of public transport is to satisfy the needs of passengers and the community. From the perspective of social benefits and costs, efficiency of public transport is considered through a number of criteria such as: saving fuel costs, exploitation costs, time; reducing congestion, noise, traffic accidents and environmental pollution. The efficiency and benefits of public transport are reflected in the cost and saving of social resources when using buses compared to using private vehicles. The economic - social - environmental efficiency of public bus transport are reflected in the following main aspects:

- Restriction on use of private vehicles.
- Benefits of reducing traffic congestion and accidents.
- Benefits of fuel cost savings.
- Saving environmental protection tax for the State.
- Benefits of reducing vehicle emissions and noise.
- Benefit of reducing traffic accidents.
- Efficiencies on pointview of operators and users.

3. Current Situation of Urban Public Bus Transport in Hai Phong City

Hai Phong is an industrial center and a seaport of the north of Vietnam. With an average growth rate of 15% per year and many advantages of location and development potential to make a strong economic breakthrough, Hai Phong is investing resources on social and transport infrastructure. According to the development planning to 2030, Hai Phong will become a special level city in Vietnam. Therefore, the transport system is synchronously and modernly invested, with high connectivity, contributing to socio-economic development and connecting to neighboring provinces. However, the city is also facing huge challenges with the increase of private vehicles, which puts more pressure on the transport infrastructure. In this context, the city identifies development of urban public transport, in which focusing on public bus transport is an important goal for sustainable development, contributing to enhance urban transport capacity and meet travel demand in the city.

Table 1 Number of vehicles in Hai Phong in the period 2010 - 2020

Year	Number of car	Number of motorcycle	Number of bus
2010	55,492	680,458	116
2011	63,643	760,401	118
2012	67,418	819,076	112
2013	69,930	881,119	109
2014	84,269	935,783	114
2015	100,876	986,481	110
2016	113,288	1,043,430	106
2017	121,497	1,105,418	104
2018	165,156	1,172,150	97
2019	176,953	1,336,914	79
2020	187,990	1,285,837	72

Source:[7]

Currently, public transport in Hai Phong includes many types such as: bus, taxi, motorbike taxi, piloting electric vehicles. The main types are bus and taxi, there is no urban railway or BRT. In particular, bus routes was formed in the period 2004 - 2009 when the city restored and developed the bus network. In the period 2010 - 2019, the city maintained 10 - 14 bus routes. The length of bus route network is about 380.5 km. The operating time of bus is from 5am to 9pm daily, frequency is from 15-40 minutes/trip, with 559 trips/day. The network of routes is not rationally distributed. Most of them are radial routes, there are no inner-city circular routes or branch routes to connect widely across areas with great travel demand. Passenger volume is also on a downward trend. In the period 2019 - 2020, due to the impact of the Covid-19 pandemic, passenger volume dropped dramatically, only 02 operators on 4 - 7 routes with 79 buses. Number of buses is too small compared to the number of private vehicle.

Besides, bus fleets are small and medium sized buses, including buses with a capacity of 35 to 60 passengers (B35 - B60). Buses with a capacity of 50 seats account for the majority (65.8%); the percentage of vehicles over 10 years old is still high (accounting for 45.6%), especially 32.9% of the vehicles are over 15 years old. Most of buses use diesel fuel and meet Euro II and Euro III of emission standards. Currently, capacity and quality of fleets are in low level. Most of vehicles are second-hand, domestically produced and imported from China.[7]

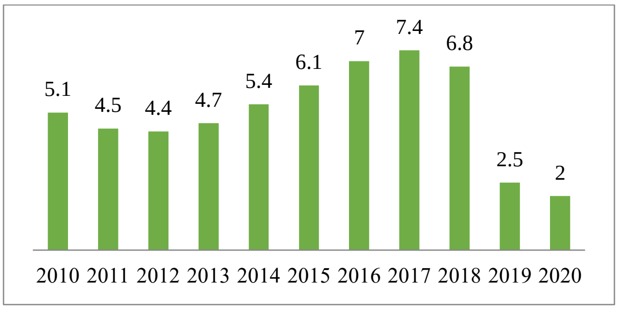

Fig. 1 Passenger volume in the period 2010 – 2020 (million passengers/year)

Besides, the infrastructure also shows the weakness and lack of synchronization. In the route network, there are a number of works to serve bus operations such as: 1 station, 1 depot and 1 garage invested by the state, 18 terminal points but only 6 /18 standard terminal points, 590 stops, 81 shelters and 03 ticketing kioses.[7] The whole network has no transfer points. There are not works to support bus operation such as priority lanes or bus-only roads, pedestrian lanes, overpasses or tunnels. In addition, the fare structure is only included 2 types of one-way tickets and monthly tickets, which have not been uniformly managed to apply to the whole city. Fare on each route is different, depending on passengers, distance and travel time. The city issued paper tickets and no integrated tickets as well as fare reduction. A trip based fare system where customers pay a flat fare per ride. In general, bus fares are still relatively high compared to people's income (accounting for about 7-9% of average income).

Bus service quality is relatively limited, not really meeting the people's expectations. Most people do not want to use buses due to low quality and modernity, relatively high fare, inconvenience. In addition, the bus system also reveals limitations in the planning of route network and infrastructure, information and operation technology, on organization and management,…

In order to promote and implement the development planning of public bus transport, the city issued the policies to support bus operation such as: lending the enterprise with preferential interest rate; supporting lending interest rate for vehicle investment; exempting and rents for building parking area, workshop of repair and maintenance...; exempting or reducing ticket prices for priority subjects such as pupils, students, elderly and people with disabilities; subsidizing for 4 routes of 02 operators through bus service ordering mechanism (The subsidy level is about 20 billion VND/year, equal to about 30%-40% of operating costs). The city has not granted any incentive policy for the private bus transport companies operating the other routes. They have no access to subsidy and seem to have difficulty to survive commercially. Mechanisms and policies to support public bus transport are basically ineffective.

In the Master Plan on development of public bus transport to 2025 and after 2030, the city expected that the bus network would increase by 3 times its current size (the rate of meeting travel demand increases from less than 2% to more than 10%).[6] Although it is not impossible to achieve the above goal, it is an expectation quite far from reality. While private vehicles (mainly motorbikes and cars) account for 80% of trips in the city, bus operations only meet less than 2% of demand and passenger volume continues to strongly down.

4. Analysis of Efficiency of Urban Public Bus Transport in Hai Phong City

4.1 Restriction on Use of Private Vehicles

In Hai Phong, the fleets uses buses B35, B40, B50, B55, B60. Normally, bus exploits an average rate of least 40 passengers (40P) per turn, a car carries 5 persons (5P) and a motorbike carries 2 persons (2P). It can be calculate and compare the capacity of bus or cars and motorbikes, thereby determining how many private vehicles will be reduced in traffic.

According to statistics on bus passenger volume, in the period of 2013 - 2017, buses operate relatively stably. The growth rate of private vehicles (car and motorbike) is also relatively high. It shows that within 5 years, if buses are used to replace private vehicles, 5,355,000 turns of cars and 14,535,000 turns of motorbikes will be reduced (Table 2). Thereby, social costs will be saved, reducing congestion, restrict the risk of traffic accidents and environmental pollution caused by emissions and noise.

4.2 Benefits of Reducing Traffic Congestion and Accidents

When a vehicle moves on the road, it will create an dynamic occupied area of the vehicle, this area is determined by the formula:

$$S_Đ = (b + 2a)\,(l + v.t + \alpha.v^2) \qquad [4]$$

In which:
$S_Đ$: Dynamic occupied area of the vehicle (m^2)
l: length of vehicle (m)
b: Width of vehicle (m)
a: Safe distance when moving (m)
v: Speed of vehicle (m/s)
t: Reaction time of driver (s)
α: Braking coefficient (m/s^2)

Occupied area of road surface of a bus is larger than occupied area of road surface of a cars or a motorbikes (Table 3), but using bus instead of car or motorbike, it will greatly reduce the occupied area of road. It means that capacity of road will be improved, contributing to reduce traffic congestion, accidents and maintenance costs of road.

Calculation results in the 5-year period (2013 - 2017), the average area occupied of bus is 65,637,000 m^2, of car is 360,468,000 m^2 and of motorbike is 521,730,000 m^2 (Table 4) . From there, level of safety is improved, saving time and reducing costs in traffic.

4.3 Benefits of fuel cost savings

According to research [4, p.81], the fuel consumption per trip (liter) for buses, cars and motorbikes is respectively 0.032, 0.21 and 0.124. Thus, if you use bus instead of car, you will save 0.21 - 0.032 = 0.178 liters of fuel/trip and if you use bus instead of motorbike, you will save 0.124 - 0.032 = 0.092 liters of fuel/trip.

When people use bus, there will be benefits due to fuel saving as the following formula:

$$B_{TKNL} = Q_{TKNL} \times G_{NL}\ (VND) \qquad [4]$$

In which:
B_{TKNL}: Saving fuel costs;
Q_{TKNL}: The amount of fuel saved due to using bus;
G_{NL}: Current fuel price;
$Q_{TKNL} = \sum_{i=1}^{n} Qi \times (Mnlcd\text{-}i\ -\ Mnlcd\text{-}VTHKCC)$;
Qi: Number of trips by vehicle i changed by bus;
Mnlcd-i: Fuel consumption per trip by vehicle i;
Mnlcd-VTHKCC: Fuel consumption per bus trip.

Calculation results in Table 5 show that a relatively large amount of fuel can be saved if buses are used instead of cars and motorbikes.

4.4 Saving Environmental Protection Tax for the State

Gasoline and diesel oil fuel are in the group of subjects to environmental protection tax: taxable gasoline is 4,000 VND/liter and taxable diesel oil is 2,000 VND/liter.[9] Calculation results in Table 6 show that, if using bus instead of cars and motorbikes, it is possible to save environmental protection tax for the state, thereby indirectly reducing gasoline, oil and Value-added tax is levied on essential consumer goods.

4.5 Benefits of Reducing Vehicle Emissions and Noise

Carbon dioxide (CO_2) is the main exhaust gas of vehicles after the combustion of Carbonoxide (CO), in addition to some other toxic gases such as HC, NOx... The amount of CO_2 emissions depends on 03 main factors: travel distance, fuel consumption, CO_2 emission rate of fuel used:

Amount of CO_2 emissions (kg CO_2) = Average travel distance (km) × Fuel consumption of vehicle (liter/km) × CO_2 emission rate of Fuel type (kg CO_2/liter) [5]

According to the research [4, p134], the CO_2 emission rate of gasoline and diesel fuel is respectively 1,926g CO_2/liter and 2,332g CO_2/liter. The fuel consumption of bus is larger (average 30.3 liters per 100 km) than car (12 liters per 100 km) and motorbike (2.7 liters per 100 km). However, the average amount of CO emissions/Passenger.Km of bus is only 40% of motorbike, 25% of car. The average amount of NOx emissions/Passenger.Km of bus is only 35% of motorbike and 30% of cars.

According to the Master Plan of development planning of public bus transport in Hai Phong, the average travel distance of a bus is 80km/day, a car is 15km/day, and a motorbike is 10km/day.[6] It is possible to calculate the amount of CO_2 emissions caused by vehicles as in Table 7 (Assuming 80% of registered cars and motorbikes in actual traffic every day).

The amount of CO_2 emissions caused by cars = 642.2/4.01 ~ 160 times of buses,

The amount of CO_2 emissions caused by motorbikes = 659.63/4.01 ~ 164 times of buses.

If people can replace a trip by car or motorbike to a bus, it will greatly reduce the amount of harmful CO_2 emissions.

On the other hand, common clean fuels such as LPG/CNG will save fuel costs over the same distance by 20-40% compared to gasoline/oil. Compared with gasoline and diesel engines, buses use CNG and LPG to smoothly make the engine, without emitting dust and black smoke, reducing CO emissions by 75-90%, CO emissions by 75÷90% and HC emissions by 40÷50%. Moreover, CNG fuel is thoroughly burned, so operating costs are more economical than vehicles using gasoline and diesel. Raising emission standards according to the roadmap (Euro V, VI) will reduce emissions of toxic gases (CO, HC, NOx) and dust (PM) causing air pollution. Therefore, using clean fuel is a fundamental solution to meet requirements of green transport trends.

Any noise in the living environment is considered pollution because it causes harm to the whole body and reduces the quality of life. Noise caused by vehicles includes: engine noise, car horn, brake sound, vibration of parts and some other resonant sounds. The maximum permissible noise level for vehicles is as follows: 74dBA for car, 77dBA for bus, 77dBA for motorbike.[10] Similar to the above, if a bus operates with an average rate of at least 40 persons per turn, a car carries 5 persons and a motorbike carries 2 persons, the average noise level caused by vehicles per person per turn is respectively 1,925; 14.8 and 38.5 dBA. Thus, the average noise level caused by a car is 7.6 times of a bus and the average noise level caused by a motorbike is 20 times of a bus. With the rapid increase of private vehicles, the noise pollution level will become more and more serious. Therefore, use of bus to replace private vehicles will significantly reduce noise in urban areas, contributing to ensure the health and quality of life.

4.6 Benefit of Reducing Traffic Accidents

In the period 2013 - 2017, according to the Transport Safety Board of the city, a total of 514 traffic accidents occurred in the area.[8] With the average per capita income in Hai Phong is 3,200 USD/year, the total damage caused by traffic accidents will be 514 × 3,200 = 1,644,800 USD (about 35 billion VND). On the other hand, most traffic accidents are caused by private vehicles. Thus, use of bus will significantly reduce the damage caused by traffic accidents.

4.7 Efficiencies on Pointview of Operators and Users

From the pointview of operators, investment into public bus service can be considered an unattractive activity due to low profit, even revenue is not enough to cover costs. However, operators will enjoy a series of preferential policies of the State for public bus transport. It is importance that operators must always determine the goal of activities for the community, constantly improving service quality better and better. From the user's pointview, bus service is only attractive when it is really convenient, safe and affordable. These factors determine whether passengers use bus or private vehicles. Using the bus to travel will ensure your health and safety, contributing to form the habit of using public bus transport, consciousness, traffic culture and urban civilization. Besides, according to the National Committee on Disabilities of Vietnam (NCD), there are more than 8 million people with disabilities, accounting for 7.8% of the national population, with 58% of them being women and 10% of them belonging to poor households. These are people who belong to the group of vulnerable objects in society. In which, number of people who can join in traffic is relatively large, including people in wheelchairs, the blind, and the deaf. Thus, use of bus service contributes to the formation of accessible transport, ensuring social justice for all users.

5. Conclusions and Recommendations

The research results of the paper confirm efficience of public bus transport for both the state, operators and users from economic - social - environmental perspectives. Although public bus transport has experienced ups and downs, service quality of buss has not met people's expectations, even stopped operating for a long time due to the Covid-19 epidemic, but it can be affirmed that the position and indispensable role of public bus transport to ensure the travel needs of people, contributing to sustainable development of urban areas in Vietnam in general and in Hai Phong city in particular. The important thing is the awareness of the whole society in general about the benefits of public bus transport and the vision of city leaders in particular in formulating long-term and methodical development policies. In addition, it is necessary to build an appropriate plan for development of public transport, improve management capacity, strongly and stably allocate financial resources in the long term for public transport.

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APPENDIXES

Table 2 Level of restriction on use of private vehicles in the period 2013 - 2017

Year	Number of car	Number of motorbike	Passenger volume (Million passengers/ year)	Number of turns (turn/year)			Number of reduced turns (turn/year)	
				Bus	Car	Motorbike	For car	For motorbike
(1)	(2)	(3)	(4)	(5)=(4)/ 40P	(6)=(4)/ 5P	(7)=(4)/ 2P	(8)= (6)-(5)	(9)= (7)-(5)
2013	23,006	881,119	4,700,000	117,500	940,000	2,350,000	822,500	2,232,500
2014	25,774	935,783	5,400,000	135,000	1,080,000	2,700,000	945,000	2,565,000
2015	29,081	986,481	6,100,000	152,500	1,220,000	3,050,000	1,067,500	2,897,500
2016	35,821	1,043,430	7,000,000	175,000	1,400,000	3,500,000	1,225,000	3,325,000
2017	41,303	1,105,418	7,400,000	185,000	1,480,000	3,700,000	1,295,000	3,515,000
Total	**154,985**	**4,952,231**	**30.600,000**	**765,000**	**6,120,000**	**15,300,000**	**5,355,000**	**14,535,000**

Source: Author's calculation from data of Hai Phong Department of Transport and Transport Safety Board 2021

Table 3 Dynamic occupied area of the vehicle

Parameters	Type of vehicle		
	Bus	Car	Motorbike
Carrying capacity (person)	50	5	2
l	8.18	4.1	1.9
b	2.31	1.7	0.71
a	0.5	0.5	0.5
v	5.6	5.6	5.6
t	3	3	3
α	0.03	0.03	0.04
$S_Đ$	**85.8**	**58.9**	**34.1**

Source: Author's calculation, refer to Standards TCVN 6211:2003, QCVN 10:2015/BGTVT, QCVN 14:2015/BGTVT, QCVN 09:2015/BGTVT, QCVN 41:2019/BGTVT

Table 4 Total dynamic occupied area of the vehicles in the period 2013 - 2017

Năm	Number of turns (turn/year)			Total dynamic occupied area of the vehicles		
	Bus	Car	Motorbike	Bus	Car	Motorbike
(1)	(2)	(3)	(4)	(5)=(2)×$S_Đ$	(6)=(3)×$S_Đ$	(7)=(4)×$S_Đ$
2013	117,500	940,000	2,350,000	10,081,500	55,366,000	80,135,000
2014	135,000	1,080,000	2,700,000	11,583,000	63,612,000	92,070,000
2015	152,500	1,220,000	3,050,000	13,084,500	71,858,000	104,005,000
2016	175,000	1,400,000	3,500,000	15,015,000	82,460,000	119,350,000
2017	185,000	1,480,000	3,700,000	15,873,000	87,172,000	126,170,000
Total	**765,000**	**6,120,000**	**15,300,000**	**65,637,000**	**360,468,000**	**521,730,000**

Source: Author's calculation from data of Hai Phong Department of Transport and Transport Safety Board 2021

Table 5 Benefits of fuel cost savings due to use of bus in the period 2013 - 2017

Year	Number of reduced turns (turn/year)		Amount of fuel saved (liter)		Average fuel price by year (VND/liter)		Benefits of fuel cost savings (1,000 VND)	
	For car	For motorbike	For car	For motorbike	Diesel	Mogas	For car	For motorbike
(1)	(2)	(3)	(4)= (2) × 0.178	(5)= (3) × 0.092	(6)	(7)	(8)= (6) ×(4)	(9)= (7) ×(5)
2013	822,500	2,232,500	146,405	205,390	22,900	23,700	3,352,674	4,867,743
2014	945,000	2,565,000	168,210	235,980	21,800	23,600	3,666,978	5,569,128
2015	1,067,500	2,897,500	190,015	266,570	14,300	18,500	2,717,214	4,931,545
2016	1,225,000	3,325,000	218,050	305,900	12,100	15,900	2,638,405	4,863,810
2017	1,295,000	3,515,000	230,510	323,380	14,200	17,500	3,273,242	5,659,150
Total	**5,355,000**	**14,535,000**	**953,190**	**1,337,220**			**15,648,514**	**25,891,376**

