Applying a Bayesian network for modelling the shift from motorcycle to public transport use in Vietnam

Nguyen, Son-Tung; Moeinaddini, Mehdi; Saadi, Ismail & COOLS, Mario (2024) Applying a Bayesian network for modelling the shift from motorcycle to public transport use in Vietnam. In: Transportation Research. Part A, Policy and Practice, 183 (Art N° 104062).

DOI: 10.1016/j.tra.2024.104062
Handle: http://hdl.handle.net/1942/43699

APPLYING A BAYESIAN NETWORK FOR MODELLING THE SHIFT FROM MOTORCYCLE TO PUBLIC TRANSPORT USE IN VIETNAM

Son-Tung Nguyen [a,b], Mehdi Moeinaddini [c], Ismaïl Saadi [d], Mario Cools [a,e,f]

[a] Local Environment & Management Analysis (LEMA), Urban and Environmental Engineering (UEE), University of Liege, Quartier Polytech 1, Allée de la Découverte 9 4000, Liège, Belgium

[b] University of Economics - The University of Danang Vietnam

[c] Centre for Public Health, Queen's University Belfast, UK

[d] MRC Epidemiology Unit, School of Clinical Medicine, University of Cambridge, UK

[e] Faculty of Business Economics, Hasselt University, Agoralaan Gebouw D 3590, Diepenbeek, Belgium

[f] Department of Informatics, Simulation and Modeling, KULeuven Campus Brussels, Belgium

KEYWORDS : Travel mode choice, Modal shift, Motorcyclist, Public transport, Bayesian-networks, Network-learning

ABSTRACT

Transport mode choice models commonly incorporate factors such as utility maximisation, socio-ecological considerations, socio-demographic characteristics, and psychological factors. However, there is still a lack of integrated models linking objective factors, such as travel mode attributes, demographic & socio-economic characteristics and built environmental characteristics, with subjective factors, such as attitudes, personal norms, and perceived behavioural control, to better understand the commuters' modal choices. Furthermore, a clear research gap exists on mode choice behaviour in Southeast Asian countries, where motorcycling is widespread. This study aims to address these research gaps by analysing data gathered from 618 Vietnamese motorcyclists between December 2020 and February 2021. Reliability analysis and a Bayesian network are used to identify the objective and subjective factors influencing the intention to use public transport among Vietnamese motorcyclists. The findings highlight that among five subjective factors, personal norm is the most sensitive parameter in calculating the posterior probability distribution of intention and decision to use public transport along with other objective factors, namely travel time and travel cost. The results also reveal that motorcyclists aged 23 + have a higher perceived value of travel time than those aged 23-. In contrast, motorcyclists aged 23- and female motorcyclists have a higher perceived value toward environment-friendly travel modes, such as public transport. At the same time, they do not try to differentiate themselves from the societal standards in terms of motorcycle usage. The findings of this study provide valuable insights to local urban/transport planners and policymakers in Southeast Asian countries.

1. Introduction

Most commuters perform trips using private means of transport to engage in activities instead of using public transport or emerging shared mobility services. Private vehicles are generally perceived as more convenient and comfortable than other transport alternatives and promote accessibility for supporting busy lifestyles. This travel mode is more attractive for individuals and is perceived as symbolic or reflects a person's identity (Steg, 2005; Redman et al., 2013). People without personal transportation become more disadvantaged and even isolated from society, as workplaces and public buildings are designed to accommodate people using private vehicles (Steg, 2003). Previous studies have identified many factors influencing commuters' choice of different travel modes due to the differences in living conditions and land use from country to country (Washbrook et al., 2006; Kim & Ulfarsson, 2008; Eriksson et al., 2010; Stanton et al., 2013).

For the cases of car or public transport, most recently, frameworks have been established considering different dimensions such as utility function, social-ecological system, socio-demographics, and psychology. Despite this comprehension, the link between objective factors (travel mode attributes, demographic & socio-economic characteristics and built environmental characteristics) and subjective factors (attitudes, personal norms, perceived behavioural control, etc.) was still not investigated in a model for understanding modal choices. Moreover, for the study objects, most prior studies focused on private car users, and only a few of them have attempted to understand the factors influencing motorcyclists. This can lead to a lack of understanding of the transport situation of some regions, especially in Southeast Asia, which is significantly different from the Western world with typical features of a higher proportion of motorbike users (United Nations, 2018). Among the leading 20 countries with a high number of motorcycles per 1000 population, seven come from the Southeast Asia region: Vietnam, Malaysia, Indonesia, Thailand, Lao and Cambodia (Laksanakit, 2014). Taiwan, a state in East Asia, also has a very high motorcycle usage (0.65 motorcycles per person on average) (Chang & Lai, 2015). The lower purchase and operating costs and the small size and high manoeuvrability enabling the user to operate the motorcycle on the road and parking even under poor traffic conditions can explain the rise of motorcycles in Asia (Kepaptsoglou et al., 2011). Prior research about motorcycle usage has mostly focused on traffic safety issues (Gkritza, 2009; Kepaptsoglou et al., 2011; Le & Trinh, 2016), sociodemographic analysis (Sheikh et al., 2006; Abdullah et al., 2007; Satiennam et al., 2016; Le & Trinh, 2016), and economic factors (Burge et al., 2008; Chang & Wu, 2008; Chen & Lai, 2011; Kepaptsoglou et al., 2011; Le & Trinh, 2016). Although the above variables are considered important factors in developing traffic and transport safety plans and transport policies in areas with high motorcycle usage, this travel mode has been scarcely recognised.

On the other hand, public transport is not a new concept in Vietnam, and Vietnamese people used the first type of public transport since France dominated them in the 1880 s (Tran, 2011; Thu Hang, 2016). Since 1968, the tramway system has been restored and developed to become an important public transport in the city, serving more than 30 million passengers a year (Tran, 2011; Thu Hang, 2016). Until the late 1980 s, bicycles and tramways remained familiar means of

transportation for the capital's people (Tran, 2011; Thu Hang, 2016). In 1991, since the last road was shut down, motorbikes gradually flooded Hanoi and other main cities of Vietnam, along with urbanisation, socio-economic development, and a rising population. These cities are faced with the urgency of the urban traffic crisis (Tran, 2011; Thu Hang, 2016). The rapid growth of motorcycle usage causes huge damage to the environment as each gasoline motorcycle emits 31.81 g of CO2 per km, which is approximately two times higher in terms of CO2 than the electric motorcycle (Koossalapeerom et al., 2019). Since 2001, the bus system has been reorganised and was expected to be an alternative to private vehicles (Tran, 2011; Thu Hang, 2016). Developing a reliable, efficient, and sustainable public transport system is essential to reducing private mode usage, such as motorcycle use (Bhouri et al., 2015). Furthermore, if widely adopted, public transport could be an effective, low-cost solution to current in-city transportation issues, including high CO2 emissions and traffic congestion (Lee & Erickson, 2017).

Due to the research gaps mentioned above, this paper investigates the proposed model that links intrinsic and extrinsic variables by applying reliability analysis and a Bayesian network. The paper's findings contribute to a better understanding of the factors influencing Vietnamese motorcyclists' public transport mode choice. Moreover, policy suggestions from this paper could be used to determine local government priorities related to the shift of Vietnamese motorcyclists away from the motorcycle. The remainder of the paper is organised as follows. Section 2 is about the literature review, Section 3 describes the data collection process, Section 4 explains the method, Section 5 presents the analysis results, and Section 6 discusses the results.

2. Literature review

2.1. FACTORS INFLUENCE THE MODAL SHIFT FROM MOTORCYCLE TOWARD PUBLIC TRANSPORT

A modal shift occurs when one mode of transport achieves a competitive advantage in travel over another mode by differentiating its characteristics in travel time, travel cost, capacity, flexibility, dependability, etc. (Vedagiri and Venkatachalam, 2009; Stanton et al., 2012). With competitive advantages in terms of low purchase prices and operating costs, motorcycles are the preferred means of transport in many developing countries. They are designed to suit various purposes, such as long-distance travel, cruises, and sports such as racing and off-road riding (Cossalter, 2006). Previous studies have determined that (i) psychological characteristics (Kitamura et al., 1997; Parkany et al., 2004; Steg, 2005; Beirão & Cabral, 2007; Domarchi et al., 2008; Murray et al., 2010), (ii) mode characteristics (Andreassen, 1995; Hensher et al., 2003; Washbrook et al., 2006; Beirão & Cabral, 2007), (iii) demographic and socio-economic characteristics (Morikawa et al., 2003; Sheikh et al., 2006; Abdullah et al., 2007; Satiennam et al., 2016), and (iv) built environmental characteristics (Pucher and Dijkstra, 2003; Ewing et al., 2010; Zhang et al., 2012; Wang and Lin, 2013; Zailani et al., 2016) are the considered factors influencing the modal shift from motorcycles toward public transport. The following paragraphs show in detail the considered explanatory variables.

