IMPACT ASSESSMENT OF SATELLITE CENTRE-BASED TELECOMMUTING ON TRAVEL AND AIR QUALITY IN DEVELOPING COUNTRIES
BY EXPLORING THE LINK BETWEEN TRAVEL BEHAVIOUR AND URBAN FORM

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Abstract – Lack of coordination between transport and land use in developing countries creates a variety of complications in the urban form. Due to this mismatch, vehicle ownership is uncontrollably rising, generating hyper-congestion on the road network. Suburban sprawling is one of the adverse outcomes of the transport-land use mismatch, which increases trip lengths and thereby supports traffic gridlocks in the urban areas. This paper proposes a satellite centre-based telecommuting as a solution for easing congestion in developing countries by exploring the link between travel behaviour and urban form. The investigation is conducted in two stages. In the first stage, the household travel behaviour in developing countries is analysed by using a nested logit (NL) model of two levels. The upper level is characterized by car owning, motorcycle owning and no vehicle-owning choices. The lower level consists of household related travel choices. In the second stage, the developed NL model is applied for a telecommuting policy by locating new satellite centres outside the CBD. The satellite locations are chosen considering the travel convenience, urban form and the existing road network. The impacts of the policy are assessed in terms of vehicle kilometres travelled (VKT) and emissions considering Bangkok Metropolitan Region as a case study.

Key Words: Telecommuting, Satellite Centres, Travel Behaviour, Urban Form, Developing Countries, Integrated Transport and Land use Policies
1. INTRODUCTION

The urban systems in developing countries have been facing various complications due to rapid economic development and its concomitant impacts including increased demand for travel and vehicle ownership. In particular, lack of coordination between transport and land use generates a considerable influence on the mobility problem negatively affecting the entire process of development. Although both transport and land use sectors have been improving with growing economies in developing countries, interrelationship between them has not been properly established at the initial stages of planning and decision making of these improvements. This can be a governing factor for travellers’ motives behind the use of private vehicles.

Expensive land prices in urban areas in developing countries encourage urban dwellers to locate their residences in the suburbs. The outcome of suburban sprawling has disadvantages and is troublesome if a country cannot provide adequate infrastructures and transit facilities to maintain daily transport needs between the suburbs and central business districts (CBD). Clearly, the developing countries do not have efficient transportation systems. On the other hand, the limited highway networks there do not provide sufficient accessibility to the suburbs. Consequently, most of the households in the suburbs who daily commute to CBD use their own vehicles rather than travelling by inferior transit provisions available in the system. Increased vehicle ownership and usage have been receiving more attention in recent years due to its adverse effects on the environment and society as a whole. However, urban areas in developing countries continue to suffer from traffic congestion and related impacts of motorization, including air pollution, climate change, noise pollution, travel delays, mental stress due to unreliability of travel, and the issues related to road safety, from decades causing significant damages to the quality of life. Therefore, searching socially and environmentally viable policies are becoming vital for developing countries.

Household travel behaviour is explicitly analysed in this study, since the travel decisions among the household members in developing countries are inextricably interrelated. Most of
the households in developing countries are single-vehicle owners, and therefore, the possibility of generating household serving trips is considerably high. As shown in figure 1, most of the Bangkok households are single vehicle owners, for example 70% of high-income households and 30% of low-income households are single vehicle owners. Accordingly, vehicle users, in most cases the commuters, usually take the responsibility of driving for other household members by sharing vehicles for multipurpose/destination trips.

![Figure 1. Household vehicle ownership levels in Bangkok city.](image)

By observing person trip data in developing countries, trip sharing can be identified as one of the popular travel attractions for the vehicle owning households, for instance car and motorcycle shared trips make up 30% of household trips (Fig. 2).

![Figure 2. Modal share variations for two-traveller households in BMR.](image)
Therefore, analysing trip-sharing behaviour is important, especially to investigate transport policies for developing countries. Consequently, major travel decisions of vehicle ownership, mode choice and trip sharing are analysed in the proposed model.