Source: Author's calculation from data of Hai Phong Department of Transport and Transport Safety Board 2021

Table 6 Benefits of saving environmental protection tax for the State due to use of bus in the period 2013 - 2017

Year	Number of reduced turns (turn/year)		Amount of fuel saved (liter)		Benefits of saving environmental protection tax (1,000 VND)	
	For car	For motorbike	For car	For motorbike	For car	For motorbike
(1)	(2)	(3)	(4)= (2) × 0.178	(5)= (3) × 0.092	(6)= (4) × 2,000 VND	(7)= (5) × 4,000 VND
2013	822,500	2,232,500	146,405	205,390	292,810	821,560
2014	945,000	2,565,000	168,210	235,980	336,420	943,920
2015	1,067,500	2,897,500	190,015	266,570	380,030	1,066,280
2016	1,225,000	3,325,000	218,050	305,900	436,100	1,223,600
2017	1,295,000	3,515,000	230,510	323,380	461,020	1,293,520
Total	**5,355,000**	**14,535,000**	**953,190**	**1,337,220**	**1,906,380**	**5,348,880**

Source: Author's calculation, refer to Resolution No.579/2018/UBTVQH14

Table 7 Amount of CO2 emissions of vehicles

Vehicles	Number of registered vehicles	Number of vehicles in traffic	Travel distance (km/day)	Fuel	Fuel consumption norms (liter/km)	CO2 emission rate of fuel type (kg CO2/liter)	Amount of CO2 emissions (kg CO2/day)
Bus	72	72	80	Diesel	0.303	0.0023	**4.01**
Car	187,990	150,392	15	Gasoline	0.12	0.0019	**642.92**
Motorbike	1,285,837	1,028,669	10	Gasoline	0.027	0.0019	**659.63**

Source: Author's calculation from data of Hai Phong Transport Safety Board 2021

SESSION 3.2: AYRF 2022 RESEARCH PAPER PRESENTATION

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009-2022 p.199-205	"Gap acceptance for a U-turn median opening on intercity highways"	Mr.Anuwat Chetcharatphong, Suranaree University of Technology, Thailand
022-2022 p.206-212	"การวิเคราะห์ผลกระทบของการกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกันบนทางหลวงด้วยแบบจำลองการจราจรระดับจุลภาค" Impact Analysis of Differentiated Per-Lane Speed Limits on Multilane Highways Using Microscopic Traffic Simulation Models"	ศุภศวัส สายงาม Mr.Supasawat sanigam, Chiang Mai University, Thailand

ความต้องการทำงานที่บ้านหลังโควิด-19

Preference of teleworking from home post COVID-19

หมายเลขหัวข้อ 6 หมายเลขบทความ: AYRF008-2022

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บทคัดย่อ

จากการทำงานที่บ้านในช่วงการแพร่ระบาดของโรคโควิด-19 หลายคนต้องการที่จะทำงานที่บ้านต่อถึงแม้จะหมดช่วงล็อคดาวน์ของโรคโควิด-19 แล้วก็ตาม ซึ่งปัจจัยที่ส่งผลให้เกิดความตั้งใจที่จะทำงานที่บ้านต่อ อาจนำไปสู่การเลือกซื้อที่พักอาศัยในอนาคตได้ เนื่องจากสถานการณ์การแพร่ระบาดของโรคโควิด-19 ทำให้ความต้องการที่พักอาศัยเกิดการเปลี่ยนแปลง บ้านจึงไม่ได้เป็นเพียงแค่ที่พักอาศัยเพียงอย่างเดียวอีกต่อไป การศึกษานี้มีวัตถุประสงค์เพื่อวิเคราะห์ปัจจัยที่มีผลต่อความตั้งใจในการทำงานที่บ้าน สำรวจโดยการสัมภาษณ์กลุ่มตัวอย่างจำนวน 157 ชุด ทำการวิเคราะห์องค์ประกอบเชิงยืนยันและการวิเคราะห์องค์ประกอบเชิงสำรวจ พบว่าปัจจัยแฝงที่สนับสนุนการทำงานที่บ้านอาจแบ่งได้เป็น 2 กลุ่มคือ (1) ปัจจัยเกี่ยวกับทัศนคติเกี่ยวกับการทำงานที่บ้าน เช่น การทำงานที่บ้านเป็นการทำงานที่มีประสิทธิภาพ ทำให้มีความสมดุลระหว่างการทำงานกับการใช้ชีวิตมากขึ้น และยังเป็นการใช้เวลาอย่างคุ้มค่า เป็นต้น และ (2) ปัจจัยเกี่ยวกับงานและผู้เกี่ยวข้อง เช่น ลักษณะงานสามารถทำที่บ้านได้ ค่านิยมการทำงานที่บ้านของเพื่อนร่วมงาน เป็นต้น การศึกษาทำการวิเคราะห์แบบจำลองสมการโครงสร้าง พบว่าปัจจัยแฝงด้านทัศนคติต่อการทำงานที่บ้านและปัจจัยเกี่ยวกับงานและผู้เกี่ยวข้องส่งผลต่อความตั้งใจที่จะทำงานที่บ้านในอนาคตโดยมีน้ำหนัก 0.54 และ 0.23 ตามลำดับ นั่นหมายถึงการที่กลุ่มตัวอย่างตั้งใจที่จะทำงานที่บ้านขึ้นอยู่กับตนเองมากกว่าสิ่งรอบข้าง ผลการศึกษาชี้ให้เห็นว่าการทำงานที่บ้านให้มีความสะดวกและมีประสิทธิภาพนั้น บ้านที่อยู่อาศัยและสภาพแวดล้อมมีความสำคัญเป็นอย่างยิ่ง และสามารถนำไปสู่แนวคิดการพัฒนาที่อยู่อาศัยเพื่อรองรับการทำงานและการใช้ชีวิตวิถีใหม่ที่มีประสิทธิภาพต่อไป

คำสำคัญ: โรคโควิด-19, ทำงานที่บ้าน, การวิเคราะห์องค์ประกอบเชิงยืนยัน, การวิเคราะห์องค์ประกอบเชิงสำรวจ, การวิเคราะห์แบบจำลองสมการโครงสร้าง

Abstract

According to working from home during COVID-19 pandemic, many employees wish to continue work-from-home even after the pandemic. The factors which affect intention of work-from-home may influence to residential preference due to house is not only for living anymore. This study aims to examine the factors which affect intention of work-from-home. There are 157 samples interviewed face-to-face. The exploratory factor analysis and confirmatory factor analysis extracted two latent variables: (1) Own attitude, e.g., WFH is an efficient way of working, WFH is time worthy, etc. (2) External factors, e.g., his/her present job can do WFH, co-workers also do WFH, etc. The structural equation modeling (SEM) show that attitude and external factors affect WFH intention, having path coefficients of 0.54 and 0.23 respectively. The results imply that housing and the related factors play important roles to WFH efficiently and satisfactorily. The finding would provide insight house development for the new normal life where WFH has become common.

Keywords: Covid-19 pandemic, Work from home, Exploratory Factor Analysis, Confirmatory Factor Analysis, Structural Equation Modeling

1. บทนำ

จากสถานการณ์การแพร่ระบาดของโรคโควิด-19 ที่เกิดขึ้น รัฐบาลได้มีมาตรการขอความร่วมมือให้ประชาชนปรับพฤติกรรมการอยู่ร่วมกัน ให้ความสำคัญกับการเว้นระยะห่างทางสังคม (Social Distancing) งดกิจกรรมทางสังคม เน้นอยู่บ้านให้มากที่สุดตามนโยบาย "อยู่บ้าน หยุดเชื้อ เพื่อชาติ" [1] อีกทั้งมีการบังคับใช้ข้อกำหนดนายกรัฐมนตรีที่ออกตามความในมาตรา 9 ของ พ.ร.ก. ฉุกเฉิน ฉบับที่ 27 ซึ่งเป็นมาตรการยกระดับในการสกัดกั้นการระบาดของโรคโควิด-19 ให้พนักงานของรัฐและเอกชนปฏิบัติงานนอกสถานที่ตั้ง [2] ทำให้ทั้งภาครัฐและเอกชนหลายแห่งประกาศให้พนักงานทำงานที่บ้านในช่วงการแพร่ระบาดของโรคโควิด-19 การใช้ชีวิตของผู้คนจึงเปลี่ยนแปลงไปจากเดิม

จากการทำงานที่บ้านในช่วงการแพร่ระบาดของโรคโควิด-19 หลายคนต้องการที่จะทำงานที่บ้านต่อถึงแม้จะหมดช่วงล็อคดาวน์ของโรคโควิด-19 แล้วก็ตาม [3] ซึ่งปัจจัยที่ส่งผลให้เกิดความตั้งใจที่จะทำงานที่บ้านต่ออาจนำไปสู่การเลือกซื้อที่พักอาศัยในอนาคตได้ เนื่องจากสถานการณ์การแพร่ระบาดของโรคโควิด-19 ทำให้ความต้องการที่พักอาศัยเกิดการเปลี่ยนแปลง [4] บ้านจึงไม่ได้เป็นเพียงแค่ที่พักอาศัยเพียงอย่างเดียวอีกต่อไป

การศึกษานี้มีวัตถุประสงค์เพื่อวิเคราะห์ปัจจัยที่มีผลต่อความตั้งใจในการทำงานที่บ้าน ซึ่งผลการศึกษามีประโยชน์ต่อหน่วยงานในการกำหนดนโยบายการทำงานที่บ้านของบุคลากร การศึกษาทำการสำรวจโดยการสัมภาษณ์กลุ่มตัวอย่างจำนวน 157 ชุด และนำข้อมูลที่ได้มาวิเคราะห์องค์ประกอบเชิงสำรวจ (Exploratory Factor Analysis) วิเคราะห์องค์ประกอบเชิงยืนยัน (Confirmatory Factor Analysis) และวิเคราะห์แบบจำลองสมการโครงสร้าง (Structural Equation Modeling)

2. ทฤษฎีและงานวิจัยที่เกี่ยวข้อง

2.1 การวิเคราะห์องค์ประกอบเชิงสำรวจ

การวิเคราะห์องค์ประกอบเชิงสำรวจ (Exploratory Factor Analysis: EFA) เป็นการสร้างตัวแปรใหม่ หรือจัดองค์ประกอบใหม่ขึ้นมาภายใต้ตัวแปรที่กำหนด โดยการศึกษานี้ใช้โปรแกรม IBM SPSS Version 27 เพื่อให้ทราบจำนวนขององค์ประกอบใหม่ที่เกิดขึ้น มีขั้นตอนการวิเคราะห์ดังนี้

2.1.1 หาความสัมพันธ์ระหว่างตัวแปรทั้งหมด

ทำการตรวจสอบค่าความเหมาะสมในการวิเคราะห์องค์ประกอบด้วยค่า KMO (Kaiser-Mayer-Olkin) เพื่อตรวจสอบว่าข้อมูลที่เก็บมานั้นเหมาะสมในการนำมาวิเคราะห์หรือไม่ โดยที่ค่า KMO แต่ละค่ามีความหมายดังนี้ .80 ขึ้นไป หมายความว่า เหมาะสมดีมากที่จะวิเคราะห์องค์ประกอบ .70-.79 หมายความว่า เหมาะสมดีที่จะวิเคราะห์องค์ประกอบ .60-.69 หมายความว่า เหมาะสมปานกลางที่จะวิเคราะห์องค์ประกอบ .50-.59 หมายความว่า เหมาะสมน้อยที่จะวิเคราะห์องค์ประกอบ น้อยกว่า .50 หมายความว่า ไม่เหมาะสมที่จะวิเคราะห์องค์ประกอบ [5] และทำการตรวจสอบ Bartlett's Sphericity Test เป็นการทดสอบค่าไค-สแควร์ของเมทริกซ์สัมประสิทธิ์สหสัมพันธ์ ซึ่งในโปรแกรม SPSS จะแสดงผลค่า p-value เป็นค่า sig ซึ่งหากน้อยกว่า 0.05 ถือว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ [5]

2.1.2 การสกัดองค์ประกอบ

การสกัดองค์ประกอบ เป็นการนำค่าความสัมพันธ์ระหว่างตัวแปรมาสกัดเพื่อให้ได้องค์ประกอบแรก สามารถทำได้หลายวิธี ในการศึกษานี้ใช้วิธีตัวประกอบหลักปัจจัย (Principle Components Factoring: PCF) [5]

2.1.3 การหมุนองค์ประกอบ

เนื่องจากบางตัวแปรที่สกัดแล้วมีค่าใกล้เคียงกัน ทำให้เกิดความไม่ชัดเจนในการจัดองค์ประกอบ จึงต้องทำการหมุนแกน โดยการหมุนแกนจะทำให้ตัวแปรใดๆ มีค่าน้ำหนักปัจจัยหรือน้ำหนักองค์ประกอบ (Factor Loadings) มากขึ้นหรือลดลง ทำให้เกิดความชัดเจนมากยิ่งขึ้นในการจัดองค์ประกอบ การหมุนแกนทำได้ 2 วิธี คือ วิธีการหมุนแบบฉาก (Orthogonal Rotation) และวิธีการหมุนแบบมุมแหลมหรือไม่ตั้งฉาก (Oblique Rotation) [5] การศึกษานี้ใช้วิธีการหมุนแบบมุมฉาก เนื่องจากต้องการให้แต่ละองค์ประกอบเป็นอิสระต่อกัน ไม่มีความสัมพันธ์กัน จากนั้นทำการพิจารณาตัวแปรในองค์ประกอบ โดยพิจารณาที่น้ำหนักองค์ประกอบที่ค่ามากกว่า ± .3 [5]

2.1.4 พิจารณาเกณฑ์การกำหนดองค์ประกอบ

เพื่อตรวจสอบค่าให้เป็นไปตามที่เกณฑ์กำหนดค่าไอเกน (Eigenvalue: λ) คือผลบวกกำลังสองของค่า Factor Loading แต่ละตัวแปรที่อยู่ในองค์ประกอบนั้น เป็นค่าที่บอกถึงความแปรปรวนขององค์ประกอบที่

อธิบายได้ด้วยตัวแปรทุกตัวที่อยู่ในองค์ประกอบเดียวกัน ซึ่งควรมีค่ามากกว่าหรือเท่ากับ 1.00 [5]
ค่าแปรปรวนสะสมขององค์ประกอบที่สกัดได้ (Total Variance Explained) ควรมีค่ามากกว่า 0.60 [5]
ค่าความร่วมกันของตัวแปร (Communality) คือผลบวกกำลังสองของค่า Factor Loading แต่ละองค์ประกอบที่มีตัวแปรนั้น ซึ่งควรมีค่าไม่น้อยกว่า 0.50 [5]
ค่าน้ำหนักองค์ประกอบ (Factor Loadings) เป็นค่าที่แสดงความสัมพันธ์ระหว่างตัวแปรแฝงกับตัวแปรสังเกตได้ ควรมีค่าตั้งแต่ 0.50 จึงถือว่ามีนัยสำคัญทางสถิติ [5]

2.2 การวิเคราะห์องค์ประกอบเชิงยืนยัน

การวิเคราะห์องค์ประกอบเชิงยืนยัน (Confirmatory Factor Analysis: CFA) เป็นการวิเคราะห์เพื่อยืนยันองค์ประกอบหรือปัจจัยที่สร้างขึ้นมาจากที่ได้วิเคราะห์องค์ประกอบเชิงสำรวจมาก่อนแล้ว โดยทำการสร้างแบบจำลอง และนำเข้าตัวแปรเดิมตัวแปรสังเกตได้มาในโปรแกรม และกำหนดตัวแปรแฝง เพื่อให้ตัวแปรแฝงมีความชัดเจนมากขึ้น ในการศึกษานี้ใช้โปรแกรม AMOS ในการวิเคราะห์องค์ประกอบเชิงยืนยัน โดยสามารถตรวจสอบค่าความถูกต้องของแบบจำลองได้ดังนี้

2.2.1 ค่าสถิติไค-สแควร์ (Chi-Square Statistics: CMIN) หรือ χ^2 เป็นสถิติแสดงความแตกต่างระหว่างเมทริกซ์ความแปรปรวน-ความแปรปรวนร่วมของประชากรและที่ได้จากการประมาณค่า โดยมีสมมติฐานที่ใช้ทดสอบดังสมการที่ (1) และสมการที่ (2)

$$H_0: \Sigma = \Sigma(\theta) \quad (1)$$
$$H_1: \Sigma \neq \Sigma(\theta) \quad (2)$$

โดยที่ H_0 หมายถึง กรณีที่เมทริกซ์ความแปรปรวน-ความแปรปรวนร่วมของประชากรและที่ได้จากการประมาณค่าไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ กล่าวคือ แบบจำลองมีความสอดคล้องกับข้อมูล
ส่วน H_1 หมายถึง กรณีเมทริกซ์ความแปรปรวน-ความแปรปรวนร่วมของประชากรและที่ได้จากการประมาณค่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ กล่าวคือ แบบจำลองไม่สอดคล้องกับข้อมูล

อย่างไรก็ตามการตรวจสอบค่า χ^2 จะขึ้นอยู่กับขนาดของกลุ่มตัวอย่าง ยิ่งมีกลุ่มตัวอย่างมาก ค่า χ^2 ก็มากขึ้นไปด้วย ทำให้มีโอกาสปฏิเสธ H_0 มากขึ้น ซึ่งหากตรวจสอบค่า χ^2 แล้วแบบจำลองปฏิเสธ H_0 ให้พิจารณาค่า χ^2/df โดยค่าที่แสดงความสอดคล้องคือค่าที่น้อยกว่า 2.00 ส่วนค่าที่ยอมรับได้ว่ามีความสอดคล้องคือค่าที่มากกว่าหรือเท่ากับ 2.00 แต่ไม่เกิน 5.00 หากค่า χ^2/df มากกว่า 5.00 แสดงว่าแบบจำลองไม่มีความสอดคล้อง [5]

2.2.2 ค่าดัชนีความสอดคล้องของแบบจำลอง

ค่าดัชนีความสอดคล้องของแบบจำลอง (Goodness of Fit Index: GFI) เป็นการเปรียบเทียบค่า χ^2 กับ ค่าองศาอิสระ (Degree of Freedom: df) ซึ่งค่าดัชนีความสอดคล้องของแบบจำลอง (Goodness of Fit Index: GFI) จะมีค่าระหว่าง 0.00 – 1.00 โดยค่าที่แสดงความสอดคล้องคือค่าที่มากกว่าหรือเท่ากับ 0.95 ส่วนค่าที่ยอมรับได้ว่ามีความสอดคล้องคือค่าที่มากกว่า 0.90 แต่ไม่เกิน 0.95 หากค่าดัชนีความสอดคล้องของแบบจำลอง (Goodness of Fit Index: GFI) น้อยกว่าหรือเท่ากับ 0.90 แสดงว่าแบบจำลองไม่มีความสอดคล้องกับข้อมูลเชิงประจักษ์ [5]

2.2.3 ค่าดัชนีวัดความสอดคล้องกลมกลืน

ค่าดัชนีวัดความสอดคล้องกลมกลืนเชิงสัมพัทธ์ (Comparative fit Index: CFI) เป็นการเปรียบเทียบระหว่างแบบจำลองสมมติฐานกับแบบจำลองที่ไม่มีความสัมพันธ์ระหว่างตัวแปรทั้งหมด (Null model) ซึ่งควรมีค่ามากกว่าหรือเท่ากับ 0.90 [5], [6]

