Measuring Commuters’ Behavior and Preference Towards Sustainable Mobility: Case Study of Suburban Context of Pathumthani, Thailand

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Abstract. Urban mobility has been facing changing circumstances globally including congestion, air and noise pollution, climate change which search for alternatives to mitigate the influence of fossil fuels consumption, urbanization and the impacts of new technology. Cities are currently facing ever greater social challenges in respect of the environment, transport, health and social cohesion. Especially, suburban city context represents the commuting patterns behavior differs from the general populations. This study focuses on an analysis of the behavior and preference of commuters on mobility options in relation to the perspective of the development of energy-efficient systems of the future mobility choice. This study applied factor analysis with principal component method to identify the subjective factors based on travellers’ attitude and perception comparative with their current travel choices and recommend suitable measurements. The consideration of suburban context could then be determined together with demand management scheme in term of sustainable transport system in Pathumthani, Thailand as a pilot case for suburban regions.

1. Introduction

Rapid urbanization presents policymakers with new challenges on many fronts which more than 50 percent of people lived in cities with concentration of the majority of economic activities [1, 2, 3, 4]. Over the next four decades, billions of people will continue to migrate to urban areas until more than 75 percent of the global population lives in cities which generate an unprecedented amount of urban traffic both freight and passengers [5]. The urban population has been rapid growing that require housing, transportation, energy, and water systems to be built simultaneously, ideally in an integrated way, to provide the greatest public access while create the least harm to the natural environment as much as possible [6]. Cities already account for 66 percent of total world energy use that may increase to 80 percent [7]. However, these urban areas consume more than 70 percent for transportation, especially regarding the use of energy which energy efficiency includes more than 50 percent of the world’s population [5, 6, 7]. It is due to the reason that growing urban populations can overwhelm existing infrastructures and services, especially transport systems. Traveling to work and school, and to access other services, urban dwellers need to be able to easily traverse the city and get wherever they need to go [8]. Thus, efficient transport infrastructure planning and management can positively response to the mobility challenges faced by cities: accessibility, congestion, energy efficiency,
emissions and safety which having a significant effect on social inequality and global warming [9]. Studies have shown that even small changes in people's individual behavior can lead to significant reductions in carbon emissions with alternative transport choices and the diversification of energy sources to meet climate goals [10].

Common approaches that aim at changing a person's behavior rely on providing generic normative information, i.e., communicating a given behavior is appropriate in a given context [10]. However, considering the fact of most mobility-related activities are shaped by an individual's spatial, temporal, and social constraints. It is not tightly bound by social norms, generic normative information which is often too unspecific. For commuters who has no preferred choice as to use private transport or does not have any information of transport alternatives to perform an activity equally electively (in a sustainable manner), more targeted forms of communication are needed [11]. It is necessary to consider suitable transportation plan in response to changing behavior of choice makers that promotes sustainable mobility behavior. Among all challenges, it is a must to identify the necessary information to allow for behavior change which requires information processes taking into account both the analysis and planning aspects among sustainable activity alternatives [12]. Our proposed approach aims to ask commuters on a personalized level to change their mobility behavior and make decision for more sustainable choices. The available strategies for improving the sustainability mobility vary and span from actions that affect both transportation supply and demand side.

2. Literature review
Travel behaviors change in the context of personal mobility under given urban environments is an active area of research which aim to motivate users towards making more eco-friendly choices (i.e., adopting transportation habits that rely more on the usage of public transportation, non-motorization, and less private vehicles). One of the first attempts which aimed to persuade people to use public transportation instead of their cars is mainly for emission reductions. The approach can be varied such as displaying pollution information on board (the departure time of the next bus as well as the decreasing in emissions achieved by taking the bus instead of the car). On the other hand, the encourage of greener alternatives (including carpooling, public transport and pedestrian modalities) can be recommended by asking perception feedback when users reduced driving [13]. The demand management can be also recommended at the same time for regulatory measures by restrict access to the city centre. All of this highlights the need to couple ‘smart’ regulations with or replace them where possible ‘soft’ policy interventions can be implemented. Even where alternatives are offered, the debate on regulation faces the dilemma of balancing people’s freedom of choice quintessentially expressed through the personal car and implementing normative regulations to change behavior [14].