This study attempts to employ travel behaviour modelling techniques to investigate satellite centre-based telecommuting as an urban transport policy in developing countries. The basic model is developed as a Nested Logit (NL) model to analyse household travel behaviour for vehicle ownership, mode choice and trip sharing decisions, focusing on two-traveller households. The nest structure has two levels where the upper level consists of car owning, motorcycle owning and no vehicle-owning choices, and the lower level represents the mode choice combinations for two-traveller households. Since trip sharing is a fairly popular event among the vehicle owning households in developing countries, it is considered as one of the mode choice options in the proposed model. The developed NL model is successfully applied for policy analysis by locating satellite telecommuting centres in the suburbs. Impacts of the policy are assessed in terms of congestion reduction and air quality improvements considering Bangkok Metropolitan Region (BMR) as a case study. The policy analysis reveals that the centre-based telecommuting is an effective option to reduce private vehicle usage and air pollution in order to build up a sustainable urban environment.

2. PREVIOUS APPROACHES

Interactive transport and land use modelling has been receiving great attention in recent years. Webster et al. (1998) highlighted the importance of integrating transport and land use in urban planning approaches, and developed some models taking both aspects into consideration. Handy (1996) discussed the methodologies that could explore the links between urban form and travel behaviour. The household trip rates may be affected from land use and accessibility indirectly through their effects on vehicle ownership (Ewing et al., 1996). According to Rujopakarn (2000), the 8th Bangkok transport plan will not be successful due to its incompatibility with the existing land use plans. In Bangkok, many commuters travel daily
from the outer suburbs to the city centre intensifying the traffic congestion. Therefore, integrated decision making of transport and land use is becoming an urgent issue.

With the rapid motorization, impacts on telecommuting on the vehicle miles travelled (VMT) (Choo et al., 2005) and air quality (Mokhtarian et al., 1995) have been investigated under transport policy context. Individual preferences for telecommuting are explored for both developed countries (Mokhtarian and Bagley, 1998; Scott et al., 1997) and developing countries (Iscan and Naktiyok, 2005). Lupa et al. (1995) conducted an integrated study of transport and land use for the Northern Illinois region as an attempt to reduce VMT. They proposed a transport plan considering land use inputs, and found that compacted zones of job and housing may decrease VMT regardless of transit enhancements in the area. As described by Lupa et al. (1995), the scattered patterns of housing and jobs act as a barrier to control VMT. For the choices of housing locations, trade-off against higher commuting times and lower housing costs at locations distant from the work places are found as important. As reported by Ommeren et al. (1997), commuting behaviour also depends on the labour markets in addition to the housing markets, and there is also a trade-off between higher wages and lower housing charges to maximize the benefits. This may finally cause longer commuting distances and is often identified as “wasteful commuting”. Many investigations have criticized this topic for several decades (Cropper and Gorden, 1991; Hamilton, 1982; White, 1988). Consequently, redistribution of work and house locations is identified as an appropriate method of improving the traffic condition in CBD areas, thereby supporting travellers to reduce travel distances. Scott et al. (1997) investigated the methods for reducing congestion and environmental pollution in North America, and found that implementing policies made a positive contribution for improving commuting efficiency. Accordingly, the choices of work place and house location are very important considerations to minimize the commuting distances. Cervero (1989) investigated the job-housing balance in American cities and identified that it greatly improves the regional mobility, traffic congestion, energy consumption, and environmental quality. To achieve the targets of reducing commuting distances either work place or housing
location should be fixed in the analysis. According to Ommeren et al. (1997), two basic models can be developed, for example, urban equilibrium models with fixed work location, and standard urban equilibrium models with fixed housing location.

The emergence and growth of sub-centres in the Los Angeles region were analysed by cluster analysis using census journey-to-work data (Giuliano and Small, 1991). The sub-centres can generally be identified as employment concentration sites. Handy and Mokhtarian (1996) investigated the research methods available for forecasting telecommuting and discussed about the data requirement for the advancement of forecasting techniques. Wells et al. (2001) examined the telecommuting implications for travel behaviour in the Minnesota region, and two telecommuting programs were conducted as a part of a larger research. Results of this investigation reveal that telecommuting strategies vary within and between organizations, and those approaches appear to moderate the relationship between telecommuting and complex travel behaviours, such as task completion and trip chaining. Martens and Korver (2000) conducted a study for examining and forecasting the mobility effects of tele-services taking telecommuting as a case study. The estimates in their study were based on realistic and consistent societal scenarios with the use of an operational transport model in which second-order effects including induced travel can be analysed.