2.2.4 ค่ารากที่สองของค่าเฉลี่ยของส่วนเหลือคลาดเคลื่อนกำลังสองของการประมาณค่า

ค่ารากที่สองของค่าเฉลี่ยของส่วนเหลือคลาดเคลื่อนกำลังสองของการประมาณค่า (Root Mean Square Residual Error of Approximation: RMSEA) ที่มีค่าต่ำกว่า 0.05 หมายถึง แบบจำลองสอดคล้องกับข้อมูลเชิงประจักษ์ดีมาก หากมีค่าอยู่ระหว่าง 0.05 – 0.08 หมายถึง แบบจำลองค่อนข้างสอดคล้องกับข้อมูลเชิงประจักษ์ หากมีค่ามากกว่า 0.80 แต่ไม่เกิน 0.10 หมายถึง แบบจำลองสอดคล้องกับข้อมูลเชิงประจักษ์ไม่มาก และหากค่ามากกว่า 0.10 หมายถึง แบบจำลองไม่มีความสอดคล้องเชิงประจักษ์ [5], [6]

2.3 การวิเคราะห์แบบจำลองสมการโครงสร้าง

แบบจำลองสมการโครงสร้าง (Structural Equation Modeling: SEM) เป็นการวิเคราะห์ในทำนองเดียวกับการวิเคราะห์เส้นทาง (Path Analysis) แต่ทำการวิเคราะห์เพื่อหาความสัมพันธ์ระหว่างตัวแปรแฝงด้วยกัน และระหว่างตัวแปรแฝงกับตัวแปรสังเกตไปพร้อมกัน การตรวจสอบความสอดคล้องใช้หลักเกณฑ์เดียวกับการวิเคราะห์องค์ประกอบเชิงยืนยัน [5] ซึ่งการวิเคราะห์ SEM สามารถตรวจสอบความสอดคล้องของแบบจำลองได้ด้วยหลักเกณฑ์เดียวกันกับการวิเคราะห์องค์ประกอบเชิงยืนยันที่กล่าวข้างต้น

2.4 แบบจำลองความรู้สึกส่วนตัวและบรรทัดฐานทางสังคมที่ส่งผลต่อพฤติกรรม

แบบจำลองความรู้สึกส่วนตัวและบรรทัดฐานทางสังคมที่ส่งผลต่อพฤติกรรม (Modeling Personal and Normative Influences on Behavior) เป็นแบบจำลองที่อธิบายถึงความรู้สึกส่วนตัว (Personal) และบรรทัดฐานทางสังคม (Normative) ส่งผลให้เกิดความตั้งใจจะทำพฤติกรรมนั้นๆ (Behavioral Intention) [7] ในการศึกษานี้ได้นำแบบจำลองนี้มาใช้ในการวิเคราะห์ปัจจัยที่เกี่ยวกับตนเอง (Personal) เช่น ทัศนคติ ความคิดเห็นต่อเรื่องนั้นๆ เป็นต้น และปัจจัยเกี่ยวกับสิ่งรอบข้าง (Normative) เช่น ความคิดเห็นของคนในสังคม กฎเกณฑ์หรือแนวทางปฏิบัติในสังคม เป็นต้น ที่ส่งผลต่อความตั้งใจที่จะทำงานที่บ้านหลังจากสถานการณ์โรคโควิด-19 คลี่คลาย (Intention)

คำถามที่ใช้ในการเก็บแบบสอบถามมีการประยุกต์มาจาก Taru Jain et al. (2022) [8] ที่ใช้วิธี TPB และได้นำมาปรับปรุงเพิ่มเติมเพื่อให้สอดคล้องกับประเทศไทยมากขึ้น โดยแบบสอบถามได้ผ่านการทำ Pre-survey ก่อนดำเนินการเก็บข้อมูลจริง

2.5 งานวิจัยที่เกี่ยวข้อง

Taru Jain et al. (2022) [8] ได้ทำการศึกษาการส่งผลในระยะยาวของการทำงานที่บ้านเนื่องจากการแพร่ระบาดของโรคโควิด-19 และปัจจัยทางเศรษฐกิจและสังคมที่ส่งผลให้คนอยากทำงานที่บ้านมากขึ้นในช่วงหลังการแพร่ระบาดของโรคโควิด-19 โดยใช้ทฤษฎีตามแผน (The Theory of Planned Behavior: TPB) ทำการเก็บแบบสอบถามทั้งหมด 1,364 ชุดในช่วงเดือนมิถุนายนถึงสิงหาคม พ.ศ. 2563

ผลการสำรวจพบว่า มีการทำงานที่บ้านเพิ่มขึ้นในช่วงล็อคดาวน์ 310% ส่วนในระยะยาวที่หลังการแพร่ระบาดของโรคโควิด-19 การทำงานที่บ้านคาดว่าจะมากขึ้นกว่าช่วงก่อนการแพร่ระบาดของโรคโควิด-19 ประมาณ 75%

Taru Jain ทำการวิเคราะห์ข้อมูลด้วยวิธีสมการโครงสร้าง (Structural Equation Modeling: SEM) การรับรู้ความสามารถในการควบคุมพฤติกรรม (Perceived Behavioral Control: PBC) และ การคล้อยตามกลุ่มอ้างอิง (Subjective Norm: SN) เป็นตัวแปรสำคัญที่ทำให้เกิดเจตนา (Intention) ในการทำงานที่บ้านหลังการระบาดของโรคโควิด-19 ส่วนเจตคติหรือทัศนคติ (Attitude) เป็นตัวแปรที่ส่งผลค่อนข้างน้อย ต่อเจตนาในการทำงานที่บ้านหลังการระบาดของโรคโควิด-19

Pasquale De Toro et al. (2021) [4] ได้ทำการวิเคราะห์แนวโน้มของตลาดอสังหาริมทรัพย์เพื่อการอยู่อาศัยในเมืองเนเปิลส์ ประเทศอิตาลี หลังจากเริ่มมีการระบาดของโรคโควิด-19 เนื่องจากในช่วงระยะเวลาที่มีมาตรการจำกัดพื้นที่ของภาครัฐ ทำให้ที่อยู่อาศัยเป็นทั้งที่พักผ่อน ที่ทำงานหรือเรียน รวมถึงที่ทำกิจกรรมยามว่างด้วย ดังนั้นที่อยู่อาศัยจึงถูกปรับเปลี่ยนให้ตรงกับความต้องการของผู้อาศัยที่จำเป็นต้องอยู่ในที่พักอาศัยมากขึ้น โดยทำการสำรวจความคิดเห็นของผู้ที่อยู่อาศัยในชุมชนและนายหน้าอสังหาริมทรัพย์ในช่วงเดือนกันยายนถึงตุลาคม พ.ศ. 2563 ผ่านทาง Google Form และใช้ GIS Software ในการวิเคราะห์ข้อมูลเชิงภูมิศาสตร์ในช่วงปี 2552 ถึงปี 2563

จากผลการวิเคราะห์พบว่าการแพร่ระบาดของโรคโควิด-19 ที่เกิดขึ้นทำให้ผู้ตอบแบบสอบถามมีคุณลักษณะของบ้านที่ต้องการแตกต่างไปจากเดิม เช่น ต้องการระเบียงมากขึ้น อีกทั้งยังพบว่า 68% ของผู้ตอบแบบสอบถามพึงพอใจกับที่พักอาศัยของตนเอง 27.7% ต้องการให้พื้นที่ของที่พักอาศัยกว้างขึ้น และรวมไปถึงคำตอบในด้านความต้องการพื้นที่ใหม่ในที่พักอาศัย 53% ต้องการพื้นที่เปิด 33.1% ต้องการให้มีพื้นที่สำหรับทำกิจกรรมยามว่าง และ 23.4% ต้องการให้มีพื้นที่สำหรับทำงานหรือเรียน

Pagani et al. (2021) [9] ได้ทำการสำรวจผลกระทบต่อการเลือกที่อยู่อาศัยของประชาชนที่เกิดจากการระบาดของโรคโควิด-19 ในระลอกที่ 1 บริเวณพื้นที่ประเทศสวิตเซอร์แลนด์ เนื่องจากเกิดการแพร่ระบาดของโรคโควิด-19 ทำให้สภาพแวดล้อมความเป็นอยู่ของประชาชนเปลี่ยนทันที ทำให้ประชาชนต้องปรับตัวเพื่อให้สามารถดำเนินชีวิตในสังคมได้ต่อไป ผู้เชี่ยวชาญแนะนำว่าผู้พัฒนาโครงการอสังหาริมทรัพย์ควรพิจารณาความต้องการที่อยู่อาศัยของประชาชนใหม่ เพราะประชาชนอาจมีความต้องการที่เปลี่ยนไปในช่วงที่มีมาตรการจำกัดพื้นที่ของภาครัฐ (Lockdown) การวิเคราะห์แบบบนลงล่าง (Top-Down Approach) อาจใช้ไม่ได้ผลอีกต่อไป โดยใช้ IBM SPSS Version 26 ในการกรองผลสำรวจ และหาความสัมพันธ์ระหว่างลักษณะของผู้ตอบแบบสอบถาม เช่น อายุ เพศ อาชีพ เป็นต้น กิจกรรมยามว่างที่เปลี่ยนไปและสภาพแวดล้อมที่อยู่อาศัยของผู้ตอบแบบสอบถาม โดยเก็บข้อมูลปัจจัยที่มีผลต่อการตัดสินใจเลือกที่อยู่อาศัย แล้วนำมาเปรียบเทียบกันในช่วงก่อนและหลังโควิด-19

ข้อมูลที่ได้พบว่าปัจจัยที่มีความแตกต่างกันระหว่างก่อนและหลังโควิด-19 คือด้านที่อยู่อาศัยที่แสดงถึงตัวตนของผู้อยู่อาศัย (Self-representation) และด้านการอุปโภค บริโภค (Production, Consumption) โดยผู้ทำแบบสอบถามเห็นว่าด้านที่อยู่อาศัยที่แสดงถึงตัวตนของผู้อยู่อาศัย มีความจำเป็นมากขึ้นในการเลือกที่อยู่อาศัย และ ด้านการอุปโภคบริโภค มีความจำเป็นน้อยลงจากเดิม ผลสรุปได้ว่า 40% ของผู้ทำแบบสอบถามเห็นว่าปัจจัยในการเลือกที่อยู่อาศัยยังคงเหมือนช่วงก่อนโควิด-19 และอีก 60% มีอย่างน้อย 1 ปัจจัยที่เปลี่ยนไปจากช่วงก่อนโควิด-19

Jonas De Vos et al. (2020) [10] ได้วิเคราะห์ว่าการย้ายที่อยู่อาศัยส่งผลต่อทัศนคติในการเดินทางและความถี่ในการเดินทางนั้น ๆ อย่างไร เพื่อนำข้อมูลที่ได้ไปต่อยอดให้มีโครงสร้างพื้นฐานที่เพียงพอกับความต้องการของประชาชน โดยกลุ่มตัวอย่างที่นำมาใช้วิเคราะห์เป็นผู้ที่ย้ายที่อยู่อาศัยมาที่เมือง Ghent ประเทศเบลเยียม ในช่วงปี 2558 – 2559 จำนวน 1650 ตัวอย่าง

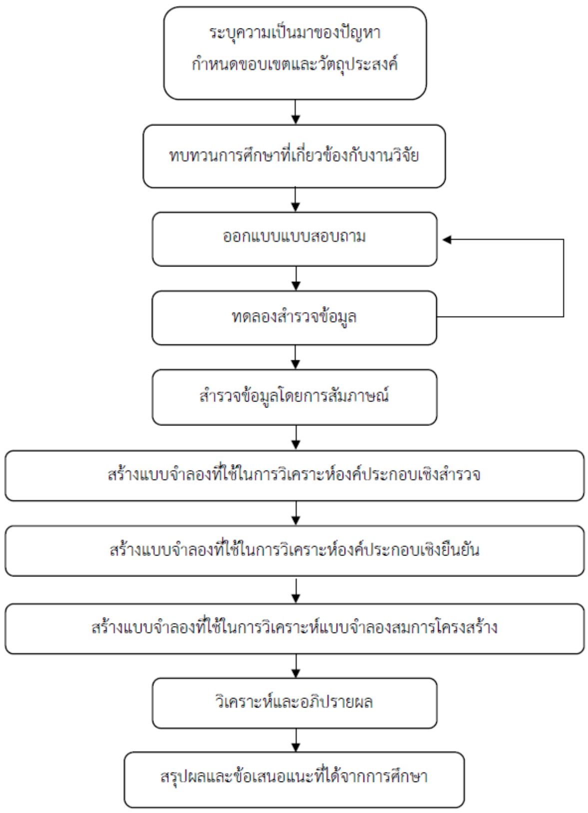
Jonas De Vos ใช้ Structural Equation Modeling หรือ SEM ในการวิเคราะห์ 8 แบบจำลอง ซึ่งวิเคราะห์ทั้งการเดินทางไป-กลับที่ทำงาน และการเดินทางส่วนตัว มีตัวแปรในด้านการเปลี่ยนแปลงด้านการย้ายที่อยู่อาศัย การเปลี่ยนแปลงด้านทัศนคติในการเดินทาง การเปลี่ยนแปลงด้านการมีรถยนต์ส่วนบุคคล การเปลี่ยนแปลงในด้านระยะทางที่ใช้ในการเดินทาง การเปลี่ยนแปลงด้านความถี่ในการเดินทางรูปแบบต่าง ๆ

จากผลการวิจัยพบว่า การย้ายที่อยู่อาศัยส่งผลให้ทัศนคติในการเดินทางเปลี่ยนแปลงไปโดยประชาชนส่วนใหญ่ย้ายไปในพื้นที่ที่มีความเป็นเมืองมากขึ้น ทำให้ทัศนคติต่อการเดินทางด้วยระบบขนส่งสาธารณะ การเดินและการปั่นจักรยาน เป็นไปในทิศทางที่ดีขึ้น มีการใช้รถน้อยลง ใช้การเดินและการปั่นจักรยานมากขึ้น

จากงานวิจัยข้างต้นพบว่า ในช่วงก่อนเกิดสถานการณ์การแพร่ระบาดของโรคโควิด-19 ผู้คนย้ายไปในพื้นที่ที่มีความเป็นเมืองมากขึ้น [10] หลังจากเกิดสถานการณ์การแพร่ระบาดของโรคโควิด-19 ปัจจัยที่ส่งผลให้เกิดความตั้งใจที่จะทำงานที่บ้านคือปัจจัยที่เกี่ยวกับสิ่งรอบข้างมากกว่าปัจจัยที่เกี่ยวกับตนเอง [7] ผู้คนต้องการพื้นที่ของที่พักอาศัยมากขึ้น เช่น พื้นที่สวน ระเบียง และส่วนหนึ่งต้องการพื้นที่สำหรับออกกำลังกาย พื้นที่สำหรับทำงาน [4] ปัจจัยในการเลือกที่พักอาศัยแตกต่างจากช่วงก่อนโรคโควิด-19 ระบาด โดยปัจจัยที่ส่งผลต่อการเลือกซื้อที่พักอาศัยมากขึ้นคือการต้องการที่พักอาศัยที่ตรงกับการใช้ชีวิตของผู้อยู่ ในทางตรงกันข้ามปัจจัยด้านสาธารณูปโภคกลับเป็นปัจจัยที่ส่งผลต่อการเลือกซื้อที่พักอาศัยน้อยลง [9]

3. วิธีการดำเนินการ

ขั้นตอนการศึกษาดังรูปที่ 1



รูปที่ 1 ขั้นตอนการศึกษา

3.1 ข้อมูล

3.1.1 ประชากรและกลุ่มตัวอย่าง

การศึกษานี้เลือกกลุ่มตัวอย่างโดยการสุ่มตัวอย่างแบบกลุ่ม (Cluster Sampling) เนื่องจากการศึกษานี้เกี่ยวกับการทำงานที่บ้าน ซึ่งต้องการเก็บข้อมูลจากผู้ที่ทำงานในกรุงเทพและปริมณฑล จึงทำการสุ่มตัวอย่างประชากรจากพื้นที่ดังกล่าวตามจำนวนที่ต้องการ โดยกำหนดกลุ่มเป้าหมายเป็นผู้ที่ทำงานหรืออาศัยอยู่ในกรุงเทพและปริมณฑล โดย

ทำการเก็บข้อมูลบริเวณที่ใกล้สถานีรถไฟฟ้าหมอชิต อารีย์ ช่องนนทรี พระราม 9 และอโศก ในช่วงเดือนพฤษภาคม พ.ศ. 2565

การกำหนดขนาดกลุ่มตัวอย่าง อ้างอิงจาก Hair et al. (2019) [6] แนะนำขนาดกลุ่มตัวอย่างขั้นต่ำควรมีอย่างน้อย 5 เท่าของจำนวนตัวแปร ซึ่งขนาดของกลุ่มตัวอย่างจะยอมรับได้มากกว่าหากใช้อัตราส่วน 10:1 (จำนวนกลุ่มตัวอย่างเป็น 10 เท่าของจำนวนตัวแปร) การศึกษานี้มีจำนวน 10 ตัวแปร จึงต้องมีกลุ่มตัวอย่างขั้นต่ำ 100 ชุด เพื่อลดอุปสรรคที่อาจเกิดขึ้นในการคำนวณทางสถิติ จึงกำหนดกลุ่มตัวอย่างขั้นต่ำที่ 150 ชุด

3.1.2 เครื่องมือที่ใช้ในการเก็บรวบรวมข้อมูล

การศึกษานี้ใช้แบบสำรวจประกอบด้วยชุดคำถาม 3 ส่วน ได้แก่ ส่วนที่ 1 สอบถามข้อมูลด้านเศรษฐกิจและสังคมของกลุ่มตัวอย่าง ส่วนที่ 2 สอบถามลักษณะที่อยู่อาศัย และส่วนที่ 3 สอบถามความคิดเห็นเกี่ยวกับการทำงานที่บ้าน ประกอบด้วย 10 ข้อความดังตารางที่ 1 โดยเป็นคำถามเห็นด้วยกับแต่ละข้อความมากน้อยเพียงใด คำตอบเป็นมาตรวัด 7 ระดับ ตั้งแต่ 1 คือไม่เห็นด้วยอย่างยิ่ง ไปจนถึง 7 คือเห็นด้วยอย่างยิ่ง ตามลำดับ [11]

3.1.3 การตรวจสอบคุณภาพเครื่องมือ

ทำการตรวจสอบความเชื่อมั่นโดยพิจารณาค่า Cronbach's Alpha (α) เป็นค่าที่แสดงถึงความสอดคล้องภายในคำถาม มีค่าระหว่าง 0-1 ค่า โดยค่าที่ได้ไม่ควรต่ำว่า 0.70 [6] ซึ่งจากผลการทดสอบ Personal ได้ค่า α เท่ากับ 0.932 และ Normative ได้ค่า α เท่ากับ 0.747 ซึ่งมากกว่า 0.70 ทั้ง 2 ค่า แสดงให้เห็นว่าคำถามมีความสอดคล้อง