2.1.1. PSYCHOLOGICAL CHARACTERISTICS

The psychological factor is the intrinsic motivation that expresses an internal state that influences the travel mode choice of an individual. The intention to use a particular mode of transport, which results from a mental function that immediately sets the stage for

mode choice behaviour, is considered a part of psychological factors. It is known as a highly effective tool for predicting as well as doing research about human behaviour, especially in the case of a hard-to-observe situation (Krueger & Brazeal, 1994; Yurtkoru et al., 2014). For studying behavioural intention, there are two most frequently used theories, namely the theory of reasoned action (TRA) (Fishbein & Ajzen, 1975) and the theory of planned behaviour (TPB) (Ajzen, 1991). According to the TPB, an individual's intention to perform a behaviour is affected by three factors: (i) attitudes, encompassing the positive and negative outcomes associated with a specific action; (ii) subjective norms, reflecting an individual's belief in the support for a particular behaviour from those around them; and (iii) perceived behavioural control (PBC), indicating an individual's perception of their ability to execute a specific behaviour (Ajzen, 1991). Over time, this theory has evolved into a prominent framework applied in numerous studies within the domain of travel behaviour, enhancing its predictive capacity in understanding travel mode choice behaviour and providing valuable insights into the decision-making processes of individuals (Betsch et al., 1998; Heath & Gifford, 2002; Bamberg et al., 2003; Steg, 2005; Haustein & Hunecke, 2007; Haustein et al., 2009; Murray et al., 2010; Chen & Chao, 2011; Olsson et al., 2018).

Investigations into the impacts of attitudes towards travel behaviour have been widespread, exploring dimensions such as service quality, flexibility, time-saving, cost sensitivity, and the inclination to use alternative travel modes (Kitamura et al., 1997; Steg, 2005; Beirão & Cabral, 2007; Steg & Brussel, 2009; Chen & Chao, 2011; Chen & Chen, 2011; Van & Fujii, 2011). Early research acknowledged that attitudes towards mode choice arise from affective, symbolic, and instrumental motives (Steg, 2003). However, subsequent studies found a lack of clear differentiation between symbolic and affective factors (Steg, 2005; Van & Fujii, 2011). In the context of Vietnam, despite advancements in the PT system's onboard services, the adoption of these services among students and employees remains limited. Consequently, a prevalent negative attitude exists towards PT services, with motor vehicles retaining their status as the preferred mode of travel for these demographics (Le & Trinh, 2016). Notably, motorcyclists exhibit a positive attitude towards motorcycle use, driven by factors such as the thrill of speeding (Chen & Chen, 2011) and the flexibility of this mode, enabling them to navigate through traffic efficiently (Steg & Brussel, 2009). In 2011, a study by Van and Fujii (2011) examined attitudes towards cars and public transport in several Asian countries, including Japan, Thailand, China, Vietnam, Indonesia, and the Philippines. The study identified a new factor, social orderliness, influencing commuters' attitudes towards travel modes. This factor encompassed safety, quietness, environmental friendliness, altruism, etc (Van & Fujii, 2011). In addition, a study conducted in Taiwan also demonstrated that PBC had a noteworthy impact on motorcyclists' intention to switch to public transport (Chen & Chao, 2011). However, this effect was not observed among car users (Chen & Chao, 2011). Another research study in Taiwan emphasised the pivotal role of PBC in predicting the intention to use motorcycles, considering it the

most influential factor in this context (Chen & Lai, 2011). Moreover, in a broader context covering environmentally friendly transportation options such as walking, bicycling, and PT, PBC also exhibited a significant direct influence (Haustein & Hunecke, 2007).

2.1.2. MODE CHARACTERISTICS

The characteristics of a transport mode are determined based on extrinsic motivational factors that influence individuals' modal choice, for example, service quality and accessibility of public transport (Andreassen, 1995; Hensher et al., 2003; Beirão & Cabral, 2007; Redman et al., 2013; Le & Trinh, 2016). Early studies on public transport mode choice concentrated on evaluating service quality and availability within the public transport system, with findings consistently underscoring the paramount importance of attributes like travel time, travel cost, service reliability, frequency, seat availability, and station facilities in determining service quality (Andreassen, 1995; Redman et al., 2013). Travel time, encompassing in-vehicle travel time, waiting time due to traffic congestion, waiting time at the bus station, and walking time to the bus station, emerged as a critical factor in the decision-making process, particularly for work and school-related journeys (Le & Trinh, 2016). Commuters generally prioritise a sense of control during travel, manifested through reduced waiting times and shorter journeys in term of travel times (Beirão & Cabral, 2007). For these commuters, travel time and cost most significantly influence their choice of transportation mode (Beirão & Cabral, 2007). In addition, lower fares would raise commuters' perceptions of public transport quality, thus affecting their satisfaction with this mode choice (Andreassen, 1995; Hensher et al., 2003).

Research focusing on Southeast Asian commuters concurs, highlighting attributes such as travel time, travel cost, station distance, and service reliability as crucial determinants prompting a shift toward PT usage (Andreassen, 1995; Hensher et al., 2003; Washbrook et al., 2006; Beirão & Cabral, 2007). Previous studies found that local commuters in Kuala Lumpur, Malaysia, would not shift to PT because these travel modes are not convenient enough (Kwan et al., 2018). Indeed, commuters want a sense of control when travelling, with short wait times and quick journeys (Beirão & Cabral, 2007). Conversely, in Thailand, an examination of modal shifts from private vehicles to bus rapid transit (BRT) indicates that BRT significantly attracts private vehicle users, particularly motorcyclists, owing to superior service (Satiennam et al., 2016). This study also establishes that travel costs significantly influence motorcyclists' choices, suggesting that increasing costs related to motorcycle use could increase the likelihood of switching to PT use (Satiennam et al., 2016).

2.1.3. DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS

Demographic and socio-economic characteristics have been shown to significantly influence commuters' behaviour, such as age and gender (Morikawa et al., 2003; Sheikh et al., 2006; Abdullah et al., 2007; Abuhamoud et al., 2011; Satiennam et al., 2016). Demographic variables such as age and gender were found to be good explanatory variables in understanding commuters' behaviour (Morikawa et al., 2003; Sheikh et al., 2006; Abuhamoud et al., 2011). In Southeast Asian countries such as Thailand, Malaysia and Taiwan, household income can influence an individual's mode choice as well as car and motorcycle ownership rate (Abdullah et al., 2007; Chang & Lai, 2015;

Satiennam et al., 2016). An improved household income would make these vehicles an affordable travel mode (Abdullah et al., 2007; Chang & Lai, 2015; Satiennam et al., 2016).

2.1.4. BUILT ENVIRONMENTAL CHARACTERISTICS

Besides psychological, demographic, and socio-economic factors, public transport usage is also influenced by built environment factors. These factors are divided into four main components, namely (i) good access to public transit, (ii) good pedestrian facilities, (iii) compact cities with mixed land use, and (iv) high residential density (Pucher and Dijkstra, 2003; Ewing et al., 2010; Wang and Lin, 2013). Previous studies found that inconvenience and inconsistent transit accessibility when using public transport would lead to more private mode choices (Jenelius, 2012; Lucas et al., 2016). Thus, increased pedestrian facilities and public transport stations would enhance the use of these modes of transportation (Pucher and Dijkstra, 2003). Also, commuters who live in a residential area that has mixed land use and high densities of social and commercial facilities tend not to use private motorised modes (Zhang et al., 2012; Zailani et al., 2016).