As Drucker and Khattak (2000) mentioned, working from home is advantageous for both employees and employers, and telecommunications technologies are facilitating the new work-at-home phenomena. The effects of socio-economic, household, locational, and accessibility variables on individuals' choices to work from home were estimated with ordered logit, ordered probit, and multinomial logit models and the results indicated that educational attainment and the presence of small children in the household encourage frequent working from home.

Telecommuting is generally defined as working from home. In contrast, Henderson and Mokhtarian (1996) conducted a research on centre-based telecommuting where the commuters work at telecommuting centres located closely to their residences. As they explained, centre-based telecommuting has advantages over home-based telecommuting as it avoids restrictions
related to the working environment at home and provides opportunities to the commuters to maintain social and professional interactions.

3. THE NL MODEL FOR TWO-TRAVELLER HOUSEHOLDS

3.1. Study area and data description

The Bangkok Metropolitan Region (BMR) in Thailand is considered for the empirical analysis in this study. BMR located in the gulf of Thailand serves as a development centre to the whole country. In conjunction with the industrial revolution in 1980s, the city has been considerably expanded. Finally Bangkok was changed into a road-based city. Before the industrial development, the vehicle ownership in Bangkok was a requirement only for rich people. In contrast, the vehicle ownership in Bangkok has risen unexpectedly after the 1980s. The employment opportunities there have been increased with the growing economy, and hence the income levels were dramatically improved. The transportation systems have been considerably changed over the years to serve the increasing travel demand.

BMR is known today as one of the worst-congested metropolitan areas in the world. Due to rapid motorization in BMR, the average travel speed has been significantly dropped down to 10.9 km/h. In the year 2001, peak hour speed in CBD was estimated to be 5.9 km/h and the commuters often caused difficulties to access Bangkok CBD.

The BMR consists of Bangkok Metropolitan Area (BMA) and five adjacent provinces of Samut Prakan, Nonthaburi, Pathum Thani, Nakorn Pathom and Samut Sakorn. The study region includes 505 internal traffic zones. The area of the BMR is about 7 760 km² and the total population was 13.8 million in 2001. The data, which are used in this study, were obtained from the household travel survey conducted by the Urban Transport Database and Model Development Project (UTDM, 1998) in BMR during 1995/96. The survey provides a wide variety of data useful for travel behaviour investigation, and the data consists of attributes of the trips that were made on the date of the survey as well as information of household members. Although there was a large amount of households in the database, 1 205 households were
selected for the empirical analysis according to the modelling requirements of two-traveller households, of the two, one traveller has to be a commuter. In the database, trips were indicated using the zones of origin and destinations with all independent mode (unlinked) trips. Therefore, it is easy to distinguish interrelations among the trips for both travellers such as trip purposes, trip patterns (chained or unlinked), origin and destination zones, transfer zones, travel times and time of day. Geographical information of the study region was computerized by ArcGIS software. Location-based information such as trip length is measured on the existing road network by using the criteria of the shortest distance between origin and destination zones. An additional database for the home interview survey was received from the Bangkok Environmental Improvement Project (BEIP, 1997).

3.2. Modelling approach

The transportation modes in BMR at the time of data collection are bus, rail, car, motorcycle, hired motorcycle, taxi, and ferry. The main mode of public transport in Bangkok is bus transportation since the rail facilities are in a very inefficient phase supplying services mostly in inter-city travel basis. Ferries are functioning along the “Chao Praya” river as well as many canals in Bangkok, even though the accessibility and the serviceability relating to those are rather poor. Since the user attraction towards rail and ferry is very low, the choice set of transport modes for the study excludes those travel options from the analysis.