ตารางที่ 1 ตัวแปรที่ใช้ในการศึกษา

ตัวแปร	ข้อความ
Improve_work	การทำงานที่บ้านทำให้ทำงานได้อย่างมีประสิทธิภาพ
Lower_cost	การทำงานที่บ้านช่วยลดค่าใช้จ่าย
Worklifebalance	การทำงานที่บ้านช่วยทำให้เกิดสมดุลระหว่างงานและชีวิตส่วนตัว (Work-life Balance)
Useful_time	การทำงานที่บ้านเป็นการใช้เวลาอย่างคุ้มค่า
Fam_support	คนในครอบครัวของท่าน สนับสนุนให้ท่านทำงานที่บ้านในช่วงโควิด-19 ระบาด
Boss_support	เจ้านายของท่าน/หุ้นส่วน/ลูกค้า สนับสนุนให้ท่านทำงานที่บ้านในช่วงโควิด-19 ระบาด
Coworker_WFH	เพื่อนร่วมงานของท่าน ทำงานที่บ้านในช่วงโควิด-19 ระบาด
Workdone_FH	งานของท่านสามารถทำที่บ้านได้
Organize_allow	องค์กร/หน่วยงานของท่าน อนุญาตให้ท่านทำงานที่บ้านได้ ในช่วงโควิด-19 สายพันธุ์เดลต้าระบาด (กรกฎาคม ถึง สิงหาคม 2564)
Intention to WFH	หากต้นปี 2566 สถานการณ์โควิด-19 คลี่คลาย ท่านอยากทำงานที่บ้านบ่อยกว่าช่วงก่อนโควิด-19 ระบาด

4. ผลการวิเคราะห์

4.1 ข้อมูล

4.1.1 ลักษณะทางเศรษฐกิจและสังคม

ลักษณะทางเศรษฐกิจและสังคมของกลุ่มตัวอย่าง 157 คน พบว่า เป็นเพศชายร้อยละ 32.48 เพศหญิงร้อยละ 67.52 โดยอายุเฉลี่ยอยู่ที่ 29.56 ปี ค่าเบี่ยงเบนของช่วยอายุเท่ากับ 3.61 ร้อยละ 84.08 เป็นผู้ที่จบการศึกษาระดับปริญญาตรี ร้อยละ 9.55 เป็นผู้ที่จบการศึกษาระดับปริญญาโท และร้อยละ 6.37 เป็นผู้ที่จบการศึกษาระดับมัธยม/ปวช./ปวส. ในส่วนของอาชีพ ร้อยละ 88.54 เป็นพนักงานบริษัทเอกชน/หน่วยเอกชน ร้อยละ 5.10 มีด้วยกัน 2 กลุ่มคือ เป็นข้าราชการ/พนักงานของรัฐ/รัฐวิสาหกิจ และธุรกิจส่วนตัว/ค้าขาย ส่วนกลุ่มสุดท้ายคิดเป็นร้อยละ 1.27 รับจ้างทั่วไป/ฟรีแลนซ์ โดยที่กลุ่มตัวอย่างมีรายได้เฉลี่ยอยู่ที่ 24,952.72 บาทต่อเดือน ค่าเบี่ยงเบนของรายได้เท่ากับ 7,729.90 บาทต่อเดือน จำนวนสมาชิกในครัวเรือนของกลุ่มตัวอย่างเฉลี่ยอยู่ที่ 2.90 คน ค่าเบี่ยงเบนเท่ากับ 0.94 ดังตารางที่ 2

พบว่ากลุ่มตัวอย่างเป็นกลุ่มที่อยู่วัยกำลังสร้างฐานะความเป็นอยู่ให้ตนเอง สังเกตได้จากช่วงอายุส่วนใหญ่ประมาณ 26-35 ปี และมีรายได้อยู่ในช่วง 20,000-30,000 บาทต่อเดือน ซึ่งเป็นกลุ่มเป้าหมายของการศึกษานี้

ตารางที่ 2 ลักษณะทางเศรษฐกิจและสังคมของกลุ่มตัวอย่าง (N=157)

ลักษณะ		ความถี่ (จำนวน)	ร้อยละ	$\bar{x}$	S.D.
เพศ	ชาย	51	32.48	N/A	N/A
	หญิง	106	67.52		
อายุ	ต่ำกว่า 20	0	0.00	29.56	3.61
	21-25	9	5.73		
	26-30	100	63.69		
	31-35	42	26.75		
	36-40	3	1.91		
	41-45	2	1.27		
	มากกว่า 45	1	0.64		
ระดับการศึกษาสูงสุด	ต่ำกว่ามัธยม	0	0.00	N/A	N/A
	มัธยม/ปวช./ปวส.	10	6.37		
	ปริญญาตรี	132	84.08		
	ปริญญาโท	15	9.55		
	สูงกว่าปริญญาโท	0	0.00		
อาชีพ	ข้าราชการ/พนักงานของรัฐ/รัฐวิสาหกิจ	8	5.10	N/A	N/A
	พนักงานบริษัท/หน่วยงานเอกชน	139	88.54		
	ธุรกิจส่วนตัว/ค้าขาย	8	5.10		
	รับจ้างทั่วไป/ฟรีแลนซ์	2	1.27		
	พ่อบ้าน/แม่บ้าน/ดูแลบ้าน	0	0.00		
	นิสิต/นักศึกษา/นักเรียน	0	0.00		
รายได้ต่อเดือน (บาท)	น้อยกว่า 15,001	4	2.55	24,952.72	7,729.90
	15,001 - 20,000	28	17.83		
	20,001 - 25,000	64	40.76		
	25,001 - 30,000	36	22.93		
	30,001 - 35,000	11	7.01		
	35,001 – 40,000	6	3.82		
	40,001 - 45,000	2	1.27		
	45,001 - 50,000	3	1.91		
	มากกว่า 50,000	3	19.1		
จำนวนสมาชิกในครัวเรือน (คน)	1	5	3.18	2.90	0.94
	2	54	34.39		
	3	57	36.31		
	4	33	21.02		
	มากกว่า 4	8	5.10		

4.1.2 ลักษณะที่อยู่อาศัย

ลักษณะที่อยู่อาศัยของกลุ่มตัวอย่างพบว่า เป็นบ้านเดี่ยว/บ้านแฝด ร้อยละ 26.75 แฟลต/อพาร์ทเมนต์ ร้อยละ 25.48 ทาวน์เฮ้าส์/ทาวน์โฮม ร้อยละ 21.66 คอนโดมิเนียม/อาคารชุด ร้อยละ 21.02 และเป็นอาคารพาณิชย์/ตึกแถว ร้อยละ 5.10 ซึ่งอาศัยอยู่ในกรุงเทพมหานครคิดเป็นร้อยละ 96.82 และปริมณฑลคิดเป็นร้อยละ 3.18 โดยร้อยละ 98.73 ทำงานในกรุงเทพมหานคร และปริมณฑลคิดเป็นร้อยละ 1.27 ดังตารางที่ 3 เห็นได้ว่ากลุ่มตัวอย่างมีประเภทที่อยู่อาศัยที่แตกต่างกัน กล่าวคือมีการกระจายตัวของกลุ่มอย่าง

ตารางที่ 3 ลักษณะที่อยู่อาศัย

ลักษณะ		ความถี่ (จำนวน)	ร้อยละ
ประเภทที่อยู่อาศัย			
	บ้านเดี่ยว/บ้านแฝด	42	26.75
	ทาวน์เฮ้าส์/ทาวน์โฮม	34	21.66
	คอนโดมิเนียม/อาคารชุด	33	21.02
	แฟลต/อพาร์ทเมนต์	40	25.48
	อาคารพาณิชย์/ตึกแถว	8	5.10

4.1.3 ความคิดเห็นเกี่ยวกับการทำงานที่บ้าน

จากการเก็บแบบสอบถามในช่วงเดือนพฤษภาคม พ.ศ. 2565 เกี่ยวกับการทำงานที่บ้านในกลุ่มตัวอย่าง 157 คน ด้วยการใช้เกณฑ์การตัดสินใจชนิด 7 ระดับ พบว่ากลุ่มตัวอย่างส่วนใหญ่เห็นว่าการทำงานที่บ้านทำให้ทำงานได้อย่างมีประสิทธิภาพ ช่วยลดค่าใช้จ่าย และช่วยทำให้เกิดสมดุลระหว่างงานและชีวิตส่วนตัว (Work-life Balance) สามารถใช้เวลาได้อย่างคุ้มค่า ซึ่งจากค่าเบี่ยงเบนมาตรฐาน (Standard deviation: S.D.) ที่มีค่าน้อย แสดงถึงกลุ่มตัวอย่างมีความคิดเห็นเป็นไปในทิศทางเดียวกัน คนในครอบครัว เจ้านาย หุ้นส่วน ลูกค้า ของกลุ่มตัวอย่างให้ความสนับสนุนในการทำงานที่บ้าน ในส่วนของเพื่อนร่วมงานของกลุ่มตัวอย่างนั้น ทำงานที่บ้านในช่วงโรคโควิด-19 ระบาด ส่วนลักษณะของงานเป็นงานที่สามารถทำที่บ้านได้ และรวมไปถึงองค์กร/หน่วยงานของกลุ่มตัวอย่าง อนุญาตให้ทำงานที่บ้านในช่วงโรคโควิด-19 ระบาดได้ และหากต้นปี 2566 สถานการณ์โรคโควิด-19 คลี่คลาย กลุ่มตัวอย่างเห็นด้วยว่าอยากทำงานที่บ้านบ่อยกว่าช่วงก่อนโรคโควิด-19 ระบาด ซึ่งค่าเบี่ยงเบนมาตรฐานมีค่าน้อย บ่งบอกว่าคำตอบของกลุ่มตัวอย่างเป็นไปในทิศทางเดียวกัน ดังตารางที่ 4

ตารางที่ 4 ความคิดเห็นเกี่ยวกับการทำงานที่บ้าน

ตัวแปร	ข้อความ	$\bar{x}$	S.D.
Work_efficiency	การทำงานที่บ้านทำให้ทำงานได้อย่างมีประสิทธิภาพ	5.14	1.45
Lower_cost	การทำงานที่บ้านช่วยลดค่าใช้จ่าย	6.26	0.84
Worklifebalance	การทำงานที่บ้านช่วยทำให้เกิดสมดุลระหว่างงานและชีวิตส่วนตัว (Work-life Balance)	5.60	1.30
Valuable_time	การทำงานที่บ้านเป็นการใช้เวลาอย่างคุ้มค่า	5.76	1.05
Family_support	คนในครอบครัวของท่าน สนับสนุนให้ท่านทำงานที่บ้านในช่วงโควิด-19 ระบาด	6.45	1.08
Boss_support	เจ้านายของท่าน/หุ้นส่วน/ลูกค้า สนับสนุนให้ท่านทำงานที่บ้านในช่วงโควิด-19 ระบาด	5.35	1.27
Co-worker_WFH	เพื่อนร่วมงานของท่าน ทำงานที่บ้านในช่วงโควิด-19 ระบาด	6.25	1.19
Workable_athome	งานของท่านสามารถทำที่บ้านได้	5.62	1.23
Organization_allow	องค์กร/หน่วยงานของท่าน อนุญาตให้ท่านทำงานที่บ้านได้ ในช่วงโควิด-19 สายพันธุ์เดลต้าระบาด (กรกฎาคม ถึง สิงหาคม 2564)	5.59	1.21
Intention to WFH	หากต้นปี 2566 สถานการณ์โควิด-19 คลี่คลาย ท่านอยากทำงานที่บ้านบ่อยกว่าช่วงก่อนโควิด-19 ระบาด	5.01	1.14

4.2 การวิเคราะห์องค์ประกอบเชิงสำรวจ

จากการตรวจสอบค่าความเหมาะสมในการวิเคราะห์องค์ประกอบ ได้ค่า KMO เท่ากับ .857 มากกว่า .80 เหมาะสมดีมากที่จะวิเคราะห์องค์ประกอบ [5] ค่า Bartlett's Sphericity Test เท่ากับ 983.405 ค่าองศาอิสระเท่ากับ 36 และ Sig <.001 น้อยกว่า p=.005 ถือว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ [5]

ค่าแปรปรวนสะสมขององค์ประกอบที่สกัดได้ (Total Variance Explained) เท่ากับ 70.346 มากกว่า 60 ถือว่าผ่านเกณฑ์ [5]
ค่าไอเกนที่มากกว่า 1 มีอยู่ด้วยกัน 2 องค์ประกอบ

องค์ประกอบที่ 1 ตั้งชื่อว่า ปัจจัยที่เกี่ยวกับตนเอง (PERSONAL) ประกอบด้วย 4 ตัวแปรดังนี้ Work_efficiency, Lower_cost, Worklifebalance และ Valuable_time
ส่วนองค์ประกอบที่ 2 ตั้งชื่อว่า ปัจจัยเกี่ยวกับสิ่งรอบข้าง (NORMATIVE) ประกอบด้วย 5 ตัวแปรดังนี้ Family_support, Boss_support, Co-worker_WFH, Workable_athome และ Organization_allow ดังตารางที่ 5

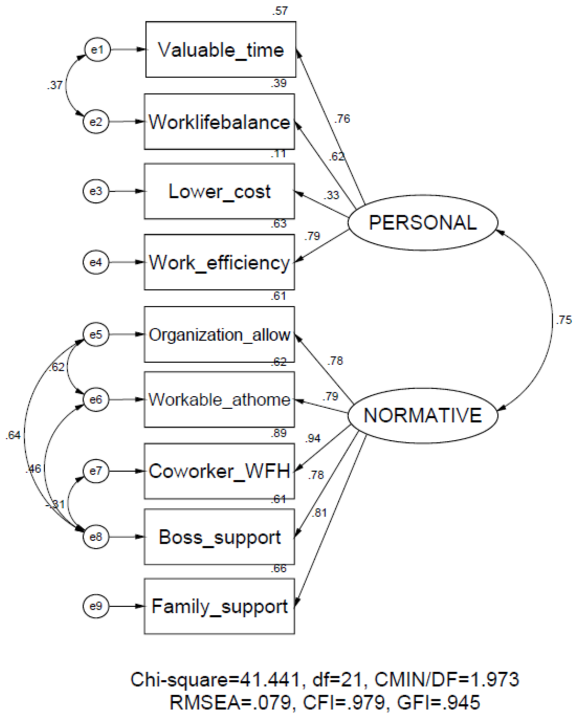
ตารางที่ 5 ผลการวิเคราะห์องค์ประกอบเชิงสำรวจ

ตัวแปร	ค่าน้ำหนักปัจจัย		ค่าความร่วมกัน
	องค์ประกอบที่ 1	องค์ประกอบที่ 2	
Organization_allow	.915		.596
Boss_support	.893		.399
Workable_athome	.888		.633
Co-worker_WFH	.823		.748
Family_support	.719		.651
Valuable_time		.801	.824
Worklifebalance		.738	.783
Work_efficiency		.638	.838
Lower_cost		.632	.858

4.3 การวิเคราะห์องค์ประกอบเชิงยืนยัน

จากการตรวจสอบค่าความถูกต้องของแบบจำลอง พบว่า ค่าไค-สแควร์เท่ากับ 41.441 ค่าองศาอิสระเท่ากับ 21 χ^2/df เท่ากับ 1.973 น้อยกว่า 3.00 ถือว่าผ่านเกณฑ์ ค่าดัชนีความสอดคล้องของแบบจำลอง (Goodness of Fit Index: GFI) เท่ากับ 0.945 มากกว่า 0.90 ถือว่าผ่านเกณฑ์ ค่าดัชนีวัดความสอดคล้องกลมกลืนเชิงสัมพัทธ์ (Comparative fit Index: CFI) เท่ากับ 0.979 มากกว่า 0.90 ถือว่าผ่านเกณฑ์ ค่ารากที่สองของค่าเฉลี่ยของส่วนเหลือคลาดเคลื่อนกำลังสองของการประมาณค่า (Root Mean Square Residual Error of Approximation: RMSEA) เท่ากับ 0.079 น้อยกว่า 0.08 ถือว่าอยู่ในเกณฑ์ยอมรับได้ [5], [6]

โดยความสัมพันธ์ระหว่างตัวแปรแฝง PERSONAL มีตัวแปรสังเกตได้ Work_efficiency ที่มีน้ำหนักปัจจัย 0.79 เป็นตัวแปรที่มีอิทธิพลต่อ PERSONAL มากที่สุด และมีตัวแปรสังเกตได้ Lower_Cost ที่มีน้ำหนักปัจจัย 0.33 เป็นตัวแปรที่มีอิทธิพลต่อ PERSONAL น้อยที่สุด ส่วนตัวแปรแฝง NORMATIVE มีตัวแปรสังเกตได้ Co-worker_WFH ที่มีค่าน้ำหนักปัจจัย 0.94 เป็นตัวแปรที่มีอิทธิพลต่อ NORMATIVE มากที่สุด และมีตัวแปรสังเกตได้ Organization_allow และ Boss_support ที่มีน้ำหนักปัจจัย 0.78 เป็นตัวแปรที่มีอิทธิพลต่อ NORMATIVE น้อยที่สุด ดังรูปที่ 2



รูปที่ 2 ผลการวิเคราะห์องค์ประกอบเชิงยืนยัน

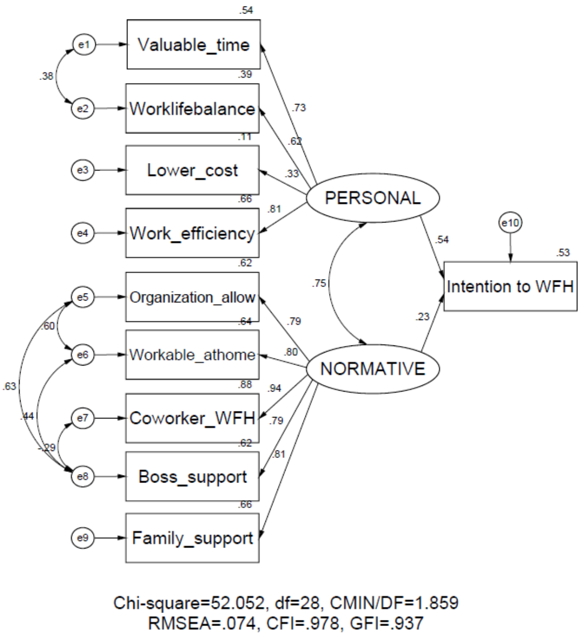
4.4 การวิเคราะห์แบบจำลองสมการโครงสร้าง

จากการตรวจสอบค่าความสอดคล้องของแบบจำลอง ค่า χ^2/df เท่ากับ 1.859 น้อยกว่า 2.00 แสดงถึงแบบจำลองมีความสอดคล้อง ค่าดัชนีความสอดคล้องของแบบจำลอง (Goodness of Fit Index: GFI) เท่ากับ 0.937 มากกว่า 0.90 เป็นค่าที่ยอมรับได้ ค่ารากที่สองของค่าเฉลี่ยของส่วนเหลือคลาดเคลื่อนกำลังสองของการประมาณค่า (Root Mean Square Residual Error of Approximation: RMSEA) เท่ากับ 0.074 น้อยกว่า 0.08 ถือว่าแบบจำลองค่อนข้างสอดคล้องกับข้อมูลเชิงประจักษ์ และค่าดัชนีวัดความสอดคล้องกลมกลืนเชิงสัมพัทธ์ (Comparative fit Index: CFI) เท่ากับ 0.978 มากกว่า 0.97 แสดงถึงแบบจำลองมีความสอดคล้อง [5]