2.2. THE DAG ILLUSTRATES THE MODAL SHIFT FROM MOTORCYCLE TOWARD PUBLIC TRANSPORT USAGE

The above paragraphs describe both objective and subjective variables that influence PT usage among motorcyclists. The relationships between these variables are shown in Fig. 1. This Figure illustrates the hypothesised causal pathway from motorcycle usage to PT usage. The total causal effect of the intention to shift to PT mode shift intention on actual PT usage can be objectively estimated by adjusting the attitude towards PT (including instrumental, symbolic, and social orderliness attitudes), personal norm, which is affected by injunctive norms and descriptive norms, and perceived behaviour control. The intention to shift to PT and PT usage are also determined by mode characteristics (including travel time and travel cost, traffic safety, etc.), socio-demographic factors (including age, gender, socio-economic status, etc.), and built-environment characteristics (including the distance to the most nearby bus station and parking space) that mutually influence PT usage.

Figure 1. *DAGs illustrating the hypothesised causal pathway from motorcycle usage toward public transport mode usage. DEC - decision to use PT, INT - intention to use PT, PN - personal norm, PBC - perceived behavioural control, AI - instrumental attitude, ASA - Symbolic/Affective attitude, AO - social orderliness attitude, SES - socio-economic status, Age - motorcyclists' age, Gender - motorcyclists' gender, MS - motorcycle status, CS - car status, ENV - environmental, RS - road safety, PE - physical effort, BSD - bus station distance, Time - Travel time, Cost - Travel cost.*

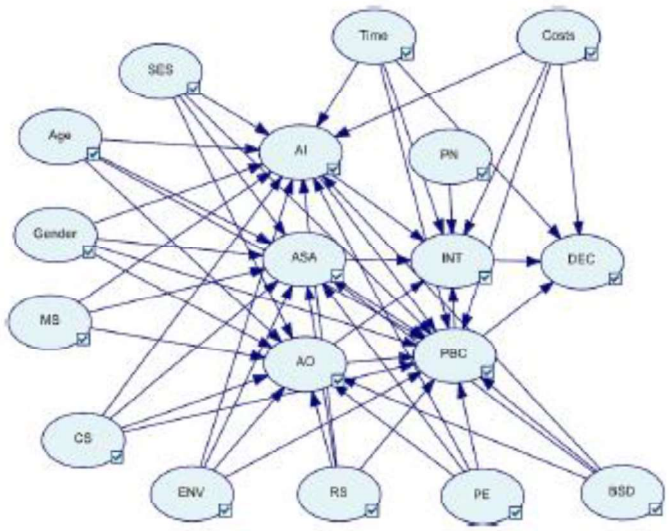


Table 1. *Items for measuring psychological factors influencing intention to use PT.*

No.	Code	Details	Sources
Attitude			
Instrumental			
1	AI1	For me, using public transport is convenient.	Steg, 2005; Choocharukul et al., 2006
2	AI2	For me, using public transport is fast.	
3	AI3	For me, using public transport is safe.	
4	AI4	For me, using public transport is simple.	
5	AI5	For me, using public transport is comfortable.	
Symbolic/Affective			
6	ASA1	For me, using public transport is exciting.	Steg, 2005; Choocharukul et al., 2006
7	ASA2	For me, using public transport can make me feel rich.	
8	ASA3	For me, using public transport can make me feel pleasant.	
9	ASA4	For me, using public transport is attractive.	
10	ASA5	For me, using public transport is superior.	
11	ASA6	For me, using public transport can make me feel fashionable.	
12	ASA7	For me, public transport is a clean travel mode.	
13	ASA8	For me, using public transport is cool.	
14	ASA9	For me, using public transport can make me feel relaxed.	
15	ASA10	For me, using public transport can make me feel positive.	
16	ASA11	For me, public transport is an esteemed travel mode.	
Social orderliness			
17	AO1	For me, public transport is an environmentally friendly travel mode.	Van & Fujii, 2011
18	AO2	For me, using public transport is constructive.	
19	AO3	For me, using public transport is non-aggressive.	
20	AO4	For me, using public transport is non-arrogance.	
21	AO5	For me, using public transport is along with altruistic feeling.	
Social norms (injunctive norms and descriptive norms) and personal norms			
22	SIN1	Most people who are important to me would support my choice of using public transport instead of a motorbike for daily travel from my current place of residence.	Olsson et al., 2018
23	SDN1	Most of the people important to me would use public transport instead of other travel modes.	
24	PN1	Regardless of what other people do, because of my own values, I feel an obligation to use public transport instead of a motorbike for daily travel from my current place of residence.	
Perceived behavioural control			
25	PBC1	For me, using public transport can take me to all the places I want to.	Chen & Lai, 2011
26	PBC2	For me using public transport for daily travel from my current place of residence would be easy.	
Intention			
27	INT	In the next six months, my intention to use public transport for daily travel from my current place of residence is strong.	Chen & Lai, 2011
Decision			
28	DEC	How likely is it that, over the next six months, you will use public transport for daily travel from your current place of residence?	Chen & Lai, 2011

3. Data

The final list of items identified from the systematic review was presented at a meeting of experts to ensure that all relevant items were present in the final list. These items were then used to prepare a survey questionnaire for data collection. The questionnaire consists of an introduction with questions such as main travel route, main travel mode, distance, cost per trip, etc. In the questionnaire, the main travel route refers to the primary route that respondents take on a daily basis, while the main travel mode denotes the mode of transportation used for the longest distance travelled daily. Next, the respondents were asked to rate 28 statements (Table 1) on a 7- point Likert scale (Likert-1 totally disagree, and Likert-7 totally agree). These statements were built based on the assumption that PT was the main travel mode for the respondents to participate in their main activities (school and work commuting). The authors asked the respondents to rate the statements based on the situation before the Covid-19 pandemic. Note that until the end of February 2021, Vietnam had less than 1,700 Covid-19 infected cases and less than 40 deaths in total, which brings the infection and death rates much lower in Vietnam than elsewhere in the world, even though Vietnam's population reached nearly 100 million people (Worldometer, 2022). Because of timely policies and actions, the Vietnamese government could keep daily activities running as normal during the time of the data collection, particularly in Danang City. Thus, this situation would not strongly influence Vietnamese norms as norms are influenced through informational social influence and normative social influence (Deutsch & Gerard, 1955). Therefore, the authors believe that querying information about the pre-Covid-19 situation yielded valuable information for further analysis in this study.[1] Finally, the respondents were asked to provide their socio-demographic characteristics (including age, gender, monthly income, etc.), built-environment characteristics (including the distance to the most nearby bus station and parking space, house location, etc.), and obstacles to use PT (including physical effort, time, cost, etc.).

The survey took place in Danang city - a class-1 municipality, the largest city in the central and in the top 5 populated cities in Vietnam. The authors used a purposive sampling method to gather data. Most questionnaires were sent to employees at the Danang Administrative Centre, members of the Facebook group of Danang, people interested in local urban management, and students at the University of Economics. The target population are Vietnamese motorcyclists, as this study aims to explore the modal shift from motorcycle to PT. A total of 800 Vietnamese motorcyclists living in

[1] Until the end of February 2021, Vietnam reported fewer than 1,700 confirmed cases of COVID-19 and less than 40 deaths in total, reflecting significantly lower infection and mortality rates compared to other regions. Although the original dataset was collected before the substantial increase in Covid-19 cases in Vietnam, the authors recognized the necessity of conducting a supplementary survey to illuminate any potential shifts in post-pandemic attitudes. Consequently, a supplementary survey (Appendix A) was expeditiously conducted from December 5th to December 12th, 2023. A comparative analysis, delineated in Table 4 and Appendix B, underscores the neglectable changes in the attitudes of Vietnamese motorcyclists during and after COVID-19. The authors contend that this supplementary survey demonstrates the persistence of attitudes among Vietnamese motorcyclists amidst the COVID-19 pandemic.

Danang city were randomly selected. All respondents are from 7 districts of Danang and represent nearly 0.1 % of this city's population.

4. Methods

In the first step, Cronbach's Alpha test, including internal consistency and item-to-total correlation analysis, was used to assess the reliability of each scale's items. This test measures the correlation of each item to the sum of the remaining items within one factor (Hair et al., 2014). This procedure also can eliminate unsuitable variables. The minimum acceptable value is 0.70 (Hair et al., 2014).

In the second step, a Bayesian network is developed. This network is a probabilistic graphical model representing a statistical dependence on a set of random variables, where the nodes represent the variables and the arcs represent the conditional dependencies (Pearl, 1988). The joint probability distribution of the variables is determined by the graph structure of the network (Pearl, 1988). In most cases, nodes can represent different types of variables, such as a measurable parameter, a latent variable, or a hypothesis, rather than just observable variables.