In developing countries, travel decisions of the household members are interrelated and therefore, this study is based on two-traveller households in Bangkok. Two-traveller households are selected in order to comprehend the household travel behaviour with a feasible modelling approach as having three or more travellers may complicate the modelling process. Among the two-travellers, one of the travellers makes a commuter trip. The travel purpose of the second traveller in the household can be any type, such as work, shopping, private business, social or recreation. When both travellers share the same vehicle, the commuter has to drop by the destination of the second traveller before reaching his destination (Fig. 3). The commuter
trip can be home-to-work (work-bound) or work-to-home (homebound). Therefore, detours of both work-bound and homebound trips are explicitly incorporated in the analysis. This approach contrasts with the others, which deal with conventional definition of home-to-home trips with complete cycles.

![Diagram of household based trip sharing](image)

Fig. 3. Household based trip sharing.

The nest structure for the two-traveller households developed in this study has two levels, as shown in figure 4. The upper level characterizes the household choices for car owning, motorcycle owning, and no vehicle owning. The lower level represents the corresponding mode choice combinations for two-traveller households. Altogether it has 17 options to represent household travel patterns. In Figure 4, C, CSH, M, MSH, B, H and T represent the modes of car, car sharing, motorcycle, motorcycle sharing, bus, hired motorcycle, and taxi, respectively.

For car owning households, Alternatives 1 through to 7 are the possible mode choice combinations, use either car (Alternatives 1~4) or other modes (Alternatives 5~7). In detail, Alternatives 1 through 4 are various car travel patterns in which the commuter (main traveller) travels by a car and the second traveller of the same household travels by the available options of car sharing (CSH), bus (B), hired motorcycle (H) or taxi (T). In Alternatives 5 through 7, both travellers, who belong to the group of car owning, travel by B, H, or T. Alternatives 8 through 14 are applicable for the motorcycle owning nest. Among them, Alternatives 8 through
Alternatives 15 through 17 are the mode choice options in which both travellers use B, H or T since they have to manage their travel needs by other available modes in the system.

Fig. 4. A Nested Logit (NL) model of vehicle ownership, mode choice and trip sharing.

Attributes, which are obtained from the database, are explicitly incorporated in the analysis. Since this study is based on two-traveller households, attributes for both travellers are appropriately included in the model. In each alternative, level-of-service variables such as travel time and travel cost are calculated with explicit consideration of both travellers in a household. For example, travel time for Alternative 2 (commuter uses car and second traveller uses bus) is obtained by adding commuters’ travel time (car travel) and second travellers travel time (bus travel). Similarly, travel cost for the alternatives is also calculated. When the household shares the trips, the commuter first drives to the second travellers’ destination (travel
distance X) and then, drives to his work place (travel distance Y). In this study, the shortest route between the destinations is considered. Accordingly, X and Y are kept to within their minimum distances, and the travel time and the travel cost of the shared trips are calculated considering the minimum travel distances X and Y.

3.3. Model estimation

Simultaneous estimation (full information maximum likelihood) method is employed in this study. A NL model is analysed using GAUSS statistical software. It is assumed that the scale parameter for the bottom level of the nesting structure (i.e., the level of mode choices) is unity, and the scale parameter for the upper level is estimated.

For the Alternatives 7, 14 and 17 in the NL model where both travellers travel by taxi (T), alternative specific constants are considered as zero. In addition, alternative specific constants for the alternatives where both travellers travel by bus (Alternatives 5, 12 and 15) share a common parameter in the corresponding utility functions. Similarly, alternative specific constants for the alternatives where both travellers travel by hired motorcycle (H) for car owning and motorcycle owning groups (Alternatives 6 and 13) share the same parameter. However, the constant for the Alternative 16 where both travellers travel by hired motorcycle (H) for no vehicle owning households is kept to be different from the constant in Alternatives 6 and 13 by considering the variations of choice attitudes over vehicle owning and no vehicle owning groups.