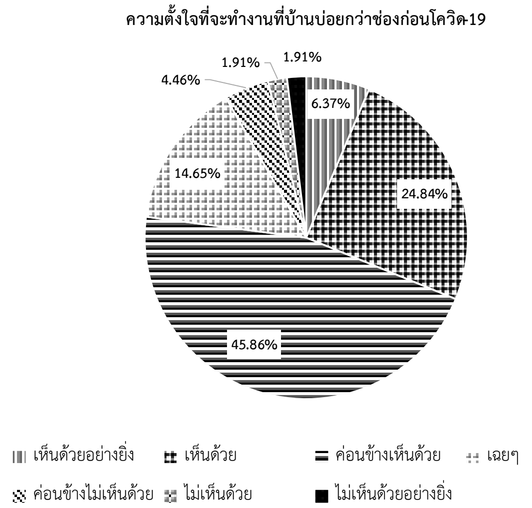
โดยความสัมพันธ์ระหว่างตัวแปรสังเกตได้ Intention มีตัวแปรแฝง PERSONAL ที่มีน้ำหนักปัจจัย 0.54 และตัวแปรแฝง NORMATIVE มีน้ำหนักปัจจัย 0.23 แสดงให้เห็นว่า PERSONAL มีอิทธิพลกับ Intention มากกว่า NORMATIVE ตัวแปรแฝง NORMATIVE มีตัวแปรสังเกตได้ Work_efficiency ที่มีน้ำหนักปัจจัย 0.81 เป็นตัวแปรที่มีอิทธิพลต่อ PERSONAL มากที่สุด และมีตัวแปรสังเกตได้ Lower_Cost ที่มีน้ำหนักปัจจัย 0.33 เป็นตัวแปรที่มีอิทธิพลต่อ PERSONAL น้อยที่สุด

ส่วนตัวแปรแฝง NORMATIVE มีตัวแปรสังเกตได้ Co-worker_WFH ที่มีค่าน้ำหนักปัจจัย 0.94 เป็นตัวแปรที่มีอิทธิพลต่อ NORMATIVE มากที่สุด และมีตัวแปรสังเกตได้ Organization_allow และ Boss_support ที่มีน้ำหนักปัจจัย 0.79 เป็นตัวแปรที่มีอิทธิพลต่อ NORMATIVE น้อยที่สุด ดังรูปที่ 3

ในส่วนของ Intention หรือความตั้งใจที่จะทำงานที่บ้านบ่อยกว่าช่วงก่อนโควิด-19 พบว่าร้อยละ 77.07 อยากทำงานที่บ้านบ่อยกว่าช่วงก่อนโควิด-19 ดังรูปที่ 4



รูปที่ 3 ผลการวิเคราะห์แบบจำลองสมการโครงสร้าง



รูปที่ 4 ความตั้งใจที่จะทำงานที่บ้านบ่อยกว่าช่วงก่อนโควิด-19

5. การอภิปราย

จากการวิเคราะห์ปัจจัยที่มีผลต่อความตั้งใจในการทำงานที่บ้านด้วยการวิเคราะห์องค์ประกอบและแบบจำลองสมการโครงสร้าง พบว่าปัจจัยที่ส่งผลต่อความตั้งใจที่จะทำงานที่บ้านหลังจากสถานการณ์โรคโควิด-19 คลี่คลายมากที่สุด คือปัจจัยที่เกี่ยวกับตนเอง โดยเฉพาะอย่างยิ่งการทำงานที่บ้านทำให้ทำงานได้อย่างมีประสิทธิภาพ ส่วนปัจจัยที่เกี่ยวกับสิ่งรอบข้างที่ส่งผลต่อความตั้งใจที่จะทำงานที่บ้านหลังจากสถานการณ์โรคโควิด-19 คลี่คลาย คือการที่เพื่อนร่วมงาน ทำงานที่บ้านในช่วงโรคโควิด-19 ระบาด ซึ่งไม่สอดคล้องกับ Taru Jain et al. (2022) ที่พบว่าการรับรู้ความสามารถในการควบคุมพฤติกรรมและ การคล้อยตามกลุ่มอ้างอิงเป็นตัวแปรสำคัญที่ทำให้เกิดความตั้งใจที่จะทำงานที่บ้านหลังการระบาดของโรคโควิด-19 ส่วนเจตคติหรือทัศนคติเป็นตัวแปรที่ส่งผลค่อนข้างน้อย ต่อเจตนาในการทำงานที่บ้านหลังการระบาดของโรคโควิด-19 และการศึกษานี้ยังพบว่ากลุ่มตัวอย่างส่วนใหญ่ (77.07%) ต้องการที่จะทำงานที่บ้านบ่อยกว่าช่วงก่อนโควิด-19 ซึ่งสอดคล้องกับ Taru Jain et al. (2022) ที่กล่าวว่าการทำงานที่บ้านคาดว่าจะมากขึ้นกว่าช่วงก่อนการแพร่ระบาดของโรคโควิด-19 ประมาณ 75% และสอดคล้องกับ Pasquale De Toro et al. (2021) ที่กล่าวว่าหลังจากเกิดโรคโควิด-19 ระบาด 23.4% ต้องการพื้นที่ใหม่สำหรับทำงานที่บ้าน ซึ่งอาจส่งผลต่อการตัดสินใจซื้อที่อยู่อาศัยในอนาคต โดย Pagani et al. (2021) พบว่า 60% ของกลุ่มตัวอย่างมีปัจจัยในการเลือกซื้อที่อยู่อาศัยเปลี่ยนไปจากช่วงก่อนโรคโควิด-19 ระบาด ซึ่งมีแนวโน้มจะสอดคล้องกับการศึกษานี้ที่กลุ่มตัวอย่างส่วนใหญ่มีความตั้งใจที่จะทำงานที่บ้านมากขึ้น อาจส่งผลต่อปัจจัยในการเลือกซื้อที่อยู่อาศัยในอนาคตได้ โดยช่วงก่อนโรคโควิด-19 ระบาด Jonas De Vos et al. (2020) กล่าวว่าผู้คนย้ายที่อยู่อาศัยไปในพื้นที่ที่เป็นเมืองมากขึ้น และเลือกที่จะใช้ระบบขนส่งสาธารณะแทนการใช้รถ แต่การศึกษานี้เห็นว่าจากผลการวิเคราะห์ที่แสดงถึงการที่กลุ่มตัวอย่างต้องการทำงานที่บ้านบ่อยกว่าช่วงก่อนโรคโควิด-19 ระบาด การย้ายที่อยู่อาศัยไปในพื้นที่เมืองอาจไม่จำเป็นอีกต่อไป

โดยแบบจำลองในการศึกษานี้เป็นเพียงแบบจำลองเบื้องต้น ในการพัฒนาแบบจำลองนี้ อาจพิจารณาจากคุณลักษณะของกลุ่มตัวอย่าง เช่น อายุ เพศ ระดับการศึกษา รายได้ เป็นต้น ซึ่งอาจส่งผลต่อความตั้งใจที่จะทำงานที่บ้านหลังสถานการณ์โควิด-19 คลี่คลาย

6. สรุป

จากการศึกษาพบว่ากลุ่มตัวอย่างมีความต้องการทำงานที่บ้านหากเป็นไปได้ และจากผลการวิเคราะห์องค์ประกอบเชิงยืนยันและการวิเคราะห์องค์ประกอบเชิงสำรวจ พบว่าปัจจัยแฝงที่สนับสนุนการทำงานที่บ้านอาจแบ่งได้เป็น 2 กลุ่มคือ (1) ปัจจัยเกี่ยวกับทัศนคติเกี่ยวกับการทำงานที่บ้าน เช่น การทำงานที่บ้านเป็นการทำงานที่มีประสิทธิภาพ ทำให้มีความสมดุลระหว่างการทำงานกับการใช้ชีวิตมากขึ้น และยังเป็นการ

ใช้เวลาอย่างคุ้มค่า เป็นต้น และ (2) ปัจจัยเกี่ยวกับงานและผู้เกี่ยวข้อง เช่น ลักษณะงานสามารถทำที่บ้านได้ ค่านิยมการทำงานที่บ้านของเพื่อนร่วมงาน เป็นต้น ส่วนผลการศึกษาทำการวิเคราะห์แบบจำลองสมการโครงสร้างพบว่าปัจจัยแฝงด้านทัศนคติต่อการทำงานที่บ้านและปัจจัยเกี่ยวกับงานและผู้เกี่ยวข้องส่งผลต่อความตั้งใจที่จะทำงานที่บ้านในอนาคตโดยมีน้ำหนัก 0.54 และ 0.23 ตามลำดับ นั่นหมายถึงการที่กลุ่มตัวอย่างตั้งใจที่จะทำงานที่บ้านขึ้นอยู่กับตนเองมากกว่าสิ่งรอบข้าง

ผลการศึกษาชี้ให้เห็นว่าการทำงานที่บ้านให้มีความสะดวกและมีประสิทธิภาพนั้น บ้านที่อยู่อาศัยและสภาพแวดล้อมมีความสำคัญเป็นอย่างยิ่ง และสามารถนำไปสู่แนวคิดการพัฒนาที่อยู่อาศัยเพื่อรองรับการทำงานและการใช้ชีวิตวิถีใหม่ที่มีประสิทธิภาพต่อไป

อย่างไรก็ตาม ความตั้งใจที่จะทำงานที่บ้านมีส่วนที่ส่งผลมาจากบรรทัดฐานทางสังคม ไม่ว่าจะเป็นการที่องค์กร เจ้านายอนุญาตให้ทำงานที่บ้านได้ การที่เพื่อนร่วมงานทำงานที่บ้าน องค์กรสามารถนำผลที่ได้จากการศึกษานี้ ไปต่อยอดในการกำหนดนโยบายการทำงานที่บ้านของพนักงาน ซึ่งจะช่วยองค์การทั้งในด้านการลดค่าใช้จ่ายในสถานที่สำนักงาน สามารถจ้างพนักงานที่ตรงกับความต้องการ โดยที่ไม่มีปัญหาในเรื่องการเดินทาง หากหลังสถานการณ์โควิด-19 คลี่คลาย แล้วหลายองค์กรยังอนุญาตให้พนักงานทำงานที่บ้านต่อได้ จะส่งผลให้พนักงานมีความตั้งใจที่จะทำงานที่บ้าน และทำให้งานมีประสิทธิภาพมากขึ้น อาจนำไปสู่ความก้าวหน้าขององค์กรได้ อีกทั้งการทำงานที่บ้าน ยังช่วยลดความหนาแน่นในการสัญจรในช่วงเวลาเร่งรีบอีกด้วย

ข้อจำกัดของการศึกษานี้คือการเข้าถึงกลุ่มเป้าหมาย ซึ่งคือกลุ่มคนวัยทำงาน ที่ทำงานอยู่ในองค์กรต่างๆ โดยการศึกษานี้เก็บข้อมูลจากการสัมภาษณ์คนที่สัญจรไปมาในบริเวณที่ต้องการ หากสามารถเก็บข้อมูลผ่านองค์กรที่กลุ่มตัวอย่างทำงานได้โดยตรง อาจทำให้ได้ผลที่มีความน่าเชื่อถือมากขึ้น และควรทำการศึกษาปัจจัยด้านการเดินทางเพิ่มเติม เนื่องจากการทำงานที่บ้านทำให้ประชาชนไม่จำเป็นต้องเดินทางออกจากที่พักอาศัย เพื่อเป็นประโยชน์กับภาครัฐในด้านการคมนาคมต่อไป

5. กิตติกรรมประกาศ

การศึกษานี้ได้รับทุนสนับสนุนจากสมาคมวิจัยวิทยาการขนส่งแห่งเอเชีย (Asian Transportation Research Society: ATRANS)

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Gap Acceptance for a U-turn Median Opening on Intercity Highways

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Abstract

A U-turn was built to accommodate a vehicle that needs to reverse direction on 4-lane roads or greater. The U-turn is often a black spot and likely causes an accident. The study of the U-turn user's behavior is generally analyzed using the concept of gap acceptance. In this study, gap acceptance and waiting time at U-turn median opening with unsignalized were studied, both on 4-lane and 6-lane intercity highways. Six models were created to analyze the relationship between gap acceptance and various characteristics with logit models. The first model is the overall model that combines all characteristics used to predict gap acceptance including the type of vehicles, the geometric characteristics of the road, the size of the gap, and the waiting time to U-turn. The second and third model are separate models by the 4-lane and 6-lane traffic. The fourth to sixth model are separate models by type of vehicle groups: light, medium and heavy vehicle, respectively. The results showed that (1) the larger the gaps lead to the greater the chances of accepting that gap, (2) the longer waiting time associates with the probability of the gap acceptance, (3) the number of lanes increases from the 4-lane highway to the 6-lane highway will increase the probability of acceptance of the gap, (4) the medium and heavy vehicles tend to accept larger gaps compared to the light vehicles, (5) the waiting time does not significantly affect the probability of acceptance of the gap for light vehicles, and (6) the number of 4-lane and 6-lane affect to the probability of acceptance of the gap for light, medium, and heavy vehicle differently.

Keywords: Gap acceptance, U-turn median opening, Logit model

1. Introduction

In Thailand, several arterial highways are four-lane roads (or more than four lanes) with a median. Its function is to serve drivers who want to travel intercity. The main highways often connect with the collector roads. However, due to the poor road hierarchy, most local roads directly connect with the arterial highway instead of connecting to the collector roads. In addition, there is a lot of land development along the arterial highway, so call ribbon development, which often occurs in several developing countries. As a result, when the driver wants to access the area on the opposite side of the road, they must use a U-turn, which is a median opening with unsignalized. The heavy traffic on the main road usually causes vehicles requiring a U-turn to wait for a long time, and it may cause drivers risky behaviors that try to merge and constrain vehicles on main roads to slow down or stop suddenly which may cause danger to road users.

Most U-turn median openings on intercity highways are unsignalized because the intercity road function focuses on the movement of the main road. Therefore, the drivers who want to use the U-turn need more care. The gap between vehicles on the major road that the driver requires must be wide enough to accept their safety.

Gap acceptance is the gap between two consequent vehicles on a major road that a vehicle at a U-turn accepts and performs a U-turn using that gap to safely merge the major road. As the vehicle arrives at the U-turn and waits for a gap, a gap may be rejected because the gap is too small for the vehicle to use the U-turn. This can be called reject gaps. [1] stated that "accepted gaps are one of the very important and widely used traffic characteristics in the analysis of intersections with unsignalized where drivers will accept or reject gaps."

In Thailand, most gap acceptance studies were focused on the urban streets, whereas rarely study was conducted in the intercity. The percentage of large vehicles on the urban streets is less than that on the intercity highway. Moreover, the accident at the U-turn median openings on intercity highways causes serious injury and several death tolls compared to that on urban streets.

This study aimed to investigate the gap acceptance behavior of drivers at the U-turn median opening with unsignalized of intercity highways for three types of vehicles including light vehicles, medium vehicles, and heavy vehicles.

2. Literature Review

There are several methods used in the analysis of gap acceptance behavior. The critical gap is estimated in several available methods, including Raff, Wu, Logit model, Greenshield, Lag, MLM, Ashworth, Harder, Acceptance curve, and Clearing behavior approach. Previous research has focused on factors that affect the behavior of U-turns with unsignalized on urban streets. It was found that the factors affecting the behavior of U-turns are the size of the gap between the vehicles on major roads and the position of the vehicle's arrival on the major road. However, it was not found that the waiting time significantly affected the behavior of U-turns [2]. There are also researches whose main objective is to analyze critical gaps. In the decision to accept the gap to turn left or turn right for drivers of various types of vehicles at intersections. The analysis revealed that the critical gap for a right turn from a major road ranged from 6-9s, the critical gap for a left turn from a major road was in the range of 4-10s and the critical gap for the U-turn on major roads was in the range of 5-9s, and the variance of gap decreased when traffic flow increasing. This research indicates that the waiting time for reversal does not affect the critical gap. It may be because the study site was in urban areas with a typically small proportion of trucks, whereas a large proportion of heavy trucks often occur on the intercity highway. More research for study in the intercity road is needed due to different driving behaviors [3].

Most of the studies reviewed above were in urban areas, where their waiting times for U-turns are lower than that of the U-turns on high-traffic volumes on intercity highways. In addition, the time for U-turns of heavy vehicles is longer than for passenger cars. This affects the driver's decision in that it causes the driver accepts a gap that is less than the critical gap and potentially results in an accident.

U-turns are the most vulnerable areas on highways as the behavior of drivers at U-turns is quite complex and risky [4]. The study focused on the gap acceptance of drivers at U-turn median openings on 4-lane intercity roads. The data collected were from video and two models developed in this study. The first model estimated the time of the driver-accepted gap, and the second model calculated the type of driver's turn. which uses an estimate of the probability of accepting a gap. The result showed that male drivers accept shorter gaps than female drivers. The same for younger drivers to accept shorter gaps than older drivers. Waiting times have an impact on drivers' gap acceptance behavior. That is, drivers tend to accept shorter gaps due to long wait times in U-turns.

The factors studied that may affect the acceptance of the left turn gap from the major road [5]. (In this study, the vehicle was driven in the right-hand direction) at an intersection with unsignalized. Six intersections were surveyed. The factors in the analysis were age, sex, and speed used on the major road. Geometrics of the road, such as whether there is a left turn lane or not, and 2 or 4 traffic lanes of major roads, were analyzed using binary decision and correlated logit models. The interval of the gap, the number of reject gaps, the average and the total interval of the rejected gap, and the gender of the drivers were statistically significant. But the number of traffic lanes of the major road for a left turn (left turn lane) is used at low speed and the age ranges classified were not statistically significant in the probability of the gap being recognized. Future research may explore additional factors that affect gap acceptance, perhaps learn about these factors on the intercity U-turn or other geometric characteristics.

The potential capacity of a U-turn on Phutthamonthon 5 road [6] to use as a criterion for U-turn improvement. The analysis was based on the critical gap, conflicting flow, main flow, and follow-up time. The results showed that during peak hours the number of vehicles requiring U-turns exceeds the acceptable capacity of the U-turn, so it causes an extremely long queue length, and it takes a long time for vehicles to use the U-turn. Moreover, it is also a dangerous U-turn due to very conflict flows. They suggest that future research should focus on U-turns on intercity roads with long waiting times for U-turns due to the heavy traffic on the major road. This may cause drivers who need a U-turn to choose a gap that is smaller than the critical gap causing a high risk of accidents.

The critical gap is a concept that engineers use for determining the capacity of each direction of movement on intersections with unsignalized [7]. Most of the critical gap estimations are presented in homogeneous traffic conditions from the perspective of traffic discipline and priority rules in driving behavior. Drivers and vehicle characteristics at unsignalized intersections are factors in highly complex mixed traffic. In this study, the critical gap was estimated by Lag, Harder, Logit, Probit, Modified Raff, and Hewitt methods on two T-intersections. The results showed critical gap estimates as 1.6s and statistically significant (12-38%). This study used a new concept, so call a clearing behavior approach. The outcome was lower than HCM (2000) but was higher than the estimate of the existing method. It is a suitable method and may be better than the existing method. This study only found a critical gap in driving behavior for unsignalized intersections. Future research may explore other types of intersections or U-turns, etc.