A Bayesian network is constructed as a directed acyclic graph (DAG) in which:

- Nodes represent variables,
- The arcs represent the statistical dependencies between the nodes and the local probability distribution for each node's value, given the values of its parent variables.

For example, if there is an arc from node α to node β, then node β depends directly on node α, and α is called the parent of β. If each node $\beta_i, i \in \{1, \cdots, N\}$, then the dependent conditional distribution of the variables is the product of the local distributions:

$$\Pr(\beta_1, \cdots, \beta_n) = \prod_{i=1}^{n} \Pr(\beta_i | \alpha_i)$$

One advantage of Bayesian networks is that, visually, it is easier to understand the dependencies directly and the local distributions. Particularly, the prototypical constraint-based algorithm (PC algorithm), an efficient algorithm for learning Bayesian networks from data, was performed. In particular, based on independence tests, the algorithms analyse the relationship between the dependent and independent variables and then try to find a network that represents these relationships as well as possible (Tsagris, 2018). They take a list of conditional independent relationships as input and create a network representing most of these relationships (Tsagris, 2018). Specifically, the PC structure learning algorithm starts by forming a complete undirected network. Then it thins by removing edges with a conditional independent relationship of zero-order and then re-considers with first-order conditional independence relations, etc. (Tsagris, 2018). The set of conditional variables just needs to be a subset of the variables set adjacent to one or the other of the conditional variables; this keeps changing as the algorithm progresses. Although the PC structure learning algorithm starts by forming a complete undirected network, PC is a constraint-based

algorithm for directed acyclic graphs, just like Bayesian networks (Tsagris, 2018). In addition, the values of observable items are converted into binary variables, which helps bring all considered variables into the same reference scale. By doing this, the authors reduce the complexity while implementing this algorithm. Table 2 shows the complete list of variables in the Bayesian network. After the network is developed, network validation, the strength of influences, sensitivity analysis, and probability of evidence are performed.

Specifically, cross-validation was used to train and test the data set. This method is the most appropriate model evaluation to achieve the goal of both learning and evaluating the model on the same dataset. It splits the dataset into K equal-sized parts, trains the network on K-1 parts, and tests it on the Kth one. The process is repeated K times, with another part of the data selected for testing. The number of folds is set through fold count, and the random allocation of records for different folds is set up through folding seed.

Next, the influence strength test was performed to see the different thicknesses of the arc, depending on the influence strength between the nodes to which they connect. The influence strength is computed from the child node's conditional probability table (CPT). Basically, it represents the distance between different conditional probability distributions over the child node conditional on the parent node situation.

Also, the probability parameters of the Bayesian network were confirmed through sensitivity analysis. This is conducted by examining the effect of small changes in numerical parameters, such as probabilities, on the output parameters, such as posterior probabilities, in which parameters with high sensitivity affect the inference results more significantly. Their identification allows for an oriented allocation of effort to obtain the correct results of the Bayesian network model. The algorithm proposed by Kjaerulff and Van der Gaag (2000) was used for the sensitivity analysis. Generally, given a set of objective nodes, the algorithm will efficiently compute an adequate set of derivatives of the posterior probability distributions over the objective nodes on each numerical parameter of the network. These derivatives show the importance of the network numerical parameters' accuracy in calculating the objectives' posterior probabilities. In case the derivative is large with respect to the parameter α, a minor change in α can lead to a big change in the posteriors of the objectives. On the contrary, when the derivative is small, large changes in the parameter still make a small change in the posteriors. In the final step, the probability of the evidence was calculated for different situations to assess how likely it is that the set of observations in the model occurs.

Table 2. *Variables used in the Bayesian network analysis.*

Factors	Variables		Labels	Categories
Psychological factors	Decision to use PT		DEC	1: Yes, 2: No
	Intention to use PT		INT	1: Yes, 2: No
	Instrumental attitude toward PT		AI	1: Yes, 2: No
	Symbolic/Affective attitude toward PT		ASA	1: Yes, 2: No
	Social orderliness attitude toward PT		AO	1: Yes, 2: No
	Personal norms		PN	1: Yes, 2: No
	Perceived behavioural control		PBC	1: Yes, 2: No
Mode characteristics	Travel time		Time	1: Important, 2: Not Important
	Travel cost		Cost	1: Important, 2: Not Important
Socio-demographic factors	Age		Age	1: Below 23, 2: From 23 and above
	Gender		Gender	1: Male, 2: Female
	Marriage status		MS	1: Single, 2: Marriage, 3: Divorce, 4: Widow
	Socio-economic status	Having a job Having a monthly income above average Having a bachelor's degree and above	SES	1: None, 2: Have one, 3: Have two, 4: All
	Car status	Having a driver's licence Having a car Having a parking space	CS	1: None, 2: Have one, 3: Have two, 4: All
Built-environment & Pro-environment	Road safety		RS	1: Important, 2: Not Important
	Physical effort		PE	1: Important, 2: Not Important
	Environment		ENV	1: Important, 2: Not Important
	Bus station distance		BSD	1: From 1 km and below, 2: Above 1 km

5. Results

The data from 800 respondents were collected from December 2020 to February 2021. First, we checked the data for incomplete and invalid responses. Data with high-item non-response and invalid data due to social desirability bias (e.g. straight-line respondents, scoring all the observable items with a one or seven) were discarded for further analysis. After data cleaning, we retained 618 valid survey responses in the final analysis (Table 3), out of which 437 were female motorcyclists (70.7 per cent) and 181 male motorcyclists (29.3 per cent). Furthermore, 368 respondents use motorcycling for school trip purposes (59.5 per cent), and 250 respondents for work trip purposes (40.5 per cent).

Table 3. *Descriptive statistics of Danang motorcyclists*

Most frequency trip		Gender		Age	
School	368	Male	85	< 23 years old	82
				>= 23 years old	3
		Female	283	< 23 years old	282
				>= 23 years old	1
Work	250	Male	96	< 23 years old	11
				>= 23 years old	85
		Female	154	< 23 years old	29
				>= 23 years old	125
Total	**618**	**Total**	**618**	**Total**	**618**

Firstly, the instruments' reliability was checked with Cronbach's alpha test using SPSS 16.0 to assess the reliability of the study's constructs. Particularly, the coefficient alpha of factors and the item-to-total correlation of items included in each factor were evaluated to determine the construct's

internal consistency and reliability. The reliability analysis results in Table 4 show that all five factors have the accepted Cronbach's value ($0.7 < \alpha < 1$), and all observed variables within each factor have a high coefficient of item to-total correlation (> 0.3) (Hair et al., 2014). Therefore, the reliability analysis met the reliability requirements and demonstrated high internal consistency (Hair et al., 2014). This set of variables would be used for further analysis.

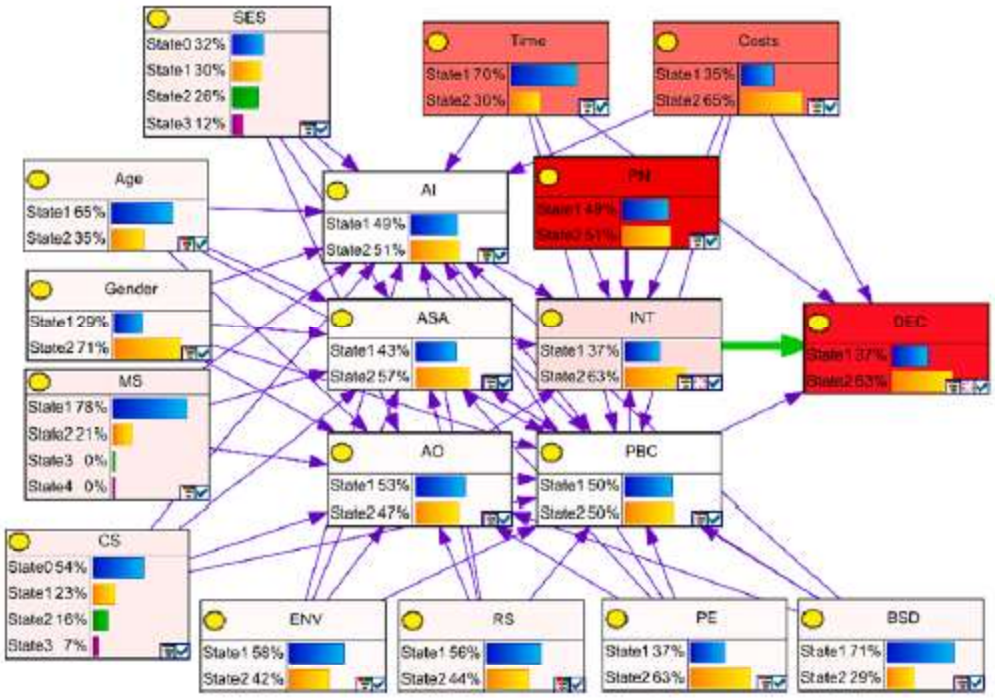
The results in Table 4 reveal that all items of personal norm and perceived behavioural control factors are closely related. Regarding the five items of the instrumental attitude factor, the item representing the safe characteristic of public transport (AI3) is discarded due to the increase in the alpha value if the item is deleted. Similarly, the items representing the pleasant (ASA3) as well as the attractiveness of public transport (ASA4), relaxed (ASA9), and positive feeling (ASA10) when using public transport are excluded due to the improvement in the alpha value if items are deleted. As shown in Table 4, the Cronbach's alpha values support the re-categorisation of the three original factors in TPB theory: attitude, personal norms, and perceived behaviour control into five factors: (i) instrumental attitude, (ii) social orderliness attitude, (iii) symbolic/affective attitude, (iv) personal norms, and (v) perceived behaviour control. This result is consistent with previous studies which applied TPB theory (Kitamura et al., 1997; Steg, 2005; Beirão & Cabral, 2007; Steg & Brussel, 2009; Chen & Chao, 2011; Van & Fujii, 2011; Chen & Chen, 2011).