3.4. Estimation results and discussion

Table 1 shows the parameter estimation results for the proposed NL model. Most of the estimated parameters are with reasonable significance and expected signs. Alternative specific constants for Alternatives 2, 3, 4, 9, 10, 11 and 16 have significant positive effect suggesting the household preference of using separate modes than forming shared trips. In addition, all households with or without vehicles have a preference for bus mode (Alternative 5, 12, 15) since the common alternative specific constant shows a significant positive effect.
Table 1. Estimation results for the proposed NL model of vehicle ownership, mode choice and trip sharing

<table>
<thead>
<tr>
<th>Variable description</th>
<th>Parameters</th>
<th>t-statistics</th>
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<tbody>
<tr>
<td><strong>Alternative specific constants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Car (shared ride)</td>
<td>-1.62</td>
<td>-1.4</td>
</tr>
<tr>
<td>2 Car &amp; Bus</td>
<td>4.60</td>
<td>9.4</td>
</tr>
<tr>
<td>3 Car &amp; Hired Motorcycle</td>
<td>3.11</td>
<td>5.1</td>
</tr>
<tr>
<td>4 Car &amp; Taxi</td>
<td>2.02</td>
<td>2.8</td>
</tr>
<tr>
<td>5, 12, 15 Bus &amp; Bus</td>
<td>2.67</td>
<td>6.1</td>
</tr>
<tr>
<td>6, 13 Hired Motorcycle &amp; Hired Motorcycle</td>
<td>0.25</td>
<td>0.3</td>
</tr>
<tr>
<td>8 Motorcycle (shared ride)</td>
<td>1.26</td>
<td>1.3</td>
</tr>
<tr>
<td>9 Motorcycle &amp; Bus</td>
<td>5.02</td>
<td>9.6</td>
</tr>
<tr>
<td>10 Motorcycle &amp; Hired Motorcycle</td>
<td>4.00</td>
<td>7.5</td>
</tr>
<tr>
<td>11 Hired Motorcycle &amp; Taxi</td>
<td>2.13</td>
<td>2.8</td>
</tr>
<tr>
<td>16 Hired Motorcycle &amp; Hired Motorcycle</td>
<td>1.01</td>
<td>2.3</td>
</tr>
<tr>
<td>Motorcycle-owning</td>
<td>1.53</td>
<td>2.4</td>
</tr>
<tr>
<td>No Vehicle-owning</td>
<td>1.87</td>
<td>2.7</td>
</tr>
<tr>
<td><strong>Level-of-service variables</strong></td>
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<tr>
<td>Travel time (hrs)</td>
<td>-0.42</td>
<td>-2.8</td>
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<tr>
<td>Travel cost/income/10^2</td>
<td>-2.34</td>
<td>-5.3</td>
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<tr>
<td><strong>Scale parameters</strong></td>
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<td></td>
</tr>
<tr>
<td>( \mu )</td>
<td>0.49</td>
<td>5.0</td>
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<tr>
<td><strong>Alternative specific dummies</strong></td>
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<td></td>
</tr>
<tr>
<td>Distance between destinations ≤ 15km, Alternatives 1, 8</td>
<td>1.05</td>
<td>2.7</td>
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<tr>
<td>Distance between destinations ≥ 10km, Alternative 9</td>
<td>0.94</td>
<td>3.8</td>
</tr>
<tr>
<td>Travel distance for each traveller &gt; 30km, Alternative 2</td>
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<td>Second travellers’ travel distance &gt; 5km, Alternative 3</td>
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<tr>
<td>Distance shared in the trip chain ≥ 75%, Alternative 8</td>
<td>1.05</td>
<td>4.1</td>
</tr>
<tr>
<td>Time compatibility, Alternative 1</td>
<td>5.05</td>
<td>4.9</td>
</tr>
<tr>
<td>Trips within CBD, Alternative 8</td>
<td>-0.87</td>
<td>-3.5</td>
</tr>
<tr>
<td>Trips within CBD, Alternative 16</td>
<td>-1.86</td>
<td>-3.4</td>
</tr>
<tr>
<td>Trips within CBD, Car-owning</td>
<td>-1.02</td>
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<td>Trips touching CBD, Alternative 2</td>
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<td>Commuter’s job(executive), Alternative 8</td>
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<td>-3.8</td>
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<td>Commuter’s job(executive/business), Car-owning</td>
<td>2.52</td>
<td>4.0</td>
</tr>
<tr>
<td>Both travelers jobs not executive, No Vehicle-owning</td>
<td>0.88</td>
<td>2.5</td>
</tr>
<tr>
<td>Male commuter, Alternatives 1, 8</td>
<td>1.85</td>
<td>6.7</td>
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<tr>
<td>Commuter’s age &gt; 50 yrs, No Vehicle-owning</td>
<td>1.14</td>
<td>2.1</td>
</tr>
<tr>
<td>Trip purpose work-work, work-school, Alternative 8</td>
<td>1.52</td>
<td>2.1</td>
</tr>
<tr>
<td>Household income ≤ 25 000, No Vehicle-owning</td>
<td>3.00</td>
<td>3.6</td>
</tr>
<tr>
<td>School children in household ≥ 1, Car-owning</td>
<td>1.78</td>
<td>4.3</td>
</tr>
<tr>
<td><strong>Number of observations</strong></td>
<td>1205</td>
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</table>
Coefficients for the travel time and the travel cost/income have significant negative effect as expected. According to the estimation, the scale parameter of the upper level has a significant effect with a magnitude of 0.49, and it falls in the limit between 0 and 1 preserving the nesting behaviour of the proposed NL model.