The ASI model (Avoid/Reduce, Shift/Maintain, Improve) can help conceptualise and identify the different factors which incentivise the utilization of sustainable transport modes or disincentivise less sustainable ones as described in the following detail [15];

1. “Avoid/Reduce” refers to the need to improve the efficiency of the transport system. Through the transit-oriented and compact development, the need for motorized travel and the trip length can be reduced. Transport demand management (TDM) plays an important role into this objective as well. Residential, work, commercial and leisure districts must become more closely connected and intermixed.

2. “Shift/Maintain” instruments seek to improve individual trip efficiency. A modal shift from the most energy consuming and polluting urban mobility mode (i.e., cars) towards more environmentally friendly modes addresses all the aforementioned challenges of transport systems. Especially, shifting and maintaining the following transport modes is crucial which are active transport, walking and cycling, public transport (bus, rail, tram, including autonomous electric, etc.).

3. “Improve” focuses on vehicle and fuel efficiency as well as on the optimization of the operational efficiency of public transport. This includes the attractiveness of public transport. Additionally, improvement of the energy sources required for their operation is key. Introducing
renewable energy sources into the mobility sector must become a basic principle for motorized transport which can be illustrated in figure 1.

![Figure 1. The ASI model](image)

Source: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). (2004)

In this paper, face-to-face interview by using questionnaire survey was designed towards their current travel choices and recommend for the sustainable mobility measurement. More subtle changes in attitudes and perceptions could be explained under sub-urban context together with demand management in term of efficient transport systems. Finally, the recommendation of the policy planning with the explicit goal can be launched for more accessible, safe, efficient, affordable and sustainable infrastructure in the study area of Pathumthani, Thailand.

3. Research methodology and analysis
In this study, 1,000 data sets were collected from Pathumthani residents which focus on measuring behavior and preference changes of sustainable mobility in the sub-urban area. The questionnaire was divided into 3 parts which includes; 1) personal characteristic (social-economic factors), 2) travel behavior and 3) preference on sustainable mobility choices in sub-urban area context. The assessment based on interview was questioned into 6 levels of perception which was ranged from 1-6, from the strongly disagree to totally agree (1-6). The group of factors was analysed based on quantitative approach of factor analysis. In the study, the classification of factor groups applied the explanatory factor analysis method which was used to determine the grouping among different factors. It is an analysis technique by reducing the number of variables with similar statistical characteristics to the same group of factors. To reduce the redundancy of variables, 31 factors were extracted as shown in table 1. To avoid the interference of heteroscedasticity, some variables are processed in logarithms. The descriptive statistical analysis of the main variables is shown in table 2 and analysed by Principal Component Analysis: PCA. From the analysis, it was found that among 31 input factors, 3 groups of factors were extracted. The eigenvalue of that factor was determined when the statistical test exceeded 1.0 and rotation sums of squared loadings were considered. The cumulative percentage (cumulative %) found that the factors obtained after the analysis among all 3 group factors were able to explain the total variability of the variables about 64.40 percent.
Travel by personal car