Table 4. *The Cronbach's Alpha reliability analysis for each scale.*

Factor	Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	Factor average
Instrumental	AI1	10.96	19.374	0.777	0.819	0.873	3.671
	AI2	11.39	20.773	0.749	0.830		
	AI4	10.62	21.562	0.711	0.845		
	AI5	11.08	21.757	0.681	0.857		
Social orderliness	AO1	17.27	32.779	0.782	0.824	0.872	4.363
	AO2	17.13	32.452	0.817	0.815		
	AO3	17.78	37.200	0.572	0.875		
	AO4	18.02	38.969	0.556	0.877		
	AO5	17.07	33.686	0.777	0.825		
Symbolic/Affective	ASA1	17.07	44.273	0.551	0.869	0.872	2.917
	ASA2	18.02	47.862	0.581	0.862		
	ASA5	17.96	44.572	0.771	0.840		
	ASA6	17.97	45.165	0.731	0.844		
	ASA7	17.33	43.579	0.623	0.858		
	ASA8	17.18	43.731	0.692	0.847		
	ASA11	16.97	43.442	0.657	0.852		
Personal norms	SIN1	7.21	7.348	0.603	0.691	0.77	3.789
	SDN1	8.01	7.551	0.634	0.659		
	PN1	7.51	7.459	0.576	0.722		
Perceived behavioural control	PBC1	3.75	2.952	0.581		0.735	3.651
	PBC2	3.55	2.903	0.581			

Secondly, from the reliability analysis results, the authors compute five psychological variables using the transform variables function in SPSS 16.0. The authors convert the values of these variables from the 7-point Likert scale to binary (1 is Yes, and 2 is No); values from 4 to 7 are recoded as Yes, and values from 1 to 3 as No. Then, we estimate the underlying Bayesian network based on the PC structure learning algorithm (Fig. 2).

Figure 2. *The Bayesian network model after the PC structure learning algorithm DEC - decision to use PT, INT - intention to use PT, PN - personal norm, PBC - perceived behavioural control, AI - instrumental attitude, ASA - Symbolic/Affective attitude, AO - social orderliness attitude, SES - socio-economic status, Age - motorcyclists' age, Gender - motorcyclists' gender, MS - motorcycle status, CS - car status, ENV - environmental, RS - road safety, PE - physical effort, BSD - bus station distance, Time - Travel time, Cost - Travel cost.*



Three parameters are required to run the PC algorithm:

- Max adjacency size limits the number of neighbours of a node and has a default of 8. This parameter is essential to limit the number of parents a node corresponding to a variable can have. The size of a node's conditional probability tables grows exponentially in terms of parent node numbers, which should be limited, so that network construction does not exhaust all existing machine memory counts.

- The significance level is the alpha value used in the classical independent tests that the PC algorithm is based on. It has the default at 0.05.

- Max time (seconds) limits the search phase duration and has a default of 0 (no time limit). A time limit should be set on any large data set so that the algorithm converges within a reasonable computer run-time.

All developed Bayesian networks are statistically significant, with a p-value at most equal to 0.05. Next, K-fold cross-validation was performed by setting the folding seed to any value other than 123, allowing the evaluation to be reproducible. The results from Table 5 highlight the accuracy achieved by the model during validation. In this case, the modes achieved 71.76 % accuracy in predicting the

correct intention and decision to use PT - the model correctly guessed 887 out of the total of 1236 records. During the process, the model selects for each record the state of the class node that is most likely to occur over all other states.

Table 5. *The results of K-fold cross-validation and strength of influences.*

K-fold cross-validation		71.76 %
Parent	**Child**	**Weighted**
Costs	DEC	0.13
INT	**DEC**	**0.68**
PBC	DEC	0.11
Time	DEC	0.10
AI	INT	0.15
AO	INT	0.17
ASA	INT	0.18
Costs	INT	0.15
PBC	INT	0.14
PN	**INT**	**0.25**
Time	INT	0.18

After the cross-validation step, a sensitivity analysis is performed to confirm the probability parameters of the Bayesian network. This analysis will change the network's colour to indicate the location of sensitive parameters (Fig. 2). The red nodes contain the parameters critical for computing the posterior probability distributions in the nodes marked as targets (intention and decision in this case). From Fig. 2, personal norm, time, and cost are the most sensitive and important parameters for calculating the posterior probability distribution of intention and decision to use PT.

Also, the strength of influences was tested to observe the influence strength between the nodes to which they connect. The thickness of the arcs shows the strength of parental influence on the offspring, while the colour of the arcs indicates local influence (Fig. 2). In detail, the colour can be green for positive, red for negative, grey for null, or purple for ambiguous. Fig. 2 shows that intention positively influences the decision to use PT. This finding confirms Ajzen's (1991) results mentioning that intention is one of the best indicators for predicting human behaviour.

In addition, based on observational data entered into a network, we create different scenarios and provide different answers to compute the likelihood of a combination of observations within the model. For each scenario, we define stage 1 to yes, as the final choice for intention and decision to use PT, and then we set the evidence for each of the observed variables listed in the table below. The results of the (a-priori) probability of evidence are shown in Table 7. The results from Table 7 show that Vietnamese motorcyclists younger than 23 years old or female or single have a higher chance of shifting their intention toward PT usage and using this travel mode in the near future. Also, results from Table 6 show that these groups of commuters do not perceive that the behaviour of using PT would decrease or mislead their social status. These groups of commuters also prefer safe and environmentally friendly modes as most answered "agree" on social orderliness. Interestingly, as Vietnamese motorcyclists get older, they feel more that they need to be obligated to use PT as an environmentally friendly travel mode. Also, when Vietnamese motorcyclists graduate from college

and join the job market, their perception of the value of travel time and travel cost is different. These results could provide further policy insights for urban planners and decision-makers.