In the NL model, many dummy variables are included to investigate the behavioural trend on vehicle ownership, mode choice, as well as trip sharing features. The dummies such as distance between travellers’ destinations, individual travel distances, distance shared in the trips, time compatibility, CBD travel, trip purpose, household income, number of school children, commuter’s job, gender and age are selected for the analysis according to the data availability. The distance between the travellers’ destinations is included as a dummy in several utility functions.

The distance between the travellers’ destinations is included as a dummy in several utility functions. When the distance between destinations is less than or equal to 15 km, the corresponding dummy in the alternatives of Car sharing (Alternative 1) and Motorcycle sharing (Alternative 8) has a significant positive effect expressing the household tendency to make car or motorcycle shared trips for closer destinations. Similarly, when the destinations are far from each other, households prefer separate modes such as Alternative 9 (commuter uses motorcycle and second traveller uses bus). If both travellers’ travel distances are long, for example more than 30 km, the corresponding dummy in Alternative 2 is significant and positive suggesting that the commuter prefers a car and the second traveller prefers the bus for long distance travel.

If the second traveller’s travel distance is more than 5 km, the dummy in Alternative 3 (commuter uses a car and second traveller uses a hired motorcycle) is significantly negative, indicating that a hired motorcycle is not a suitable option for long distance travelling. When both travellers of the household share their travel distance more than or equal to 75%, the motorcycle sharing is found as an attractive option for Bangkok travellers.

The dummy variable for time compatibility, which mainly compares both travellers’ activity start and finish times, has a significant positive effect indicating its importance in trip
sharing. In other words, when the commuter’s work start time (finish time) is later (earlier) than the second traveller’s activity start time (finish time), car sharing is found as an attractive alternative.

Travelling in CBD is also analysed with several dummies in the estimated model. When both travellers’ trips are in CBD, the travellers’ preference to make motorcycle shared trips is negative. Similarly, when both travellers’ trips are in CBD, travelling by hired motorcycle is not an attractive choice for them since it may not be a safe travel option in highly congested areas such as Bangkok. Also, if the trips of both travellers are in CBD, owning a car is not a preferable option for them. For the trips that touch CBD, Alternative 2 is a suitable travel option. Travelling through CBD zone, especially in BMR, is extremely difficult during peak congestion hours, and therefore, the commuter drives alone and has the second traveller use a bus rather than attempting to share the trips in congestion areas.

The commuter’s job is tested as a dummy in Alternative 8 (motorcycle sharing) and car-owning utility functions. According to the results, executive job holding commuters are less likely to share motorcycle trips. When the commuter’s job is either executive or business, the related dummy in car-owning utility function is with positive sign indicating the greater propensity to own vehicles. It indirectly highlights the interaction between the car owning and the reputation linking with the job condition. When both travellers in the household do not have executive jobs, the dummy in the no vehicle-owning utility function yields with positive significant effect.

The dummy variable for male commuters, which is included in the alternatives of car sharing (Alternative 1) and motorcycle sharing (Alternative 8), significantly yields the positive sign expressing their contribution for household travel responsibilities by sharing trips. The commuter’s age is also tested as a dummy and found that commuters over fifty years of age prefer not to own vehicles.

