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Special Issue

LOGISTICS

PREFACE

Dear Readers,

Welcome to the first issue of the JOURNAL OF SOCIETY for TRANPORTATION and TRAFFIC STUDIES, a new international peer-reviewed on-line journal. Four issues of the journal will be published annually. This issue covers topics from travel time estimation, bus route optimization, trendy travel in Europe, sustainable urban form in Asia and road safety. The special issue covers the timely topic of logistics.

Pichai Taneerananon

Chair of Editorial Board

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ACCURACY IMPROVEMENT OF TRAVEL TIME ESTIMATION IN URBAN ENVIRONMENT USING STATE TRANASITION-DEPENDENT TIME-OCCUPANCY

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Abstract: A methodology to estimate travel time with acceptable accuracy in urban environment is proposed. In this study, the traffic states which were used in modeling were classified into three states; free flow state, saturated flow state and over-saturated flow state. These states were defined based on time-occupancy value. The most congested traffic is called over-saturated flow state whereas the least congested traffic is free flow state. However, this travel time estimation model based on time-occupancy alone is not sufficient to estimate accurately by applying only static linear regression method. This is because static linear regression method is a linearization technique. This method cannot capture time-occupancy value during transition period. This paper aims to improve the accuracy of travel time estimation in urban environment using state transition-dependent time-occupancy. We proposed separate models to capture time-occupancy during different transition period and consequently to estimate travel time more accurately. We then applied the concept of dynamic time-series regression (ARIMAX). The results revealed that our proposed separate models can improve the accuracy of travel time estimation based on only time-occupancy.

Key Words: travel time estimation, time occupancy, state transition dependence, urban road

1. INTRODUCTION

Recently, Traffic Information System has been increasingly developed in order to report useful traffic information to the motorists on a highway or even on an urban roadway. Apart from those advantages, the system seems to be more complex if implemented on the urban road way. One of the systems used in Bangkok nowadays is the Traffic Sign Board which reports the Congestion Color Levels, i.e. Green, Amber and Red. Although, reporting Congestion Color Levels could be useful to the motorists, it is only qualitative traffic information. Therefore, reporting quantitative traffic information, such as, Travel Time becomes the motivation and challenges for authors. Many researchers have proposed the schemes of Travel Time Prediction, i.e. J.W.C. van Lint *et al.* (2006), Angshuman, (2006), Daniel Billing *et al.* (2006), Zhi-Peng *et* *al*. (2008), and John Rich *et al*. (2004). From their schemes, the reliability of their models depends on the amount of collected data which means that they need to use a large amount of data to guarantee the reliability of the model. As a result, the cost will be gained as they increase the number of collected data. In Bangkok, reporting travel time information on urban roadway is not suitable to happen yet. This is because current traffic equipments, such as, traffic camera are still incapable of collecting enormous traffic data to support travel time information. If we upgrade these equipments, it would need a large investment. Traffic equipments have been installed on roadside around Bangkok. They have installed only one or two camera(s) per a road segment (A road segment represents distance between a signal-controlled intersection upstream to another signalcontrolled intersection downstream) for detecting vehicles and applying Image Processing to generate time-occupancy value as in reference of Markos Papageorgiou *et al.* (2008). From the inadequacy problem stated above, we are interested on estimating travel time based on only available traffic data from current situation which is time-occupancy. Benefits of our proposed concept are to save cost to service provider for equipment installation and also to be able to report more useful traffic data such as travel time information on road segments instead of Congestion Color Levels to motorists. In the proposed methodology to estimate travel time based on only time-occupancy in urban environment, traffic states which were used in modeling were classified into three states as shown in Fig.1. The first state is "*free flow*" state which means that vehicles will not get disturbed by the others. They can accelerate their speed up to a maximum speed. The second state is "*saturated*" flow state. Flow value is stable whereas the density value is increasing until it reaches some density values. The third state is "*over-saturated*" flow state. It represents traffic flow that is influenced by the effects of downstream bottleneck.