In developed countries when the traffic distribution is uniform, priorities and voluntary compliance are observed, whereas in developing countries such as India very little obedience to priority rules is typically found, which leads to complexity in uncontrolled intersections [8]. In this study, surveys have been conducted by setting up a video camera to collect information about vehicles entering the intersection in various movements. Then, the critical gap estimation for direct movement from minor roads on this uncontrolled intersection is estimated. The gaps of the three types of vehicles: passenger car, 3-wheeler, and 2-wheeler, are compared with the different available methods of critical gaps: Raff, Wu, Logit, Greenshield, MLM, Ashworth, Lag, Harder, acceptance curve, and clearing behavior approach. The Raff method is based on the macroscopic model and is the easiest to estimate critical gaps, but the disadvantage of the Raff method is very sensitive to traffic volume. Harder method uses gap time, whereas Lag method uses lag time. Acceptance curve approach tends to bias. The Logit model can determine the effect of various independent variables such as the waiting time, average speed, etc. Wu model provides the average of the critical gap between vehicles and does not necessarily specify the pattern of the critical gap between vehicles and the assumptions related to consistency and homogeneity, while MLM method is necessary to identify the relevant patterns and assumptions, Clearing Behavior Approach is used for mixed traffic conditions. The results showed that the method of explicit intersection behavior under mixed traffic conditions is quite reasonable. From the aspect of statistical, it could be seen that the Logit simulation approach was reasonable and statistically based and was therefore used in this research.

3. Methodology

3.1 Theory

Gap acceptance is a gap between two consequent vehicles on a major road that is wide enough for vehicles on minor roads or vehicles that need to perform a U-turn to accept the gap and merge into the major road.

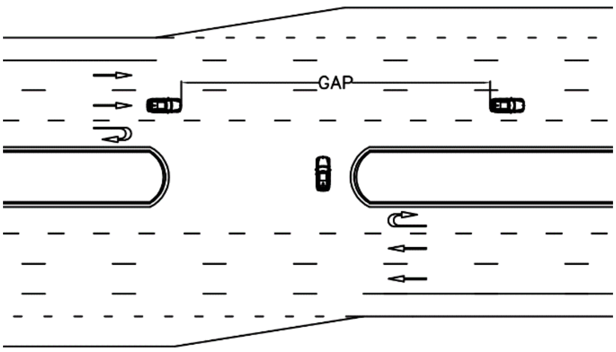

Fig.1 Gap acceptance for U-turns median opening on 4-lane highways

In this study, the logit model was used to analyze driving behaviors at U-turns median opening with unsignalized because it is easy to understand and is a widely used method for analyzing driving behavior. The drivers who need to take a U-turn have two alternatives: (1) accepting a gap on a major road and merging into the major road or (2) rejecting a gap on a major road and waiting until there is a gap sufficient on the major road to accept the gap and take a U-turn. The driver's decision to take a U-turn usually depends on the gap between two consequent vehicles on the major road, the type of vehicle that takes a U-turn, and the waiting time, used for the U-turn which is considered based on the logit model in the following equation:

$$P_{in} = \frac{\exp(V_{in})}{\exp(V_{in})+\exp(V_{jn})} \quad (1)$$

$$V_{in} = \beta_1 x_{in1} + \beta_2 x_{in2} + \cdots + \beta_k x_{ink} \quad (2)$$

Where:
P_{in} is the probability of vehicle n choosing alternative i (accept a gap)
V_{in} is the systematic component of the utility of vehicle n choosing alternative i
$\beta_1, \beta_2, \ldots, \beta_k$ are the coefficients of attribute k
x_{ink} is attribute k of vehicle n choosing alternative i

3.2 Location

The U-turn site on the intercity highways where several heavy vehicles take the U-turn is chosen because the behavior of heavy vehicles U-turns is required in the analysis and the sites, where several heavy vehicles U-turns are rarely found.

3.3 Research Instrument

A video camera is used to record the vehicle at a U-turn. Nlogit version 5 software package is used to estimate the parameter for the logit model.

3.4 Data Collection

The data was collected by video recording at U-turn median openings on intercity highways with the following details:

Traffic: Friday and Saturday, for 8 hours from 8:00 a.m. to 4:00 p.m. on 4-lane and 6-lane intercity highways.

Geometric characteristics: a U-turn median opening with unsignalized on 4-lane and 6-lane intercity highways.

Type of vehicles: vehicles are grouped into 3 main categories of 12 vehicle types according to the classification of Department of highways [9] as follows:

(1) Light vehicles: bicycles, tricycles, motorcycles, and motor tricycles.

(2) Medium vehicles: passenger cars, mini-bus, and trucks (4-wheels).

(3) Heavy vehicles: medium bus, heavy bus, semi-truck (6-10 wheels), semi-trailers, and trailers.

The recorded video file was extracted. The features of interest are the type of vehicle that takes a U-turn, the number of vehicles that perform gap acceptance, and the waiting time of the vehicle that takes the U-turn. The accepted gap is the space between the leading vehicles and following vehicles on the major road, the waiting time for the U-turn is the waiting period from vehicle stops and waits for a U-turn until complete the U-turn.

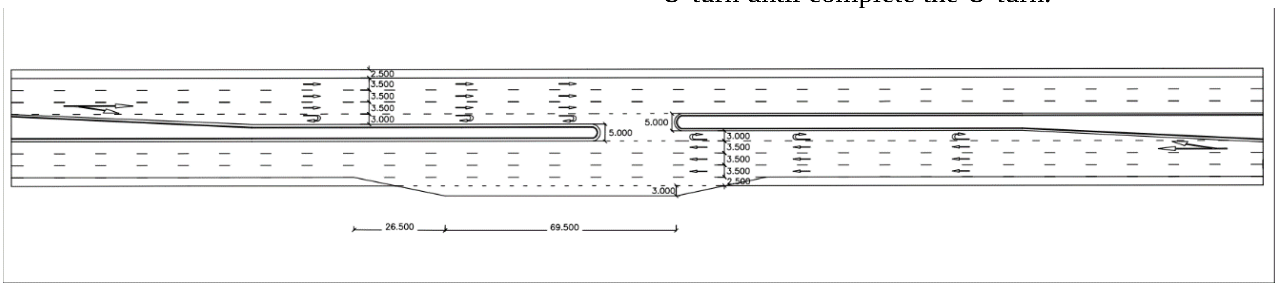

Fig.2 U-turn median opening 4-lanes highway on the intercity highway

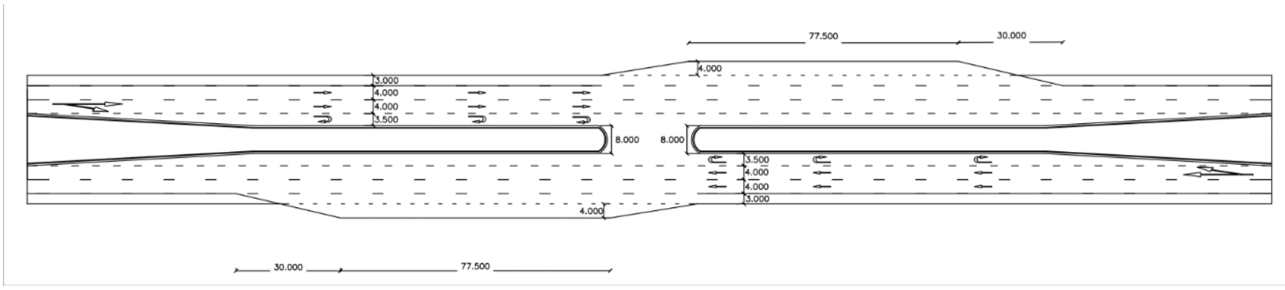

Fig.3 U-turn median opening 6-lanes highway on the intercity highway

4. Results

The total 2,128 vehicles were conducted the statistical summary of each vehicle group: light, medium and heavy vehicle are shown in Table 1, 2, and 3, respectively.

Table 1 Light_vehicle

	N	Min.	Max.	Mean	Std. Deviation
Gap	169	1.30	31.27	11.29	5.61
Waiting	169	3.74	120.03	21.93	23.06

Table 2 Medium_vehicle

	N	Min.	Max.	Mean	Std. Deviation
Gap	1615	0.27	60.03	10.30	4.79
Waiting	1615	4.13	415.00	33.66	37.99

Note: min, max, mean, and std. unit is second

Table 3 Heavy_vehicle

	N	Min.	Max.	Mean	Std. Deviation
Gap	344	1.50	84.96	16.46	11.38
Waiting	344	6.43	290.70	54.33	52.42

Note: min, max, mean, and std. unit is second

The results indicate that the majority of vehicle is medium vehicle, followed by heavy, and light vehicles (1,615, 344, and 169 vehicles), respectively. The mean gap of light vehicle and medium vehicle are not much different (11.29, and 10.30 seconds), whereas the mean waiting time are quite different (21.93 and 33.66 seconds). And as expected, the mean gap and mean waiting time of heavy vehicles (16.46 and 54.33 seconds) are larger than that of the light and medium vehicles.

Table 4 Model_1 Overall model

	coefficient	Std. error	z	Sig.
GAP	0.07590	0.00202	37.54	0.0000
Waiting	-0.002420	0.00038	-6.29	0.0000
GEO	0.16924	0.05324	3.18	0.0015
ME_veh	-0.58778	0.03912	-15.02	0.0000
HE_veh	-0.94776	0.06796	-13.95	0.0000

As shown in Table 4 to Table 6 are models used to study the driving behavior at U-turns unsignalized on intercity roads. Model_1 is the overall model (Table 4), it consists of all factors used to predict gap acceptance including the type of vehicle, geometric characteristics, size of the gap, and the waiting time to U-turn.

It can be interpreted from the coefficient of the model that (1) if the gap between vehicles on major roads (GAP) increases by one second, it will increase the probability of acceptance of the gap by 7.89% [exp(0.0759)-1], (2) if the waiting time (Waiting) increase by one second, it will reduce the probability of acceptance of the gap by 0.24% [exp(-0.00242)-1], in other words, the more waiting time, the more gap requires to be accepted, (3) geometric characteristics (GEO) found that if the number of lanes increases from the 4-lane highway to the 6-lane highway, it will increase the probability of acceptance of the gap by 18.44% [exp(0.16924)-1], (4) the coefficients of medium and heavy vehicles are significant and negative (the coefficients of light vehicle is base). It shows that the medium and heavy vehicles tend to accept larger gaps compared to the light vehicles by 44.44% and 61.24%, respectively.

Model_2 is a model based on the geometric characteristics of the road. This is a U-turn behavior model of a 4-lane highway (Table 5) and a 6-lane highway (Table 6). It was found that on the 4-lane highway, the coefficients of all variables are like the Model_1 except for the coefficient of the heavy vehicle. It indicates that heavy vehicles tend to accept larger gaps compared to the light vehicles by 49.72% [exp(-0.68757)-1], whereas the result in the Model_1 is 61.24%.

Table 5 Model_2 model: 4-lane highway

	coefficient	Std. error	z	Sig.
GAP	0.07528	0.00399	18.86	0.0000
Waiting	-0.00540	0.00163	-3.32	0.0009
ME_veh	-0.57468	0.06283	-9.15	0.0000
HE_veh	-0.68757	0.10122	-6.79	0.0000

Model_3 shows slightly different coefficients. First, if the gap between vehicles on major roads (GAP) increases by one second, it will increase the probability of acceptance of the gap by 9.28% [exp(0.08872)-1], which is slightly higher than that of Model_1 (7.89%). Second, it shows that the medium and heavy vehicles tend to accept larger gaps compared to the light vehicles by 38.17% and 67.65%, while the results from the Model_2 are 43.71% and 49.72%, respectively. It means that the heavy vehicles need a larger gap than the light vehicles when taking the U-turn on the 6-lane highway compared to that on the 4-lane highway.

Table 6 Model_3 model: 6-lane highway

	coefficient	Std. error	z	Sig.
GAP	0.08872	0.00255	34.82	0.0000
Waiting	-0.00234	0.00038	-6.12	0.0000
ME_veh	-0.48086	0.05612	-8.57	0.0000
HE_veh	-1.12871	0.07589	-14.87	0.0000

Model_4, Model_5, and Model_6 are separate models based on the type of vehicle including a light vehicle (Table 7), a medium vehicle (Table 8), and a heavy vehicle (Table 9), respectively. The results show interesting details that (1) for light vehicles, the waiting time does not significantly affect the probability of acceptance of the gap (the *p*-value = 0.2624, which is greater than 0.05), contrary to the medium and heavy vehicles (the *p*-value = 0.000, and 0.0259, respectively, (2) the number of 4-lane and 6-lane affect to the probability of acceptance of the gap for the light, medium, and heavy vehicles differently. For the light vehicles, the coefficient of geometric characteristics (GEO) shows that if the number of lanes increases from the 4-lane highway to the 6-lane highway, it will increase the probability of acceptance of the gap by 16.25% [exp(0.15056)-1]. On the contrary, for the medium and heavy vehicles, if the number of lanes increases from the 4-lane highway to the 6-lane highway, it will reduce the probability of acceptance of the gap by 9.15% [exp(-0.09594)-1], and 6.86% [exp(-0.0711)-1], for the medium and heavy vehicles respectively. It may be explained that the light vehicle can easily merge to the 6-lane traffic compared to that of the 4-lane traffic, so the light vehicle tent to accept the gap when the number of lane increase. However, the medium and heavy vehicles need more space to make a U-turn because of their turning radius, thus they require a greater gap to take a U-turn on the 6-lane highway compared to that of the 4-lane highway.

Table 7 Model_4 model: light vehicle

	coefficient	Std. error	z	Sig.
GAP	0.03707	0.00802	4.63	0.0000
Waiting	-0.00549	0.00490	-1.12	0.2624
GEO	0.15056	0.37294	0.4	0.6864

Table 8 Model_5 model: medium vehicle

	coefficient	Std. error	z	Sig.
GAP	0.04788	0.00235	20.34	0.0000
Waiting	-0.00283	0.00064	-4.42	0.0000
GEO	-0.09594	0.09695	-0.99	0.3224

Table 9 Model_6 model: heavy vehicle

	coefficient	Std. error	z	Sig.
GAP	0.02452	0.00363	6.75	0.0000
Waiting	-0.00261	0.00117	-2.23	0.0259
GEO	-0.0711	0.22851	-0.31	0.7557

5. Discussion

A previous study [2] found that the waiting time for taking a U-turn does not significantly affect the behavior of the U-turn. On the contrary, in this study, the result shows that the waiting time of taking a U-turn is significantly associated with the probability of acceptance of the gap. It may be explained that the contexts of U-turns are different. The former studied on the urban streets, whereas the latter focused on the intercity highways. The percentage of medium and heavy trucks on the intercity highways is greater than that of the urban street. In addition, the time for U-turns of heavy vehicles is longer than for passenger cars.

The gap acceptance study [5] found a similar result in this study that the waiting time affects the behavior of taking the U-turn, but that study focused only on the 4-lane street. However, 4-lane and 6-lane are included in this study. The results show the effect of the waiting time on the gap acceptance for medium and heavy vehicles, while the waiting time does not significantly affect the gap acceptance for light vehicles.

Furthermore, a possible reason why waiting time affected the driver's behavior on intercity highways as compared to urban roads is not only the number of heavy/medium vehicles on highways but also the speed of vehicles on the main roads that may affect the decision to perform a U-turn [10].

6. Conclusion

This research examines the gap acceptance behavior at U-turn median openings with unsignalized on intercity highways by analyzing various factors and using the logit model. The first model includes all the factors used to predict gap acceptance, which consists of the type of vehicle, geometric characteristics of the road, size of the gap, and waiting time. The overall model shows that (1) increasing the gap of vehicles on major roads results in increasing the probability of gap acceptance, (2) the longer waiting time is associated with the probability of gap acceptance, (3) the number of lanes increases from the 4-lane highway to the 6-lane highway will increase the probability of acceptance of the gap, (4) the medium and heavy vehicles tend to accept larger gaps compared to the light vehicles. Moreover, other models based on the type of vehicle indicate that (5) the waiting time does not significantly affect the probability of acceptance of the gap for the light vehicles, and (6) the number of 4-lane and 6-lane affect the probability of acceptance of the gap for light, medium, and heavy vehicle differently. For light vehicles, if the number of lanes increases from the 4-lane highway to the 6-lane highway, it will increase the probability of acceptance of the gap, whereas, for medium and heavy vehicles, it will reduce the probability of acceptance of the gap instead.

This research used only the logit model to study the gap acceptance behavior at the U-turn median opening with unsignalized on intercity highways. Future research may apply other methods of analysis to compare the results. Other aspect of the behavior of the U-turn e.g., the type of U-turns [3]: free U-turn, force U-turn, and cooperative U-turn may further investigate on the intercity highways. Finally, speed of vehicles on the main roads that delayed the decision to perform a U-turn may further investigate.

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การวิเคราะห์ผลกระทบของการกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกันบนทางหลวงด้วยแบบจำลองการจราจรระดับจุลภาค

Impact Analysis of Differentiated Per-Lane Speed Limits on Multilane Highways Using Microscopic Traffic Simulation Models

หมายเลขหัวข้อ 4 หมายเลขบทความ: AYRF 022-2022

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บทคัดย่อ

ในปัจจุบัน ประเทศไทยได้กำหนดอัตราการใช้ความเร็วของยานพาหนะบนทางหลวงให้มีขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกันในหลายสายทาง โดยกำหนดอัตราความเร็วสูงสุดที่ 120 กิโลเมตรต่อชั่วโมง อย่างไรก็ตาม ผลการศึกษาเกี่ยวกับผลกระทบของการกำหนดขีดจำกัดความเร็วของยานพาหนะในแต่ละช่องจราจรที่มีต่อการปรับเปลี่ยนพฤติกรรมการขับขี่และการใช้ความเร็วของยานพาหนะบนทางหลวงยังไม่ชัดเจนเท่าที่ควร งานวิจัยนี้จึงมุ่งเน้นศึกษาและวิเคราะห์ผลกระทบด้านการจราจรและพฤติกรรมการขับขี่ของยานพาหนะบนทางหลวงที่มีการกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกน โดยอาศัยการประยุกต์ใช้แบบจำลองการจราจรระดับจุลภาคด้วยโปรแกรม PTV Vissim ซึ่งงานวิจัยนี้ศึกษาการปรับเปลี่ยนพฤติกรรมการใช้ความเร็ว (Speed behavior) และพฤติกรรมการเปลี่ยนช่องจราจร (Lane-change behavior) ของผู้ขับขี่จำแนกตามประเภทยานพาหนะในแต่ละช่องจราจร โดยทำการสำรวจรวบรวมข้อมูลปัจจัยด้านจราจรและด้านพฤติกรรมการขับขี่ของผู้ใช้ทาง เพื่อวิเคราะห์เปรียบเทียบความคล่องตัวและความปลอดภัยในการสัญจรของผู้ใช้ทาง ผลการพัฒนาแบบจำลอง พบว่า การกำหนดขีดจำกัดความเร็วที่แตกต่างกันในแต่ละช่องจราจร ส่งผลให้พฤติกรรมการใช้ความเร็วของยานพาหนะในแต่ละช่องจราจรมีลักษณะเหมือนกัน (Uniform) มากขึ้น และความถี่ในการเปลี่ยนช่องจราจรของยานพาหนะลดลง เนื่องจากยานพาหนะแต่ละประเภทใช้อัตราความเร็วเหมาะสมกับช่องจราจรที่กำหนด

คำสำคัญ: ผลกระทบการจราจร, การใช้ความเร็ว, การเปลี่ยนช่องจราจร, ขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกัน, แบบจำลองการจราจรระดับจุลภาค

Abstract

Currently, the configuration of the differentiated per-lane speed limits has been introduced on several multilane highways in Thailand. Specifically, the speed limit of 120 kilometers per hour has been presented on major highways. However, there has been no sufficient evidence of the effect of the differentiated per-lane speed limits on the change of driving behavior and speed behavior. This study focused on examining the impacts of the configuration of the differentiated per-lane speed limits on multilane highways. The study developed the microscopic traffic simulation models using PTV Vissim software to investigate the speed behavior and lane-change behavior of road users by vehicle type and by lane. The study gathered data on traffic and behavior to conduct the comparative analysis of mobility and safety performance of road users. The results of simulation-based analysis showed that the differentiated per-lane speed limits perform the speeds of vehicles on each lane are more homogeneous, the frequency of lane-change behavior is reduced, and vehicles travel more proper speed in each lane on highways.