Road design allows people to use public transport

Road safety awareness

Mitigated road safety problems

Reduce road accidents

Speed-reducing road design

Road environment design

Provide shading/trees for accommodation active travel choices

Road design allows people for safer travel by personal car

Table 1. Input variables for analysis

| Variables                                                               | Description                                                                 |
|------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Creating flexibility operational                                      | \( X_1 \) Creating flexibility operational of the time, such as working 8 hours a day, able to come to work from 10:00 and finish work by 19:00, etc. will help reduce traffic jams. |
| Encourages personnel to use public transport                          | \( X_2 \) The encourages of personnel to use public transport as well as provides reward points for lowering prices of travel-related goods and services and help reduce the use of personal cars. |
| Encourages congestion pricing                                          | \( X_3 \) The encourages of congestion fees (Congestion Pricing) only in urban areas with comprehensive public transport, helping to reduce congestion during rush hour. |
| Encourage people to use clean energy vehicles                          | \( X_4 \) The government sector should establish policies to encourage people with clean energy vehicles. |
| Private cars in public areas with parking fee                          | \( X_5 \) Private parking for private cars in public areas with service rates (per day and month). |
| Expansion of a Bus Rapid Transit (BRT) route                           | \( X_6 \) Expansion of a Bus Rapid Transit (BRT) route with special traffic lanes, to promote the use of public transport. |
| Encourage people to use the carpooling                                 | \( X_7 \) The government sector should have the policy to encourage people to use the carpooling by specifying special lanes in conjunction with bus lanes. |
| More car-sharing in transportation center point                        | \( X_8 \) The service points for a car-sharing to cover the important nodes/locations of the trip. |
| More bike-sharing in transportation center point                       | \( X_9 \) Service points for bike-sharing to cover the important nodes/locations of the trip. |
| More use ridesharing                                                   | \( X_{10} \) Ride sharing service should be provided to reduce the number of personal vehicles on the road. |
| Intelligent traffic management (Smart Mobility)                        | \( X_{11} \) Promote the use of intelligent traffic management (smart mobility) by developing technology to provide travelers with important information when planning their trips. |
| Seamless public transportation                                         | \( X_{12} \) The connection of public transport should be seamless in order to reduce travel time. |
| Encourage a work online application system development                 | \( X_{13} \) Encourage a flexible working online system, in any location which will help better productivity of daily work. |
| Infrastructure development                                             | \( X_{14} \) Infrastructure development and various facilities to consistence with users’ demand. |
| Bus stops with automated ticketing service                             | \( X_{15} \) Encourage public transport bus stops to have an automated ticketing service. |
| Promoting offer selling products in transit stop                       | \( X_{16} \) Public transport bus stops should be promoted for offering selling products. |
| Bus stops to provide basic services                                     | \( X_{17} \) Encourage public transport bus stops to provide basic services such as coffee shops, food and beverage vending machines and automatic ATMs, etc. |
| Standard public transport design                                       | \( X_{18} \) Encourage the standard public transport design. |
| Applications for specific public transport systems                     | \( X_{19} \) Provide applications for specific public transport in urban and metropolitan areas as a travel resource and able to propose appropriate routes. |
| Expanding public transport routes                                       | \( X_{20} \) Expanding public transport network to suburban and metropolitan areas. |
| Smart cards covering all public transport                              | \( X_{21} \) The use of smart cards (cards covering all public transport) should be encouraged to ensure a seamless connection for reduce the travel time. |
| Promoting facility for the elderly, the disabled and children          | \( X_{22} \) The promotion should be provided for the elderly, the disabled and children when travelling by public transport. |
| Connecting feeder system to railway station                            | \( X_{23} \) Feeder system route should be connected to the Red Line MRT station that connects to Bangkok and its vicinity. |
| Connecting pedestrian paths and bicycle lanes                          | \( X_{24} \) Along the canal, housing estate should offer the connection of pedestrian paths and bicycle lanes. |
| Road safety awareness                                                  | \( X_{25} \) Road safety issues should be priority when choosing a mode of transport. |
| Mitigated road safety problems                                         | \( X_{26} \) Road safety problems can be mitigated by switching from private vehicles to public transportation. |
| Reduce road accidents                                                  | \( X_{27} \) Reducing conflicts such as U-turns and intersections can help reduce road accidents. |
| Speed-reducing road design                                            | \( X_{28} \) Speed-reduction for road design will help on reducing frequency and severity of road accidents. |
| Road environment design                                                | \( X_{29} \) Good road environment design affects the choice of traveling. |
| Provide shading/trees for accommodate active travel choices            | \( X_{30} \) Shade of trees influences commuters’ decisions on walking and cycling. |
| Road design allows people for safer travel by personal car             | \( X_{31} \) Road design allows people to travel by personal car rather than by public transport or by walking and cycling. |
4. Results and discussions
Table 2 presents the most important factor which was built environment design by allow commuters to travel by personal car (X31 = 5.348), followed by transportation choices promoted to the elderly, the disabled and children (X22 = 5.345), connectivity of feeder system to railway station (X23 = 5.332) and shading/trees influences active travel choices (X30 = 5.320). The analysis result showed that people who are Pathumthani resident have a focus on built environment connected to transportation planning options, especially in promoting travel choices for elderly, children and disabled. In addition, there were factors related to the road safety problem which consists of road safety awareness (X25 = 5.249), and speed-reduction for road design (X28) and road environment design (X29), with average value of 4.902, which represent the important level. Factor analysis can be used to classify all factors into 5 main group factors which can be summarized in table 3. The five group factors were generated which were named as; Factor 1: Built Environment, Factor 2: Shared Mobility, Factor 3: Basic services, Factor 4: Infrastructure development and Factor 5: Flexible transportation services. Based on the classification of the five group of factors, the strategy in transportation management can be recommended as depicted in figure 1.