Trip purpose is found as an important factor in mode selection. Therefore, both travellers’ trip purposes are tested as a dummy in Alternative 8 (motorcycle sharing). When the trip
purpose of the second traveller is for commuting or for schooling, the motorcycle-shared trip is a considerably preferred option for Bangkok travellers.

Household income is also incorporated as a dummy in the No Vehicle-owning utility function. When the household income is less than or equal to 25,000 Thai Baht, vehicle owning is not a suitable option for them. When there are school children in the household, car owning is a preferred option for Bangkok households.

Calculation of the Value of Time (VOT) for the estimated model is important to measure the external validity of the model, and it generally incorporates the coefficients of travel time and travel cost. According to the specification of the proposed NL model, VOT also depends on the household income in addition to the coefficients of travel time and travel cost. Since the data set has a variety of household incomes, different VOT figures exist. Therefore, average VOT is calculated, and is obtained as 30 Thai Baht/hr. The VOT obtained is very similar to the study that was conducted in the same region by the UTDM project (UTDM, 1998). Therefore, the estimated model is intuitively reasonable to represent the actual circumstances in the study region. The goodness of fit for the model has a value of 0.41 demonstrating a remarkable level of model fit.

4. MODEL APPLICATION FOR TELECOMMUTING POLICY ANALYSIS

Finding interactive transport and land use policies is becoming an urgent issue due to the discrepancies of urban systems in developing countries. Previous studies on telecommuting are basically focused on aggregate assessments leading to macro-level investigations. This study applies the estimated NL model for evaluating telecommuting impacts under the disaggregate assessment trial.

4.1. Analysing telecommuting by considering satellite centres in suburbs

Telecommuting policy in this study is mainly conducted by relocating work places in suburbs aiming to reduce daily commuter trips to CBD and to improve the traffic condition in
the city. Several locations in Bangkok suburbs are selected as new satellite centres in the policy analysis.

Satellite centres can be described as purpose-built telecommuting centres with resourceful communication facilities that open to multiple businesses. The purpose of having satellite centres is to provide an opportunity to the employees from different companies to perform their jobs for their own companies in the CBD rather than making daily commuting trips to CBD. This option is more attractive to the commuters than home based telecommuting as they have a possibility to maintain their social and professional interactions.

In this study, five satellite offices are considered in the outer suburbs in BMR as shown in figure 5. Satellite locations are decided with explicit consideration of the available transport facilities including recently introduced Mass Rapid Transit (MRT) together with current residential locations to support commuters with easy accessibility.

![Fig. 5. Proposed locations of the satellite offices in BMR.](image)

Since this study analyses households with two-travellers, commuters’ job conditions and second traveller’s destination conditions are presumed to be the governing factors to recognize the possibility of changing their destinations to the proposed satellite locations in the outer suburbs. In this policy, housing locations are considered as fixed. Only for the households who
can change their destinations without any difficulties, new commuting distances to the closest satellite centres are re-measured using GIS maps. By using their new travel distances, attributes such as travel times and costs are calculated. For the households who live in CBD and have their work or activity places in CBD, actual trips are kept unaffected in the analysis in which the attributes of their trips are considered to be the same as the original figures. After reorganizing the attributes according to the new satellite centres, telecommuting policy is investigated as to assess the impacts in terms of reductions of VKT and air pollution.

4.2. Assessment of policy related impacts

The impacts of the telecommuting policy such as the reduction of VKT and air pollution (NOx, SO2, CO, PM, HC) are analysed. For the calculation of VKT and air pollution quantities, household choice probabilities for each alternative in the NL model in figure 4 are incorporated.

The calculations of VKT for each alternative and the total VKT are explained in the equations 1 and 2 as follows:

\[ VKT_n(i) = P_n(i) d_n \]

\[ T(VKT) = \sum_{n=1}^{N} \left[ \sum_{i=1,8} P_n(i) d_n^{\text{share}} + \sum_{i=1,8} P_n(i) (d_n^1 + d_n^2) \right] \]

Where, \( N \) is the total number of households in the data sample, \( VKT_n(i) \) is VKT by alternative \( i \) for household \( n \), \( T(VKT) \) is the total VKT, \( P_n(i) \) is the probability that alternative \( i \) is chosen by household \( n \), \( d_n \) is the travel distance of household \( n \), \( d_n^{\text{share}} \) is the distance of the shared ride, \( d_n^1 \) is the commuters’ travel distance, and \( d_n^2 \) is the second travellers’ travel distance.