Table 6. *Psychological differences between demographic groups.*

Node's stage = 1		AI	ASA	AO	PN	PBC	INT
Age	< 23	44.3 %	21.5 %	59.7 %	53.0 %	48.5 %	37.6 %
	>= 23	31.3 %	12.6 %	66.4 %	41.6 %	38.3 %	23.4 %
Gender	Male	33.7 %	14.9 %	59.1 %	55.3 %	44.8 %	33.1 %
	Female	42.3 %	19.9 %	63.2 %	46.5 %	45.1 %	32.5 %
Marriage status	Single	43.1 %	21.0 %	60.2 %	51.5 %	47.8 %	36.7 %
	Marriage	28.1 %	8.6 %	67.2 %	38.3 %	33.6 %	18.0 %

Table 7. *The results of (a-priori) probability of evidence when Vietnamese motorcyclists have both intention and decision to use PT.*

Variable	Stage	Meaning	P
Time	**1**	**Important**	**20.6 %**
	2	Not Important	10.4 %
Cost	1	Important	11.7 %
	2	**Not Important**	**19.4 %**
Bus distance	**1**	**Below 1 km**	**21.8 %**
	2	Above 1 km	9.2 %
Physical effort	1	Important	11.7 %
	2	**Not Important**	**19.4 %**
Road safety	**1**	**Important**	**17.4 %**
	2	Not Important	13.6 %
Car status	**0**	**None**	**16.7 %**
	1	One	7.1 %
	2	Two	5.0 %
	3	All	2.2 %
Socio-economic status	**0**	**None**	**9.9 %**
	1	One	9.3 %
	2	Two	8.2 %
	3	All	3.7 %
Gender	1	Male	9.2 %
	2	**Female**	**21.9 %**
Age	**1**	**Below 23**	**20.2 %**
	2	From 23	10.8 %
Marriage status	**1**	**Single**	**24.2 %**
	2	Marriage	6.6 %

6. Discussion and concluding remarks

Previous studies in western countries measure attitudes toward travel mode choice by assessing the service quality, such as being flexible, saving time, cost sensitivity, or the intention to use alternative transportation modes (Parkany et al., 2004; Beirão & Cabral, 2007). They also admitted that attitudes toward travel mode choice are formulated from instrumental, symbolic and affective motives (Steg, 2003; Steg, 2005; Gatersleben, 2007). The instrumental aspect mainly refers to the utility benefits of using travel modes. Symbolic aspects are related to personal and social identity expression, while affective motives refer to commuters' feelings (Steg, 2003; Steg, 2005). However, many studies also found a strong relationship between symbolic and affective factors and concluded that there is no clear distinction between them (Hiscock et al., 2002; Steg, 2003; Steg, 2005; Gatersleben, 2007; Van

& Fujii, 2011). Our findings reveal that both instrumental and symbolic/affective are scored very low in Vietnam as Vietnamese motorcyclists perceive public transport as an inconvenient travel mode and not attractive in terms of cost. The low score in symbolic/affective attitude component reflects that Vietnamese motorcyclists do not want to use public transport because they can be socially misclassified.

In addition, the condition of traffic in the Southeast Asia region is different, with typical features of a higher proportion of motorbike users (United Nations, 2018). Because of these particular conditions, there is another type of attitude factor influencing Vietnamese motorcyclists named social orderliness, which is related to safety, quietness, environmental friendliness, altruism, etc. (Van & Fujii, 2011). The social orderliness attitude score is high in the group of commuters aged 23 years old, meaning that this group perceives public transport as an environment-friendly and safe travel mode. However, because of their value and because they do not want to mislead their social status, their intention to use PT is still lower than Vietnamese motorcyclists whose ages are below 23 years old. From Table 3, one can also depict a very high proportion of female respondents. According to the context of social exchange theory, gender bias is intuitive in any conversation in which participants decide moral choices based on the concept of a separate self (England, 1989). This theory explains that males obtain a high value on separative selves while females consistently obtain connective selves such as empathy. Therefore, a higher percentage of female respondents would be willing to participate in a social survey. Potentially, this sample imbalance could affect the results, but a comparison between the unweighted and population-weighted data showed that differences in psycho-social variables were negligible. Thus, the gathered data would not bias the findings of this study with its subjects in proposing a model for the shift from motorcycles toward public transport.

The findings from Tables 6 and 7 offer valuable insights for Southeast Asian urban planners and policymakers as well as provide a basis for formulating policy suggestions that extend beyond the specific context of Danang, Vietnam. First, personal norm is the most important intrinsic variable that affects the decision to shift toward public transport among Vietnamese motorcyclists. In order to manipulate this intrinsic variable, urban planners and policymakers can develop marketing campaigns adapting information social influence and normative social influence (Deutsch & Gerard, 1955). The practices of information social influence and normative social influence can be related to implementing social marketing and evidence-based marketing campaigns. These actions aim to reshape and improve motorcyclists' perception of PT usage. Urban planners and policymakers need to focus on younger motorcyclists, whose main daily travel purpose is to go to school and female motorcyclists, as it would be easier to shift their travel behaviour toward PT of these two groups. For instance, a marketing strategy could be customised to target motorcyclists below 23 years of age, as they tend to place greater importance on environmentally friendly transportation modes and do not seek to distinguish themselves from a society centred on private vehicles like motorcycles. When good perceptions toward PT usage become established, the behaviour will be persistent and habitual. This recommendation holds particular significance for younger and female motorcyclists, emphasising the potential for a broader application of our insights in the context of other South Asian countries. Second, the finding underscores the significance of improving public transport

frequency and reducing station waiting times, recognising the higher perceived value of travel time over travel cost. Currently, the bus system in Danang City does not have a timetable showing at the bus stations, and most bus routes are operated with a frequency of 30 min per trip. Addressing the distance from PT stations to key destinations, such as schools and workplaces, emerges as a crucial consideration for urban planners seeking to encourage PT use. In addition, policymakers need to transparently and effectively develop a unified process of administrative law enforcement in the transport sector. This could slightly modify the mobility behaviour of local motorcyclists regarding the current status of road safety and increase the intention to use PT. For example, the Vietnamese government successfully enforced mandatory helmet wear for any motorcycle with engine power above 50 cc. After two years of helmet law enforcement, the helmet-wearing rate increased significantly to 99 % among adult motorcyclists (above 18 years old) (Pervin et al., 2009). The authors believe that these recommendations have the potential to contribute not only to enhancing PT in Vietnam but also to informing sustainable urban transportation strategies in Southeast Asia.

Despite the theoretical and practical implications, there are still some cautions due to the study's limitations. Firstly, the traffic condition of a testing area does not show the real traffic situation of megacities in Southeast Asian countries. Indeed, the infrastructure and traffic congestion of Danang city is much better than Hanoi or Ho Chi Minh city, the two most populated cities in Vietnam with more than 8 million residents. Therefore, future studies could apply the proposed Bayesian network to cross-test commuter behaviour from different megacities in Southeast Asian countries. Second, despite the challenges posed by the COVID-19 pandemic during data collection, Vietnam's bus system and ridership appeared relatively normal (Nguyen & Pojani, 2021). However, there remains a need for ongoing research into transportation systems and travel behaviours during external disruptions like the pandemic, specifically focusing on their impact on psychological factors. The current Bayesian network model does not account for the pandemic's effects. Therefore, future research should delve deeper into the psychological repercussions of the pandemic on travel mode choices in Vietnam to gain a more comprehensive understanding of this evolving landscape.

In brief, this study examined the factors influencing Vietnamese motorcyclists' choices in public transport modes. The results align with prior research and support the Bayesian network model's effectiveness in predicting Vietnamese motorcyclists' public transit behaviour. This study contributes to Southeast Asian travel mode preference knowledge and offers insights into sustainable urban transportation. The authors anticipate that these findings will catalyse further research into commuter behaviour, ultimately leading to more effective public transportation policies in Vietnam and the broader Southeast Asian region.

Acknowledgments

The authors wish to express appreciation to all of those who have supported this research for their useful discussion and comments during its completion. This work was supported by grant obtained from Wallonie-Bruxelles International (WBI) for the project 2.17: Renforcement des competences en matiere de recherche, d'enseignement et de consultance dans le domaine de la logistique.

Appendix A. *Descriptive statistics of Danang motorcyclists (2023 DATA)*

Most frequency trip		Gender		Age	
School	53	Male	14	< 23 years old	14
				>= 23 years old	0
		Female	39	< 23 years old	38
				>= 23 years old	1
Work	27	Male	6	< 23 years old	0
				>= 23 years old	6
		Female	21	< 23 years old	8
				>= 23 years old	13
Total	**80**	**Total**	**80**	**Total**	**80**

Appendix B. *The Cronbach's alpha reliability analysis for each scale (2023 DATA)*

Factor	Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	Factor average
Instrumental	AI1	11.40	13.382	0.654	0.762	0.816	3.844
	AI2	12.00	14.076	0.688	0.743		
	AI4	11.04	15.480	0.626	0.774		
	AI5	11.69	15.610	0.585	0.791		
Social orderliness	AO1	18.74	27.842	0.801	0.855	0.893	4.718
	AO2	18.51	27.721	0.856	0.843		
	AO3	19.29	32.587	0.530	0.913		
	AO4	19.28	29.974	0.699	0.878		
	AO5	18.54	27.999	0.817	0.851		
Symbolic/Affective	ASA1	20.04	40.340	0.484	0.854	0.854	3.446
	ASA2	21.39	41.000	0.564	0.840		
	ASA5	21.31	38.521	0.686	0.823		
	ASA6	21.29	37.752	0.748	0.814		
	ASA7	20.44	38.958	0.654	0.828		
	ASA8	20.54	38.556	0.680	0.824		
Factor	**Item**	**Scale Mean if Item Deleted**	**Scale Variance if Item Deleted**	**Corrected Item - Total Correlation**	**Cronbach's Alpha if Item Deleted**	**Cronbach's Alpha**	**Factor average**
	ASA11	19.75	40.747	0.522	0.847		
Personal norms	SIN1	6.79	7.942	0.630	0.751	0.803	3.529
	SDN1	7.45	7.314	0.751	0.626		
	PN1	6.94	7.831	0.577	0.809		
Perceived behavioural control	PBC1	3.66	2.707	0.554		0.713	3.706
	PBC2	3.75	2.519	0.554			

References

Abdullah, N., Ismail, A.B., Rahmat, R.A., 2007. Effect of transportation policies on modal shift from private car to public transport in Malaysia. J. Appl. Sci. 7 (7), 1014–1017. https://doi.org/10.3923/jas.2007.1013.1018.