Table 2. Statistical analysis of the main variables

| Variables | Xn | Mean | Min | Max | Std. Dev. | Sig. (2-tailed) |
|-----------|----|------|-----|-----|-----------|----------------|
| Creating flexibility operation | X1 | 4.5990 | 1.00 | 6.00 | 1.29687 | 0.000 |
| Encourages personnel to use public transport | X2 | 4.5680 | 1.00 | 6.00 | 1.21196 | 0.000 |
| Encourages congestion pricing | X3 | 4.3760 | 1.00 | 6.00 | 1.24345 | 0.000 |
| Encourage people to use clean energy vehicles | X4 | 4.8640 | 1.00 | 6.00 | 1.11479 | 0.000 |
| Private cars in public areas with parking fee | X5 | 4.3510 | 1.00 | 6.00 | 1.32724 | 0.000 |
| Expansion of a Bus Rapid Transit (BRT) route | X6 | 4.4920 | 1.00 | 6.00 | 1.17700 | 0.000 |
| Encourage people to use the carpooling | X7 | 4.3430 | 1.00 | 6.00 | 1.26133 | 0.000 |
| More car-sharing in transportation center point | X8 | 4.3410 | 1.00 | 6.00 | 1.22891 | 0.000 |
| More bike-sharing in transportation center point | X9 | 4.3290 | 1.00 | 6.00 | 1.24351 | 0.000 |
| More ridesharing service | X10 | 4.4110 | 1.00 | 6.00 | 1.17536 | 0.000 |
| Intellgent traffic management (Smart Mobility) | X11 | 4.7920 | 2.00 | 6.00 | 1.09359 | 0.000 |
| Seamless public transportation | X12 | 4.8370 | 2.00 | 6.00 | 1.13566 | 0.000 |
| Encourage a work online application system | X13 | 4.7850 | 1.00 | 6.00 | 1.14334 | 0.000 |
| development | | | | | | |
| Infrastructure development | X14 | 5.2170 | 2.00 | 6.00 | .96272 | 0.000 |
| Bus stops with automated ticketing service | X15 | 4.7728 | 2.00 | 6.00 | 1.09719 | 0.000 |
| Promoting products selling at transit stop | X16 | 4.8520 | 2.00 | 6.00 | 1.06171 | 0.000 |
| Bus stops should provide basic services | X17 | 4.8739 | 2.00 | 6.00 | 1.04225 | 0.000 |
| Standard public transport design | X18 | 5.1070 | 2.00 | 6.00 | .96876 | 0.000 |
| Applications for specific public transport systems | X19 | 5.1240 | 2.00 | 6.00 | .97958 | 0.000 |
| Expanding public transport routes | X20 | 5.2492 | 2.00 | 6.00 | .95118 | 0.000 |
| Smart cards covering all public transport | X21 | 4.9629 | 1.00 | 6.00 | 1.15570 | 0.000 |
| The promotion should be promoted for elderly, the disabled and children | X22 | 5.3220 | 2.00 | 6.00 | .85968 | 0.000 |
| Connectivity of feeder system to railway station | X23 | 5.2800 | 2.00 | 6.00 | .91676 | 0.000 |
| Connectivity of pedestrian paths and bicycle lanes | X24 | 5.2490 | 2.00 | 6.00 | .91861 | 0.000 |
| Road safety awareness | X25 | 5.1630 | 1.00 | 6.00 | .98661 | 0.000 |
| Mitigated road safety problems | X26 | 5.1900 | 1.00 | 6.00 | .92777 | 0.000 |
| Reduce road accidents | X27 | 5.2810 | 3.00 | 6.00 | .83351 | 0.000 |
| Speed-reduction in road design | X28 | 5.2880 | 3.00 | 6.00 | .87053 | 0.000 |
| Road environment design | X29 | 5.3200 | 1.00 | 6.00 | .87771 | 0.000 |
| Shading and trees to support active travel choices | X30 | 5.3480 | 1.00 | 6.00 | .87845 | 0.000 |
| Road design allows people for safer travel by personal car | X31 | | | | | |