4.2.1. Reduction of vehicle kilometres of travel (VKT). Once the NL model is tested for the policy, the VKT for both cases, for example with policy and without policy (the base case), are
calculated separately, using the equations 1 and 2. The reductions of VKT for car and motorcycle travel with the policy are represented in figure 6. The results reveal that the telecommuting policy proposed in this study makes a significant effect on easing congestion where the private vehicle usage in the area up reduces by 18%-20%.

Fig. 6. Reductions of vehicle kilometres of travel with the policy.

4.2.2. Reduction of air pollution. For the air pollution estimations, country-level emission factors are applied rather than using composite emission factors with a default speed in order to obtain accurate results. Therefore, pollutant emission factors due to mobile source emissions that are used in this study were obtained from the Pollution Control Department in Bangkok. The variations of emissions for different pollutants with respect to the vehicle speed of car and motorcycle, in BMR are shown in figure 7.

Equation 3 explains the procedure of estimating air pollution where \( E(\text{AP}) \) indicates the expected value of air pollution emission in milligrams, \( F(\text{AP})_{\text{car}} \) and \( F(\text{AP})_{\text{mc}} \) are emission factors for car travel and motorcycle travel in mg/km.

\[
E(\text{AP}) = \sum_{n=1}^{N} \left[ \frac{P_n(1)d^{\text{above}}}{P_n(2)+P_n(3)} + \frac{P_n(11)d^{\text{inner}}}{P_n(4)+(P_n(7)+P_n(14)+P_n(17))d_n + d^c_n} \right] * F(\text{AP})
\]
The reductions of air pollution levels for $\text{NO}_x$, $\text{SO}_x$, CO, PM and HC are presented graphically in figure 8. All the pollutants are found to be reasonably reduced with the telecommuting policy and the reductions are in the range from 18% to 26%.

Fig. 8. Reductions of pollution emissions from car and motorcycle travel with the policy.
5. CONCLUSIONS

In this study, urban transport policy is investigated for developing countries, especially by analysing satellite centre-based telecommuting. The NL model is found to be a suitable technique to model the basic domain of the household mobility and travel behaviour over vehicle ownership, mode choice and trip sharing decisions, which is later applied to investigate the policy on telecommuting. For the policy investigation, five satellite centres are hypothetically located in the outer suburbs assuming that the commuters who reside in suburbs may commute to the satellite centres closest to their residences.

Related impacts of the policies are estimated with corresponding reductions of VKT and emissions in the region. For the calculation of VKT and air pollution, household choice probabilities for each travel option, in other words disaggregate-levels of investigations, are explicitly incorporated in order to improve the accuracy of the analysis. In addition, country-level emission factors are used in the analysis to improve the level of accuracy of the pollution estimates. The resultant reductions of VKT and air pollution are found to be reasonable and therefore, regional mobility will be significantly improved with the suggested policy option.

Furthermore, most of the previous studies that have been conducted in this context, especially for air pollution estimations, are in aggregate basis and uncertainties can be involved in the findings. The principal objective of this study is to apply the concepts of disaggregate-level of investigation directly in estimating transport-land use policy impacts aimed at reliable impact assessment.

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REFERENCES


Legends:

Tables:

Table 1  Estimation results for the proposed NL model of vehicle ownership, mode choice and trip sharing

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Fig. 1.  Household vehicle ownership levels in Bangkok city.
Fig. 2.  Modal share variations for two-traveller households in BMR.
Fig. 3.  Household based trip sharing.
Fig. 4.  A Nested Logit (NL) model of vehicle ownership, mode choice and trip sharing.
Fig. 5.  Proposed locations of the satellite offices in BMR.
Fig. 6.  Reductions of vehicle kilometres of travel with the policy.
Fig. 7.  Variation of mobile source emissions for car travel (a & b) and motorcycle travel (c & d) with vehicle speed in Bangkok city.
Fig. 8.  Reductions of pollution emissions from car and motorcycle travel with the policy.