Keywords: Traffic impact, Speed behavior, Lane-change behavior, Differentiated per-lane speed limits, Microscopic traffic simulation model

1. บทนำ

1.1 ความสำคัญของปัญหา

ประเทศไทยได้เปิดให้ผู้ขับขี่ใช้อัตราความเร็วของยานพาหนะตามช่องจราจรที่แตกต่างกันบนทางหลวงแผ่นดินหรือทางหลวงชนบทที่กำหนด ตามนโยบายการปรับเพิ่มอัตราความเร็วของรถยนต์จากความเร็วไม่เกิน 90 กิโลเมตรต่อชั่วโมง เป็นความเร็วไม่เกิน 120 กิโลเมตรต่อชั่วโมง บนถนนที่มีทางเดินรถซึ่งแบ่งช่องเดินรถในทิศทางเดียวกันไว้ตั้งแต่สองช่องจราจรขึ้นไป มีเกาะกลางถนนแบบกำแพง และไม่มีจุดกลับรถเสมอระดับถนน [1]

ในปัจจุบัน หน่วยงานที่เกี่ยวข้องได้ดำเนินการเปิดเส้นทางนำร่องอัตราความเร็วของยานพาหนะตามช่องจราจรที่แตกต่างกันบนถนนทางหลวงหลายช่องจราจร ยกตัวอย่างเช่น ทางหลวงหมายเลข 32 (ระหว่างกิโลเมตรที่ 4+100 ถึง 50+000 และระหว่างกิโลเมตรที่ 50+000 ถึง 110+473 ทางหลวงหมายเลข 34 ระหว่างกิโลเมตรที่ 1+500 ถึง 15+000 และทางหลวงหมายเลข 1 ระหว่างกิโลเมตรที่ 35+000 ถึง 45+000 เป็นต้น โดยทางหลวงหมายเลข 32 เป็นเส้นทางแรกที่มีการนำร่องกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกัน หรือปรับเพิ่มอัตราความเร็วเป็น 120 กิโลเมตรต่อชั่วโมง

งานวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนาแบบจำลองการจราจรของสภาพการจราจรภายใต้การกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกัน และวิเคราะห์ผลกระทบของการกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกัน ที่มีต่อพฤติกรรมการใช้ความเร็ว พฤติกรรมการเปลี่ยนช่องจราจร และประสิทธิภาพด้านการจราจร

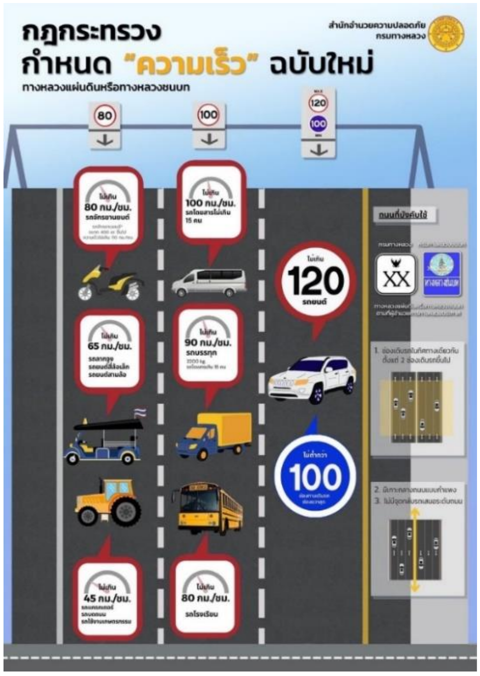
2. ทฤษฎีและงานวิจัยที่เกี่ยวข้อง

2.1 การกำหนดขีดจำกัดความเร็วตามช่องจราจร

การกำหนดขีดจำกัดความเร็วเป็นมาตรการสำคัญที่ช่วยเพิ่มประสิทธิภาพและความปลอดภัยบนทางหลวง [5, 7] เช่น การกำหนดขีดจำกัดความเร็วที่ปรับเปลี่ยนได้ (Variable Speed Limit) การกำหนดขีดจำกัดความเร็วตามบริบทพื้นที่ และการกำหนดขีดจำกัดความเร็วตามช่องจราจร (Per-Lane Speed Limit) เป็นต้น

การกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกัน (Differentiated Per-Lane Speed Limit: DPLSL) มีเป้าหมายหลักเพื่อแยกยานพาหนะที่ใช้ความเร็วที่แตกต่างกันออกจากกัน และส่งผลให้ความผันแปรของอัตราความเร็วของยานพาหนะในแต่ละช่องจราจรน้อยลง

ในประเทศไทย ได้มีกฎกระทรวงกำหนดความเร็วฉบับใหม่ ซึ่งกำหนดขีดจำกัดความเร็วตามช่องจราจรและปรับเพิ่มอัตราความเร็วสูงสุดของรถยนต์บนถนนทางหลวง ดังรูปที่ 1 ซึ่งกำหนดบังคับใช้บนถนนทางหลวงนำร่องที่มีมาตรฐานสูงขนาด 4 ช่องจราจรขึ้นไป โดยกำหนดความเร็วช่องจราจรขวาสุดสูงสุดไม่เกิน 120 กิโลเมตรต่อชั่วโมง แต่ไม่ต่ำกว่า 100 กิโลเมตรต่อชั่วดมง กำหนดความเร็วช่องจราจรซ้ายสุดไม่เกิน 80 กิโลเมตรต่อชั่วดมง และกำหนดความเร็วช่องจราจรกลางไม่เกิน 100 กิโลเมตรต่อชั่วโมง



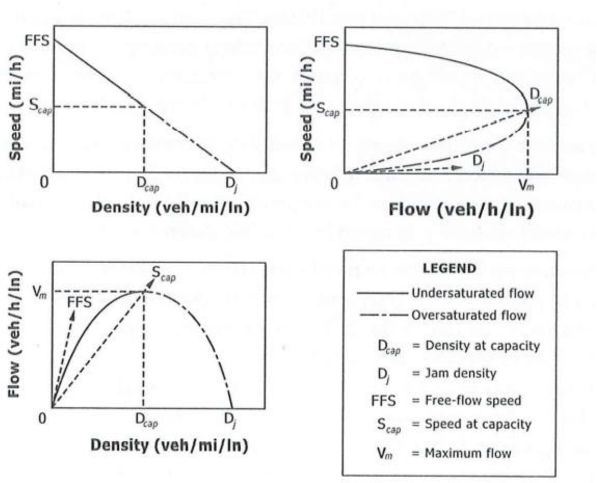
รูปที่ 1 การกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกัน
ที่มา: กรมทางหลวง (2564)

อย่างไรก็ตาม การกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกันและปรับเพิ่มขีดจำกัดความเร็วเป็น 120 กิโลเมตรต่อชั่วโมงบนทางหลวงในประเทศไทย ยังเป็นที่ถกเถียงถึงผลกระทบด้านประสิทธิภาพการจราจรและความปลอดภัยของผู้ใช้รถใช้ถนน

2.2 การวิเคราะห์ผลกระทบด้านการจราจร

การวิเคราะห์ผลกระทบด้านการจราจร [8] สามารถศึกษาและวิเคราะห์ด้วยตัวแปรด้านการจราจร 3 ตัวแปร ได้แก่ ปริมาณการจราจร (Traffic flow) ความเร็ว (Speed) และความหนาแน่น (Density) โดย

คุณลักษณะของการจราจรบนช่วงถนนในช่วงเวลาใดเวลาหนึ่ง อธิบายได้ด้วยตัวแปรทั้งสามว่า มีสภาพการจราจรคล่องตัว หรือมีสภาพการจราจรติดขัด โดยอาศัยทฤษฎีการไหลของการจราจร (Traffic Flow Theory) สามารถแสดงความสัมพันธ์ของอัตราการไหล ความเร็ว และความหนาแน่นของการจราจร ได้ดังรูปที่ 2



รูปที่ 2 ความสัมพันธ์ระหว่างอัตราการไหล ความเร็ว และความหนาแน่น
ที่มา:Highway Capacity Manual (2016)

2.3 การวิเคราะห์ผลกระทบด้านความปลอดภัย

ถนนทางหลวงหลายช่องจราจร มีรูปแบบการชนที่สำคัญ เช่น การชนท้าย (Rear-end) การชนด้านข้าง (Sideswipe) การชนมุมฉาก (Angle) การเสียหลักหลุดออกข้างทาง (Run-off) เป็นต้น การวิเคราะห์ผลกระทบด้านความปลอดภัยบนถนนทางหลวงหลายช่องจราจรแบบดั้งเดิมอาศัยข้อมูลสถิติอุบัติเหตุเป็นหลัก [2]

แต่ปัจจุบัน การวิเคราะห์พฤติกรรมเสี่ยงในการขับขี่ (Driving behavior) สามารถใช้เป็นดัชนีตัวแทนในการประเมินความปลอดภัยของผู้ใช้รถใช้ถนน งานวิจัยที่ผ่านมาชี้ให้เห็นว่า พฤติกรรมการใช้ความเร็วสูง (Speeding behavior) เป็นสาเหตุหลักในการเกิดอุบัติเหตุการชนท้ายและการเสียหลักหลุดออกข้างทาง พฤติกรรมการเปลี่ยนช่องจราจร (Lane change behavior) ที่ไม่เหมาะสม ส่งผลต่อการเกิดอุบัติเหตุการชนท้าย การชนด้านข้าง และการชนมุมฉาก [10]

2.4 การประเมินด้วยแบบจำลองการจราจรระดับจุลภาค

แบบจำลองการจราจรระดับจุลภาค เป็นการจำลองพฤติกรรมการเคลื่อนที่ของยานพาหนะแต่ละประเภทแบบรายคันบนโครงข่ายถนน โดยสามารถจำลองสถานการณ์รูปแบบโครงข่ายถนน สภาพการจราจรที่แตกต่างกันได้ เพื่อวิเคราะห์พฤติกรรมการเคลื่อนตัวของยานพาหนะและประสิทธิภาพด้านการจราจรและความปลอดภัยได้ [4]

ปัจจุบัน แบบจำลองการจราจรระดับจุลภาคมีการนำมาใช้อย่างแพร่หลาย และมีอยู่ด้วยกันหลายโปรแกรมแบบจำลอง FDOT (2014) ได้สรุปเปรียบเทียบการเลือกใช้งานในการวิเคราะห์ของโปรแกรมแบบจำลองต่าง ๆ [11] ตัวอย่างเช่น Highway Capacity Software (HCS), SIDRA INTERSECTION, CORSIM และ VISSIM ดังแสดงในตารางที่ 1

ตารางที่ 1 การเปรียบเทียบการใช้งานของโปรแกรมจำลองสภาพจราจร

ประสิทธิภาพการใช้งาน	แบบจำลองสภาพการจราจร			
	HCS	SIDRA	CORSIM	VISSIM
การทำงานและการควบคุมจราจร				
ความเร็ว	✓	✓	✓	✓
การกำหนดพฤติกรรมการขับขี่			✓	✓
การควบคุมด้วยป้ายจราจร		✓	✓	✓
การควบคุมด้วยสัญญาณไฟจราจร	✓		✓	✓
การกำหนดทิศทางจราจร	✓	✓	✓	✓
การจำกัดช่องจราจร			✓	✓
ลักษณะการจราจร (Traffic Characteristics)				
ความยาวแถวคอย		✓	✓	✓
คนเดินเท้า	✓	✓		✓
ความจุ			✓	✓
การครอบครองยานพาหนะ			✓	✓
การกำหนดการเดินทางเส้นหลัก			✓	✓
ลักษณะประเภทของถนน				
การจำแนกประเภทถนน	✓	✓	✓	✓
ลักษณะทางกายภาพ	✓	✓	✓	✓
สภาพข้างทาง	✓		✓	✓
การควบคุมการเข้าถึงพื้นที่	✓		✓	✓
การควบคุมความหนาแน่น	✓		✓	✓
การจอดรถข้างทาง		✓		✓

ที่มา : FDOT (2014) อ้างอิงในชัยวัฒน์ ใหญ่บก (2558)

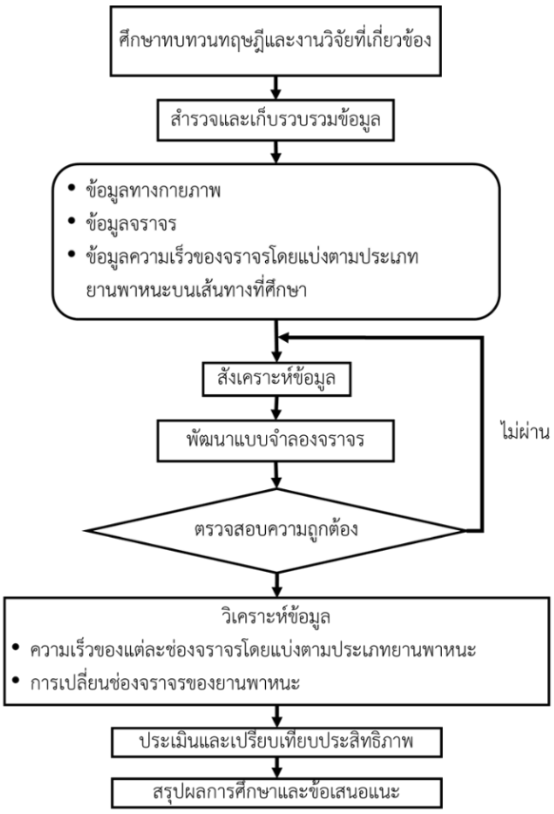
จากการทบทวนงานวิจัยที่เกี่ยวข้องทั้งในและต่างประเทศเกี่ยวกับการเปรียบเทียบคุณสมบัติและประสิทธิภาพในการทำงานของโปรแกรมที่นิยมใช้ในปัจจุบัน [3,4,9] พบว่า Vissim มีความเหมาะสมและยืดหยุ่นในการจำลองสภาพการจราจรภายใต้มาตรการกำหนดขีดจำกัดความเร็วตามช่องจราจร เนื่องจากสามารถนำออกข้อมูลความเร็ว ความเร่ง ตำแหน่ง และช่องจราจรในทุกชั่วขณะของยานพหานะแต่ละคันได้ ซึ่งช่วยให้สามารถติดตาม (track) ยานพาหนะรายคันได้ นอกจากนี้ แบบจำลองสามารถกำหนดพฤติกรรมการขับขี่ของยานพาหนะได้

สามารถสร้างแบบจำลองทางเลือกในสถานการณ์ต่าง ๆ ได้หลากหลาย และสามารถแสดงภาพแอนิเมชั่นทั้งแบบ 2 มิติและ 3 มิติ

พฤติกรรมการขับขี่ที่จำลองในโปรแกรมแบบจำลอง Vissim อาศัยหลักการจำลองพฤติกรรมการขับขี่ตามกัน (Car Following Model) ของ Rainer Wiedemann [6] โดยให้ยานพาหนะแต่ละคันสามารถกำหนดพฤติกรรมการขับขี่ในแต่ละสถานการณ์ได้ และเหมาะสมกับการจำลองสภาพจราจรบนทางด่วนหรือทางหลวงที่ใช้ความเร็วได้อย่างอิสระ

3. ระเบียบวิธีวิจัย

งานวิจัยนี้กำหนดขั้นตอนการดำเนินงานทั้งหมด 8 ขั้นตอน ดังรูปที่ 3 โดยมีรายละเอียดขั้นตอนที่สำคัญดังนี้



รูปที่ 3 ขั้นตอนการดำเนินงานวิจัย

3.1 การสำรวจรวบรวมข้อมูล

งานวิจัยนี้คัดเลือกทางหลวงหมายเลข 32 ช่วงถนน อยุธยา-อ่างทอง ระหว่างกิโลเมตรที่ 4+100 ถึง กิโลเมตรที่ 50+000 เป็นกรณีศึกษาเพื่อสำรวจและรวบรวมข้อมูล ช่วงถนนดังกล่าวมีจำนวนช่องจราจร 4 ช่องจราจร ขนาดช่องจราจรละ 3.5 เมตร ไหล่ทางกว้าง 2.5 เมตร มีเกาะกลางแบบมีกำแพงคอนกรีตกั้น ไม่มีจุดกลับรถ และมีปริมาณจราจรเฉลี่ยรายวัน 2500 คันต่อวัน และสัดส่วนรถบรรทุกร้อยละ 10

รูปที่ 4 ทางหลวงที่กำหนดขีดจำกัดความเร็วตามช่องจราจร

งานวิจัยสำรวจข้อมูลความเร็วของยานพาหนะรายคันในแต่ละช่องจราจร ณ จุดสำรวจกิโลเมตรที่ 37+175 บนสายทางในพื้นที่ศึกษาช่วงก่อนและหลังดำเนินมาตรการกำหนดขีดจำกัดความเร็วตามช่องจราจรและปรับเพิ่มขีดจำกัดความเร็วเป็น 120 กิโลเมตรต่อชั่วโมง พบว่าความเร็วของยานพาหนะในแต่ละช่องจราจร (ช่องจราจรที่ 1 ขวาสุด ถึงช่องจราจรที่ 4 ซ้ายสุด) ของแต่ละประเภทยานพาหนะ (รถยนต์ส่วนบุคคล และรถบรรทุก/รถโดยสาร) ก่อนและหลังดำเนินการมีความแตกต่างกัน ดังตารางที่ 2 ซึ่งแสดงค่าเฉลี่ย ส่วนเบี่ยงเบนมาตรฐาน และค่าเฉลี่ยความเร็วของช่วงความเชื่อมั่นร้อยละ 95

ตารางที่ 2 ข้อมูลการใช้ความเร็วจำแนกตามประเภทยานพาหนะและช่องจราจรก่อนและหลังดำเนินมาตรการ

ช่องจราจร	ความเร็ว (กิโลเมตร/ชั่วโมง)					
	ก่อนดำเนินการ			หลังดำเนินการ		
	$\bar{x}$	SD	ค่าความเชื่อมั่น	$\bar{x}$	SD	ค่าความเชื่อมั่น
รถยนต์ส่วนบุคคล						
4	63	12.1	39.2-86.7	67	13.0	41.4-92.5
3	84	13.1	62.2-105.8	85	11.2	62.9-107.1
2	91	10.8	69.7-112.3	94	10.6	73.3-114.7
1	105	11.8	81.8-128.2	110	10.2	89.9-130.0
รถบรรทุกและรถโดยสาร						
4	59	7.6	43.4-74.6	59	8.2	42.9-75.1
3	72	8.3	55.7-88.3	72	8.2	55.9-88.1
2	81	9.6	62.2-99.8	82	9	64.3-99.6
1	98	12.5	73.6-112.4	100	13.3	73.9-126.1