*p Significance (p-value) < 0.05*
The factors of flexible transportation services and infrastructure development is strongly related to the transportation management which provide a variety transportation choices in conforming with land-use planning. The determine settlement can be recommended to avoid traffic congestion or reduce travel distances and travel time, which is similar to the system management efficiency [14, 15, 16, 17]. The factors of shared mobility, built environment and basic services around transit station were related to travel efficiency by promoting modal shift from the most energy consuming to efficient urban transport mode (low-carbon modes); in particular, the shift towards non-motorized transport and

| No. | Variables                                                                 | Group of Factors |
|-----|---------------------------------------------------------------------------|------------------|
| 1   | Connected of pedestrian paths and bicycle lanes                           | 1.000            |
| 2   | Applications for specific public transport systems                        | 1.000            |
| 3   | Road safety awareness                                                    | 1.000            |
| 4   | Speed-reducing road design                                               | 1.000            |
| 5   | Connected feeder system from rail station                                | 1.000            |
| 6   | Reduce road accidents                                                     | 1.000            |
| 7   | Seamless Public Transportation                                           | 1.000            |
| 8   | Standard public transport design                                         | 1.000            |
| 9   | Road environment design                                                  | 1.000            |
| 10  | The promotion should be promoted to the elderly, the disabled and children| 1.000            |
| 11  | Road design allows people for safer travel by personal car               | 1.000            |
| 12  | Mitigate road safety problems                                            | 1.000            |
| 13  | Expanding public transport routes                                        | 1.000            |
| 14  | Shading/trees for active travel choices                                  | 1.000            |
| 15  | Smart cards covering all public transport                                | 1.000            |
| 16  | Expansion of a Bus Rapid Transit (BRT) route                            | 1.000            |
| 17  | Encourage people to use clean energy vehicles                            | 1.000            |
| 18  | Encourage a work online system                                           | 1.000            |
| 19  | Intelligent traffic management                                           | 1.000            |
| 20  | Expansion of a Bus Rapid Transit (BRT) route                            | 1.000            |
| 21  | Bus stops with automated ticketing service                               | 1.000            |
| 22  | Encourage of Congestion Pricing                                          | 1.000            |
| 23  | More car-sharing in Transportation center point                          | 1.000            |
| 24  | Encourage people to use the carpooling                                   | 1.000            |
| 25  | More bike-sharing in Transportation center point                         | 1.000            |
| 26  | More ridesharing service                                                 | 1.000            |
| 27  | Promoting products selling in stop transit                              | 1.000            |
| 28  | Bus stops should provide basic services                                  | 1.000            |
| 29  | Infrastructure development                                               | 1.000            |
| 30  | Creating flexibility operation                                            | 1.000            |
| 31  | Encourage of personal to use public transport                           | 1.000            |
public transport [14] & [15]. Especially, in road safety dimension, it can be clearly seen that majority of commuters aware the most for their travel decision.

5. Conclusions
In this paper, we presented our approach for personalized behavioral change support by leveraging travel behavior and personality profiles. Moreover, it can describe the results of a pilot study related to perception on interventions for sustainable urban mobility. The results showed evidence that our proposed approach had some impact on motivating commuters on a personal level to change their mobility behavior and make more sustainable choices. In addition to urban planning and mobility system, in other words, the design of urban infrastructure must be considered together with traffic management. This is very important elements in creating perspectives for alleviating energy efficiency problems while maintaining social inequality which is a consideration of the relevant issues and solutions arise among multidimensional of current urban problems. This study recommended that the result of factor analysis to formulate the set of policy variables is consistence with efficiency traffic management system. Finally, the three pillars of sustainability (the economy, society and the environment) must be treated with equal since suburban attracted migrants with economic prospects, people, activities, interactions and social bring opportunities and threats to sustainable development. Thus, the connectivity with diverse transportation options must be allocated with suitable coverage for time saving, less congestion, producing lower emissions, and promoting efficient land use and improved road safety.

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**Acknowledgments**

The authors gratefully acknowledge the financial support provided by Thammasat University under the TU Research Scholar of the project entitled “The tackling traffic management by focusing on travel behavior approach towards sustainable campus town development project”, contract no.6/2562. The research was conducted by Center of excellence in urban mobility research and innovation, Faculty of Architecture and Planning research fund, Thammasat university.