Abuhamoud, M., Rahmat, R.A., Ismail, A.B., 2011. Modeling of transport mode in Libya: A binary logit model for government transportation encouragement. Aust. J. Basic Appl. Sci. 5 (5), 1291–1296.

Ajzen, I., 1991. The theory of planned behavior. Org. Behav. Hum. Decis. Process. 50 (2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T.

Andreassen, T., 1995. (Dis)satisfaction with public services: The case of public transportation. J. Serv. Mark. 9 (5), 30–41. https://doi.org/10.1108/08876049510100290.

Bamberg, S., Ajzen, I., Schmidt, P., 2003. Choice of travel mode in the theory of planned behavior: The roles of past behavior, habit, and reasoned action. Basic Appl. Soc. Psychol. 25 (3), 175–187. https://doi.org/10.1207/S15324834BASP2503_01.

Beirão, G., Cabral, S.J., 2007. Understanding attitudes towards public transport and private. Transp. Policy 14, 478–489. https://doi.org/10.1016/j.tranpol.2007.04.009.

Betsch, T., Fiedler, K., Brinkmann, J., 1998. Behavioral routines in decision making: the effects of novelty in task presentation and time pressure on routine maintenance and deviation. Eur. J. Soc. Psychol. 28 (6), 861–878. https://doi.org/10.1002/(SICI)1099-0992(1998110)28:6%3C861::AID-EJSP899%3E3.0.CO;2-D.

Bhouri, N., Mayorano, F.J., Pablo, L.A., Habib, S.H., Lebacque, J.P., 2015. Public transport priority for multimodal urban traffic control. Cybernet. Inform. Technol. 15 (5), 17–36. https://doi.org/10.1515/cait-2015-0014.

Burge, P., Fox, J., Kouwenhoven, M., Rohr, C., 2008. Modeling of motorcycle ownership and commuter usage: A UK study. Transp. Res. Record J. Transp. Res. Board 2031, 59–68. https://doi.org/10.3141/2031-08.

Chang, H.-L., Lai, C.-Y., 2015. Using travel socialisation and underlying motivations to better understand motorcycle usage in Taiwan. Accid. Anal. Prevent. J. 79, 212–220. https://doi.org/10.1016/j.aap.2015.03.023.

Chang, H.-L., Wu, S.-C., 2008. Exploring the vehicle dependence behind mode choice: Evidence of motorcycle dependence in Taipei. Transp. Res. A Policy Pract. 42, 307–320. https://doi.org/10.1016/j.tra.2007.10.005.

Chen, C.-F., Chao, W.-H., 2011. Habitual or reasoned? Using the theory of planned behavior, technology acceptance model, and habit to examine switching intentions toward public transit. Transport. Res. F: Traffic Psychol. Behav. 14 (2), 128–137. https://doi.org/10.1016/j.trf.2010.11.006.

Chen, C.-F., Chen, C.-W., 2011. Speeding for fun? Exploring the speeding behavior of riders of heavy motorcycles using the theory of planned behavior and psychological flow theory. Accid. Anal. Prev. 43 (3), 983–990. https://doi.org/10.1016/j.aap.2010.11.025.

Chen, C.-F., Lai, W.-T., 2011. The effects of rational and habitual factors on mode choice behaviors in a motorcycle-dependent region: Evidence from Taiwan Ching-Fu. Transp. Policy 18, 711–718. https://doi.org/10.1016/j.tranpol.2011.01.006.

Choocharukul, K., Van, H.T., Fuji, S., 2006. Psychological determinants of moral obligation of car use reduction and acceptance of car use restriction in Japan and Thailand. IATSS Res. 30 (2), 1–7.

Cossalter, V., 2006. Motorcycle Dynamics, 2nd ed. LULU.

Deutsch, M., Gerard, H.B., 1955. A study of normative and informational social influences upon individual judgment. J. Abnorm. Soc. Psychol. 51 (3), 629–636. https://doi.org/10.1037/h0046408.

Domarchi, C., Tudela, A., Gonzalez, A., 2008. Effects of attitudes, habit and affective appraisal on mode choice: an application to university workers. Transportation 35, 585–599.

Eriksson, L., Friman, M., Ettema, D., Fujii, S., Gärling, T., 2010. Experimental simulation of car users' switching to public transport. Transport. Lett. 2 (3), 145–155. https://doi.org/10.3328/TL.2010.02.03.145-155.

Ewing, B., Moore, D., Oursler, A., Reed, A., Wackernagel, M., 2010. Ecological Footprint Atlas 2010. Global Footprint Network, Oakland.

Fishbein, M.A., Ajzen, I., 1975. Belief, attitude, intention and behaviour: An introduction to theory and research. Addison-Wesley.

Gatersleben, B. (2007). Affective and Symbolic Aspects of Car Use: Problems, Causes and Solutions. In L. Steg, & T. G¨arling (Eds.), Threats from Car Traffic to the Quality of Urban Life (pp. 219-233). Emerald Publishing. Doi: 10.1108/9780080481449-012.

Gkritza, K., 2009. Modeling motorcycle helmet use in Iowa: evidence from six roadside observational surveys. Accid. Anal. Prev. 41 (3), 479–484. https://doi.org/10.1016/j.aap.2009.01.009.

Hair, J. F., Tomas, Jr. G., Hult, M., Ringle, C., Sarstedt, M. (2014). A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). SAGE Publications.

Haustein, S., Hunecke, M., 2007. Reduced use of environmentally friendly modes of transportation caused by perceived mobility necessities: An extension of the theory of planned behavior. J. Appl. Soc. Psychol. 37 (8), 1856–1883. https://doi.org/10.1111/j.1559-1816.2007.00241.x.

Haustein, S., Klöckner, C.A., Blöbaum, A., 2009. Car use of young adults: The role of travel socialisation. Transp. Res. Part F Traffic Psychol. Behav. 12 (2), 168–178. https://doi.org/10.1016/j.trf.2008.10.003.

Heath, Y., Gifford, R., 2002. Extending the theory of planned behavior: Predicting the use of public transportation. J. Appl. Soc. Psychol. 32 (10), 2154–2189. https://doi.org/10.1111/j.1559-1816.2002.tb02068.x.

Hensher, D.A., Stopher, P., Bullock, P., 2003. Service quality – developing a service quality index in the provision of commercial bus contracts. Transp. Res. A 37, 499–517. https://doi.org/10.1016/S0965-8564(02)00075-7.

Hiscock, R., Macintyre, S., Kearns, A., Ellaway, A., 2002. Means of transport and ontological security: Do cars provide psycho-social benefits to their users? Transp. Res. Part D: Transp. Environ. 7 (2), 119–135. https://doi.org/10.1016/S1361-9209(01)00015-3.

Jenelius, E., 2012. The value of travel time variability with trip chains, flexible scheduling and correlated travel times. Transp. Res. Part B: Methodol. 46, 762–780.

Kepaptsoglou, K., Milioti, C., Christoforou, Z., Karlaftis, M.G., 2011. An empirical investigation of motorcycle ownership. First Congress Transport. Dev. Inst. (TDI) 1, 1075–1084. https://doi.org/10.1061/41167(398)103.

Kim, S., Ulfarsson, G.F., 2008. Curbing automobile use for sustainable transportation: Analysis of mode choice on short home-based trips. Transportation 35 (6), 723–737. https://doi.org/10.1007/s11116-008-9177-5.