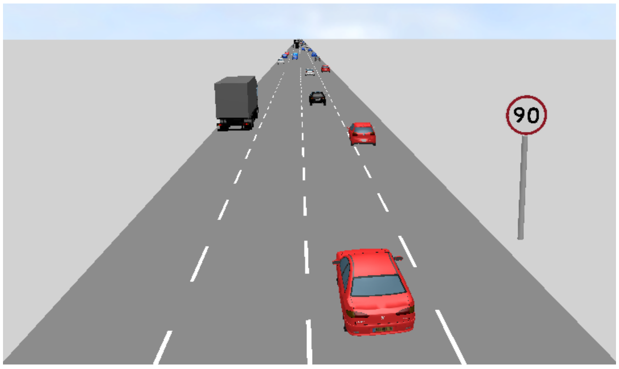
หมายเหตุ: ระดับความเชื่อมั่นร้อยละ 95

3.2 การพัฒนาแบบจำลอง

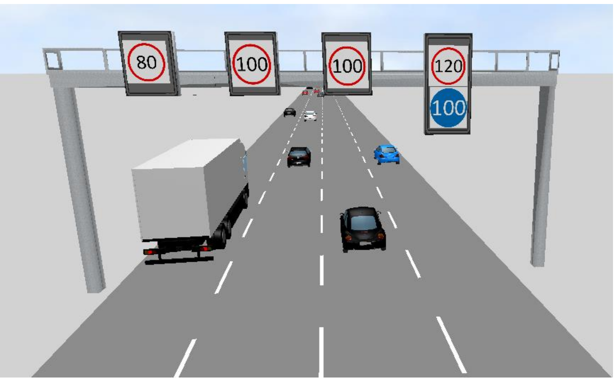
งานวิจัยได้สร้างแบบจำลองการจราจรระดับจุลภาคโดยใช้โปรแกรม PTV Vissim เพื่อประเมินผลกระทบด้านการจราจรและความ

ปลอดภัยของถนนจากการดำเนินการกำหนดขีดจำกัดความเร็วตามช่องจราจร โดยสร้างแบบจำลอง 2 กรณี ได้แก่

1) แบบจำลองของช่วงถนนที่มีการกำหนดขีดจำกัดความเร็วทุกช่องจราจรเท่ากัน (ก่อนดำเนินการ) ที่ 90 กิโลเมตรต่อชั่วโมง ดังแสดงในรูปที่ 5
2) แบบจำลองของช่วงถนนที่มีการกำหนดขีดจำกัดความเร็วตามช่องจราจร (หลังดำเนินการ) ดังแสดงในรูปที่ 6 โดยกำหนดขีดจำกัดความเร็ว ดังนี้
    - ช่องจราจรที่ 1 (ขวาสุด) ไม่เกิน 120 กม./ชม.และไม่ต่ำกว่า 100 กม./ชม.
    - ช่องจราจรที่ 2 ไม่เกิน 100 กม./ชม.
    - ช่องจราจรที่ 2 ไม่เกิน 100 กม./ชม.
    - ช่องจราจรที่ 4 (ซ้ายสุด) ไม่เกิน 80 กม./ชม.



รูปที่ 5 แบบจำลองกำหนดขีดจำกัดความเร็วเท่ากันทุกช่องจราจร



รูปที่ 6 แบบจำลองมาตรการกำหนดขีดจำกัดความเร็วตามช่องจราจร

แบบจำลองของช่วงถนนที่ศึกษาทั้ง 2 กรณี มีระยะทาง 5 กิโลเมตร ประกอบด้วย 4 ช่องจราจร ไม่มีทางเชื่อมเข้าออก โดยกำหนดปริมาณจราจร 2,500-3,500 คันต่อชั่วโมงต่อทิศทาง สัดส่วนรถบรรทุกร้อยละ 10 และความเร็วของรถยนต์ส่วนบุคคลอยู่ในช่วง 40-140 กม./ชม. และความเร็วของรถบรรทุกอยู่ในช่วง 40-120 กม./ชม. ซึ่งสอดคล้องกับข้อมูลที่ได้จากการสำรวจ

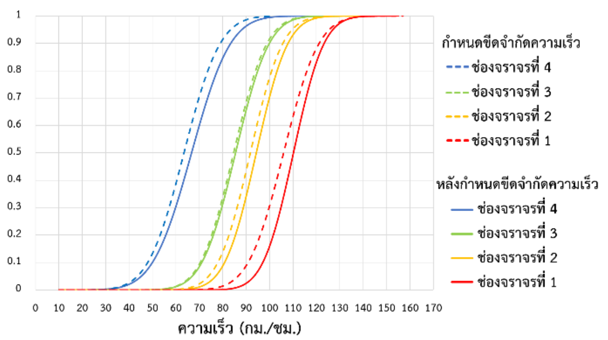
4. ผลการวิจัย

งานวิจัยนี้เปรียบเทียบผลกระทบของการกำหนดขีดจำกัดความเร็วตามช่องจราจรที่แตกต่างกัน โดยจะเปรียบเทียบก่อนดำเนินมาตรการและหลังดำเนินการ ผลการศึกษาออกเป็น 3 ส่วน ได้แก่ การเปรียบเทียบพฤติกรรมการใช้ความเร็ว การเปรียบเทียบพฤติกรรมการเปลี่ยนช่องจราจร และการปรียบเทียบประสิทธิภาพการให้บริการ

4.1 ผลการวิเคราะห์พฤติกรรมการใช้ความเร็ว

ผลการวิเคราะห์พฤติกรรมการใช้ความเร็วบนทางหลวง ที่ได้จากแบบจำลองจราจร พบว่า ภายหลังการกำหนดขีดจำกัดความเร็วตามช่องจราจรและปรับเพิ่มขีดจำกัดความเร็วเป็น 120 กม./ชม. พฤติกรรมการใช้ความเร็วมีแนวโน้มสูงขึ้น ความเร็วเฉลี่ยเพิ่มขึ้นจาก 98.0 เป็น 101.2 กม./ชม. ความเร็วเปอร์เซ็นต์ไทล์ที่ 85 เพิ่มขึ้นจาก 83.7 กม./ชม. เป็น 89.2 กม./ชม. แต่มีการใช้ความเร็วของยานพาหนะรายคันที่ใกล้เคียงกัน เกาะกลุ่มกันมากขึ้น ส่วนเบี่ยงเบนมาตรฐานของความเร็วลดลงจาก 12.2 กม./ชม. เป็น 11.8 กม./ชม.

หากพิจารณาแยกตามช่องจราจร ความเร็วเฉลี่ยและความเร็วเปอร์เซ็นต์ไทล์ที่ 85 ของยานพาหนะในแต่ละช่องจราจรเพิ่มขึ้นอย่างมีนัยสำคัญ การแจกแจงความถี่สะสมของความเร็วยานพาหนะในแต่ละช่องจราจร แสดงได้ดังรูปที่ 7



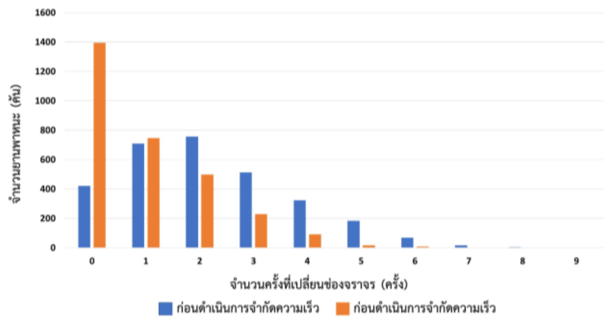
รูปที่ 7 การแจกแจงความถี่สะสมของความเร็วยานพาหนะตามช่องจราจรก่อนและหลังดำเนินการ

- ช่องจราจรที่ 1 ความเร็วเฉลี่ย เพิ่มจาก 105.0 เป็น 110.0 กม./ชม. ความเร็วเปอร์เซ็นต์ไทล์ที่ 85 เพิ่มจาก 117.1 เป็น 119.8 กม./ชม.

- ช่องจราจรที่ 2 ความเร็วเฉลี่ย เพิ่มจาก 84.2 เป็น 88.6 กม./ชม. ความเร็วเปอร์เซ็นต์ไทล์ที่ 85 เพิ่มจาก 103.3 เป็น 105.7 กม./ชม.
- ช่องจราจรที่ 3 ความเร็วเฉลี่ย เพิ่มจาก 82.7 เป็น 86.4 กม./ชม. ความเร็วเปอร์เซ็นต์ไทล์ที่ 85 เพิ่มจาก 95.5 เป็น 97.8 กม./ชม.
- ช่องจราจรที่ 4 ความเร็วเฉลี่ย เพิ่มจาก 62.3 เป็น 70.9 กม./ชม. ความเร็วเปอร์เซ็นต์ไทล์ที่ 85 เพิ่มจาก 76.2 เป็น 81.7 กม./ชม.

4.2 ผลการวิเคราะห์พฤติกรรมการเปลี่ยนช่องจราจร

ผลการวิเคราะห์พฤติกรรมการเปลี่ยนช่องจราจร พบว่า ภายหลังการกำหนดขีดจำกัดความเร็วตามช่องจราจรและปรับเพิ่มขีดจำกัดความเร็วเป็น 120 กม./ชม. พฤติกรรมการเปลี่ยนช่องจราจรมีแนวโน้มน้อยลง โดยที่ก่อนดำเนินการยานพาหนะส่วนใหญ่จะเปลี่ยนช่องจราจรอย่างน้อย 1-2 ครั้ง แต่หลังดำเนินการยานพาหนะส่วนใหญ่จะไม่เปลี่ยนช่องจราจรตลอดเส้นทาง (0 ครั้ง) ดังรูปที่ 9 อัตราการเปลี่ยนช่องจราจรของยานพาหนะมีค่าลดลงจาก 2.2 ครั้งต่อคัน (ก่อนดำเนินการ) เป็น 1.0 ครั้งต่อคัน (หลังดำเนินการ)

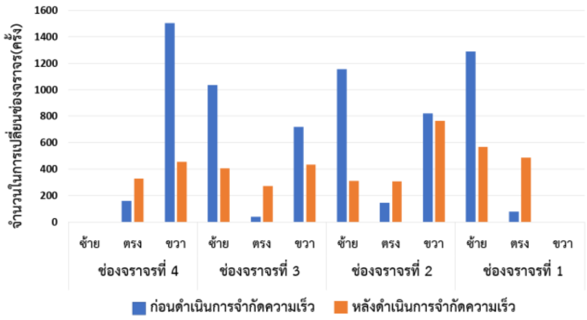


รูปที่ 9 การแจกแจงความถี่ของจำนวนครั้งของการเปลี่ยนช่องจราจรของยานพาหนะ ก่อนและหลังดำเนินการ

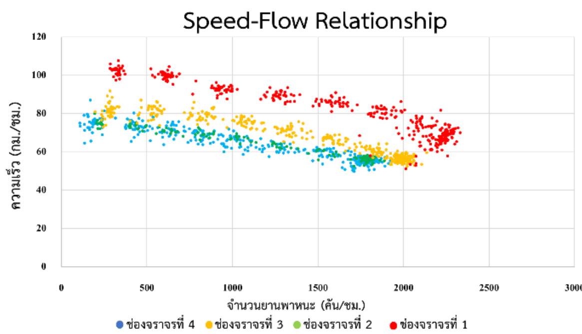
นอกจากนี้ หากพิจารณายานพาหนะที่เปลี่ยนช่องจราจร พบว่า รูปแบบทิศทางของการเปลี่ยนช่องจราจรมีความเป็นระเบียบมากขึ้น ภายหลังการกำหนดขีดจำกัดความเร็วตามช่องจราจร สัดส่วนของยานพาหนะที่เปลี่ยนช่องจราจรไปทางช่องจราจรทางขวามีมากกว่าไปทางช่องจราจรทางซ้าย ในขณะที่ก่อนดำเนินการ จะมีสัดส่วนจำนวนยานพาหนะที่เลือกเปลี่ยนช่องจราจรทั้งทางซ้ายและทางขวาใกล้เคียงกัน ซึ่งเป็นพฤติกรรมที่เสี่ยงในการขับขี่

4.3 ผลการวิเคราะห์ประสิทธิภาพความจุและการให้บริการ

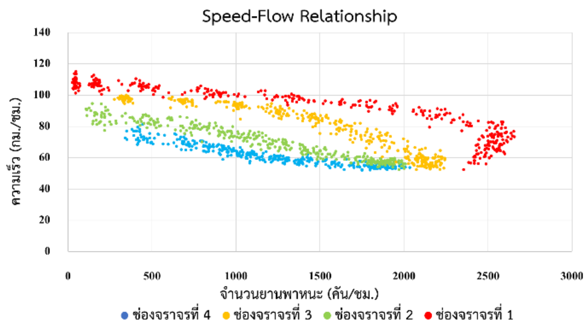
ผลการวิเคราะห์คุณลักษณะของการจราจร โดยเปรียบเทียบความสัมพันธ์ระหว่างอัตราการไหลและความเร็วของยานพาหนะแต่ละช่องจราจร ก่อนและหลังดำเนินการกำหนดขีดจำกัดความเร็วตามช่องจราจร ดังรูปที่ 11 และรูปที่ 12 ตามลำดับ พบว่า ภายหลังดำเนินการกำหนดขีดจำกัดความเร็วตามช่องจราจร กระแสจราจรสามารถเคลื่อนตัวได้มากขึ้น เนื่องจากขีดจำกัดความเร็วที่สูงขึ้น โดยเฉพาะอย่างยิ่งในช่องจราจรขวาสุดที่มีการปรับเพิ่มขีดจำกัดความเร็วเป็น 120 กม./ชม. โดยมีค่าอัตราการไหลสูงสุดเพิ่มขึ้น จาก 2,200 เป็น 2,500 คัน/ชม. หรือเพิ่มขึ้นประมาณร้อยละ 10 ของอัตราการไหลสูงสุดก่อนดำเนินการ



รูปที่ 10 จำนวนครั้งของการเปลี่ยนช่องจราจรของยานพาหนะแยกตามช่องจราจร (ซ้าย: เปลี่ยนช่องจราจรไปทางซ้าย, ตรง: ไม่เปลี่ยนช่องจราจร, ขวา: เปลี่ยนช่องจราจรไปทางขวา)



รูปที่ 11 ความสัมพันธ์ระหว่างอัตราการไหลและความเร็วของยานพาหนะก่อนดำเนินการ



รูปที่ 12 ความสัมพันธ์ระหว่างอัตราการไหลและความเร็วของยานพาหนะหลังดำเนินการ

5. อภิปรายผลและสรุปผล

งานวิจัยนี้ได้ศึกษาประสิทธิภาพของการกำหนดขีดจำกัดความเร็วแยกตามช่องจราจร บนถนนทางหลวงหมายเลข 32 โดยใช้แบบจำลองสภาพการจราจรระดับจุลภาค PTV Vissim ซึ่งพัฒนาแบบจำลองเป็น 2 สถานการณ์ ได้แก่ ก่อนดำเนินการกำหนดขีดจำกัดความเร็ว (90 กม./ชม.) และหลังดำเนินการกำหนดขีดจำกัดความเร็วแยกตามช่องจราจร จำนวน 4 ช่องจราจร ได้แก่ 120 100 100 และ 80 กม./ชม. ตามลำดับ ซึ่งผลสรุปการวิเคราะห์ด้านความเร็ว เปรียบเทียบก่อนและหลังดำเนินการกำหนดขีดจำกัดความเร็วใหม่ พบว่า กรณีหลังกำหนดขีดจำกัดความเร็วแยกตามช่องจราจร มีพฤติกรรมการใช้ความเร็วที่มีแนวโน้มสูงขึ้น เมื่อพิจารณาจากค่าความเร็วเฉลี่ยและเปอร์เซ็นต์ไทล์ที่ 85 มีค่าเพิ่มขึ้นโดยเฉลี่ยร้อยละ 3.26 และ 6.57 ตามลำดับ อีกทั้งการใช้ความเร็วของยานพาหนะรายคันเกาะกลุ่มกันมากขึ้น โดยมีค่าส่วนเบี่ยงเบนมาตรฐานของความเร็วเป็น 11.8 กม./ชม. (ลดลงร้อยละ 3.28) ส่วนผลการวิเคราะห์พฤติกรรมการเปลี่ยนช่องจราจร พบว่า กรณีหลังกำหนดขีดจำกัดความเร็วแยกตามช่องจราจร มีแนวโน้มพฤติกรรมการเปลี่ยนช่องจราจรลดลง โดยพิจารณาจากจำนวนครั้งและอัตราในการเปลี่ยนช่องจราจรของยานพาหนะจาก 2.2 ครั้ง/คันเป็น 1.0 ครั้ง/คัน (ลดลงร้อยละ 54.5) และส่วนผลการวิเคราะห์ประสิทธิภาพความจุและการให้บริการ พบว่า หลังดำเนินการกำหนดขีดจำกัดความเร็วแยกตามช่องจราจร กระแสจราจรมีความคล่องตัวมากขึ้น เนื่องจากขีดจำกัดความเร็วที่สูงขึ้น โดยมีค่าอัตราการไหลสูงสุดเพิ่มขึ้นเป็น 2,500 คัน/ชม. (เพิ่มขึ้นร้อยละ 13.6) จากผลการศึกษานี้แสดงให้เห็นว่าการกำหนดขีดจำกัดแยกตามช่องจราจร ทำให้ผู้ขับขี่สามารถใช้ความเร็วได้อย่างเหมาะสมตามช่องจราจรและมีความสอดคล้องกับลักษณะกายภาพถนนและการใช้งานพื้นที่ข้างทาง

อย่างไรก็ตาม งานวิจัยนี้มีข้อจำกัดทางด้านแบบจำลองโดยกรณีแบบจำลองหลังกำหนดขีดจำกัดความเร็วแยกตามช่องจราจรได้ตั้งสมมติฐานให้ผู้ขับขี่ปฏิบัติตามขีดจำกัดความเร็วตามช่องจราจรที่กำหนดไว้ ส่งผลให้ค่าความเร็วที่ได้ไม่เกินขีดจำกัดความเร็วที่กำหนด ดังนั้นงานวิจัยในอนาคตควรมีการศึกษาเพิ่มเติมด้านการพัฒนาแบบจำลองให้มีการกำหนดความเร็วที่สอดคล้องกับสภาพจริงมากยิ่งขึ้น อีกทั้งควรมีการพิจารณาทางเชื่อมที่อาจจะส่งผลต่อความเร็วที่ลดลงได้

6. กิตติกรรมประกาศ

ผู้วิจัยขอขอบคุณบัณฑิตวิทยาลัย และภาควิชาวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ มหาวิทยาลัยเชียงใหม่ และขอขอบคุณศูนย์วิจัยด้านโครงสร้างพื้นฐานสีเขียวและเทคโนโลยีการขนส่ง (Green Infrastructure and Transportation Technology, GITT) ที่ให้การสนับสนุนด้านการดำเนินการวิจัยและให้คำปรึกษาด้านวิชาการ จนงานวิจัยเสร็จสิ้นสมบูรณ์ได้ด้วยดี

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