Kitamura, R., Mokhtarian, P.L., Daidet, L., 1997. A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. Transportation 24 (2), 125–158. https://doi.org/10.1023/A:1017959825565.

Kjaerulff, U., & Van der Gaag, L, C. (2000). Making Sensitivity Analysis Computationally Efficient. Uncertainty In Artificial Intelligence Proceedings, 317-325.

Koossalapeerom, T., Satiennam, T., Satiennam, W., Leelapatra, W., Seedam, A., Rakpukdee, T., 2019. Comparative study of real-world driving cycles, energy consumption, and CO2 emissions of electric and gasoline motorcycles driving in a congested urban corridor. Sustain. Cities Soc. 45, 619–627.

Krueger Jr, N.F., Brazeal, D.V., 1994. Entrepreneurial potential and potential entrepreneurs. Enterp. Theory Pract. 18 (3), 91–104. https://doi.org/10.14211/regepe.v7i2.1071.

Kwan, S.C., Sutan, R., Hashim, J.H., 2018. Trip characteristics as the determinants of intention to shift to rail transport among private motor vehicle users in Kuala Lumpur, Malaysia. Sustain. Cities Soc. 36, 319–326. https://doi.org/10.1016/j.scs.2017.10.030.

Laksanakit, C., 2014. Impact of motorcycle defects on motorcycle safety. J. Soc. Transport. Traffic Stud. (JSTS) 5 (1), 1–15.

Le, P.T., Trinh, T., 2016. Encouraging public transport use to reduce traffic congestion and air pollutant: a case study of Ho Chi Minh City, Vietnam. Procedia Eng. 142, 236–243. https://doi.org/10.1016/j.proeng.2016.02.037.

Lee, C.M., Erickson, P., 2017. How does local economic development in cities affect global GHG emissions? Sustain. Cities Soc. 35, 626–636. https://doi.org/10.1016/j.scs.2017.08.027.

Lucas, K., Mattioli, G., Verlinghieri, E., Guzman, A., 2016. Transport poverty and its adverse social consequences. ICE Proc. Transp. 169 (6), 353–365.

Morikawa, T., Yamamoto, T., Dissanayake, D., Sanko, N., Kurauchi, S., Maesoba, H., Rivera, M. (2003). Travel behavior analysis and its implication to urban transport planning for Asian cities: Case Studies of Bangkok, Kuala Lumpur, Manila, and Nagoya. Japan: Nagoya University.: International Cooperative Research Activity (ICRA). . https://www.motorcyclesdata.com/2020/02/08/asean-motorcycles-industry/.

Murray, S.J., Walton, D.K., Thomas, J.A., 2010. Attitudes towards public transport in New Zealand. Transportation 37 (6), 915–929. https://doi.org/10.1007/s11116-010-9303-z.

Nguyen, M.H., Pojani, D., 2021. Covid-19 need not spell the death of public transport: Learning from Hanoi's safety measures. J. Transp. Health 23, 101279. https://doi.org/10.1016/j.jth.2021.101279.

Olsson, L.E., Huck, J., Friman, M., 2018. Intention for car use reduction: applying a stage-based model. Int. J. Environ. Res. Public Health 15 (2), 216.

Parkany, E., Gallagher, R., Viveiros, P., 2004. Are attitudes important in travel choice? Transport. Res. Record J. Transport. Res. Board 1894 (1), 127–139. https://doi.org/10.3141/1894-14.

Pearl, J. 1988. Probabilistic reasoning in intelligent systems: Networks of plausible reasoning. Los Altos: Morgan Kaufmann Publishers. Doi: 10.1016/C2009-0-27609-4.

Pervin, A., Passmore, J., Sidik, M., McKinley, T., Nguyen, T.H.T., Nguyen, P.N., 2009. Viet Nam's mandatory motorcycle helmet law and its impact on children. Bull. World Health Organ. 87 (5), 369–373. https://doi.org/10.2471/BLT.08.057109.

Pucher, J., Dijkstra, L., 2003. Promoting safe walking and cycling to improve public health: Lessons from The Netherlands and Germany. Am. J. Public Health 93 (9), 1509–1516.

Redman, L., Friman, M., Garling, T., Hartig, T., 2013. Quality attributes of public transport that attract car users: A research review. Transp. Policy 25, 119–127. https://doi.org/10.1016/j.tranpol.2012.11.005.

Satiennam, T., Jaensirisak, S., Satiennam, W., Detdamrong, S., 2016. Potential for modal shift by passenger car and motorcycle users towards bus rapid transit (BRT) in an Asian developing city. IATSS Research 39, 121–129. https://doi.org/10.1016/j.iatssr.2015.03.002.

Sheikh, I.A., Umar, R.R., Habshah, M., Kassim, H., 2006. Mode choice model for vulnerable motorcyclists in Malaysia. Traffic Inj. Prev. 7 (2), 150–154. https://doi.org/10.1080/15389580600550354.

Stanton, N.A., McIlroy, R.C., Harvey, C., Blainey, S., Hickford, A., Preston, J.M., Brendan, R., 2012. Following the cognitive work analysis train of thought: exploring the constraints of modal shift to rail transport. Ergonomics 56 (3), 522–540.

Stanton, N.A., McIlroy, R.C., Harvey, C., Blainey, S., Hickford, A., Preston, J.M., Ryan, B., 2013. Following the cognitive work analysis train of thought: exploring the constraints of modal shift to rail transport. Ergonomics 56 (3), 522–540. https://doi.org/10.1080/00140139.2012.718366.

Steg, L., 2003. Can public transport compete with the private car? IATSS Res. 27 (2), 27–35. https://doi.org/10.1016/S0386-1112(14)60141-2.

Steg, L., 2005. Car use: lust and must. Instrumental, symbolic and affective motives for car use. Transp. Res. A 39, 147–162. https://doi.org/10.1016/j.tra.2004.07.001.

Steg, L., Brussel, A.V., 2009. Accidents, aberrant behaviours, and speeding of young moped riders. Transport. Part F Traffic Psychol. Behav. 12 (6), 503–511. https://doi.org/10.1016/j.trf.2009.09.001.

Thu Hang. (2016). Radio France internationale. Retrieved 04 14, 2021, from https://www.rfi.fr/vi/viet-nam/20161125-ha-noi-va-noi-nho-tieng-leng-keng-tau-dienxua.

Tran, Q. Q. (2011). Voice of Vietnam. Retrieved 04 14, 2021, from https://vov.vn/media/anh/tau-dien-ha-noi-thoi-phap-thuoc-190099.vov.

Tsagris, M., 2018. Bayesian network learning with the PC algorithm: An improved and correct variation. Appl. Artif. Intell.: Int. J. 33 (1), 101–123. https://doi.org/10.1080/08839514.2018.1526760.

United Nations. (2018). Road Safety Performance Review Viet Nam. United Nations. https://unece.org/DAM/trans/roadsafe/unda/RSPR_Viet_Nam_FULL_e.pdf.

Van, H., Fujii, S., 2011. A cross asian country analysis in attitudes toward car and public. J. East. Asia Soc. Transp. Stud. 9, 411–421. https://doi.org/10.11175/easts.9.411.

Vedagiri, P., Venkatachalam, T.A., 2009. Modelling modal shift due to the enhanced level of bus service. Transport 24 (2), 121–128.

Wang, D., Lin, T., 2013. Built environments, social environments, and activity-travel behavior: A case study of Hong Kong. J. Transp. Geogr. 31, 286–295.

Washbrook, K., Haider, W., Jaccard, M., 2006. Estimating commuter mode choice: A discrete choice analysis of the impact of road pricing and parking charges. Transportation 33, 621–639. https://doi.org/10.1007/s11116-005-5711-x.

Yurtkoru, S.E., Kuşcu, Z.K., Doğanay, A., 2014. Exploring the antecedents of entrepreneurial intention on Turkish university students. Procedia - Soc. Behav. Sci. 150, 841–850. https://doi.org/10.1016/j.sbspro.2014.09.093.

Zailani, S., Iranmanesh, M., Masron, T.A., Chan, T-H., 2016. Is the intention to use public transport for different travel purposes determined by different factors? Transp. Res. Part D: Transp. Environ. 49, 18–24.

Zhang, L., Hong, J., Nasri, A., Shen, Q., 2012. How built environment affects travel behavior: A comparative analysis of the connections between land use and vehicle miles traveled in US cities. J. Transp. Land Use 5 (3), 40–52.