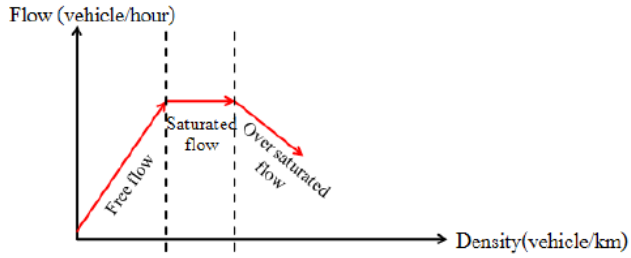

Figure 1. Fundamental diagram of traffic flow in theory

Travel time estimation models based on time-occupancy using data from traffic simulator to analyze travel time and time-occupancy relationships have already been proposed by the previous works. Sisiopiku *et al.* (1994) proposed travel time estimation model by applying "Single Linear Regression" model with piece-wise linear method. For the work of Gault (1982) and Gipps (1976), they applied "Multiple Linear Regression" model in their estimation methods. In this case, the disadvantage is that it requires traffic data that cannot routinely collect from detectors such as the arrival time of a vehicle at a detector. However, the previous works,i.e. travel time estimation based on time-occupancy using only static regression model performs reasonably well in free flow state. Nevertheless, they do not perform as well in situation of dependency on past knowledge dependence such as saturated flow state and over-saturated flow state. This is because the residuals information from past effects on current information. Therefore, this paper focuses on accuracy improvement of travel time estimation based on state transition-dependent time-occupancy in urban environment especially in state transition period from saturated flow state into over-saturated flow state. We selected Autoregressive Integrated Moving-average with External input series (ARIMAX) to track the collected data. We observed and collected travel time and time-occupancy data from microscopic traffic simulator (MITSIMLab) "MITSIMLab is a simulation-based laboratory that was developed for evaluating the impacts of alternative traffic management system designs at the operational level. The various components of MITSIMLab are organized in three modules: microscopic traffic simulator (MITSIM), traffic management simulator (TMS) and graphical user interface (GUI). MITSIMLab is adapted to model traffic flow in the simulation. This level of detail; with microscopic approach, is necessary for an evaluation at the operational level. The traffic management simulator (TMS) represents the candidate traffic control and routing logic under evaluation. The control and routing strategies generated by the traffic management module determine the status of the traffic control and route guidance devices. Motorists will respond to the various traffic controls and guidance while interacting with each other, Yang *et al.* (2000) and Moshe Ben-Akiva et al. (2001)" The remainder of this paper is organized as followed: Section 2 is the static linear regression analysis. Dynamic time series regression is described in section 3. Proposed models are described in section 4. Results are shown in section 5 and 6. And conclusion is in section 7.

2. STATIC LINEAR REGRESSION ANALYSIS

2.1 Experiment Design for traffic simulator on static linear regression analysis

The road segment has been designed for this simulation experiment. We set a signalcontrolled intersection at downstream (the stop line) and the road segment covers a total length of 1500 meters with 2-lanes, placing 1-detector in the middle of the road as in Figure 2. We first calibrated appropriate traffic data for the study of correlation between link travel time and time-occupancy. The appropriate traffic data was chosen for a consideration, i.e. the entry link flows. The entry link flows as system input was used to measure Time-Occupancy value, system output, and was calibrated until it got the whole range of time-Occupancy varied from 0 to 100 percent.

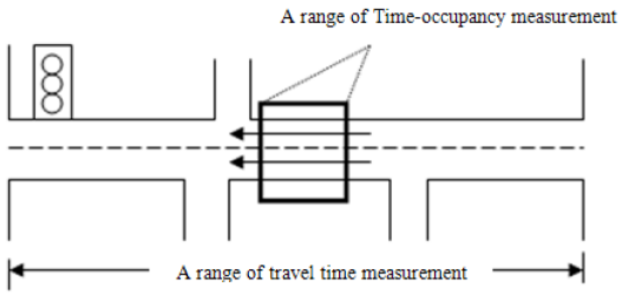

Figure 2. Observation of travel time and time-occupancy data in simulation

2.2 Classification of Traffic States based on time-occupancy value for static linear regression analysis

This part discusses on the correlation between travel time and time-occupancy value which was generated by varying entry link flows. By varying the flow value for each observation time period, traffic simulator generates 120 data points of averaged travel time and timeoccupancy per two hours (i.e. observation time period) which means that each data point in this graph was observed at every one minute as illustrated in Figure.3

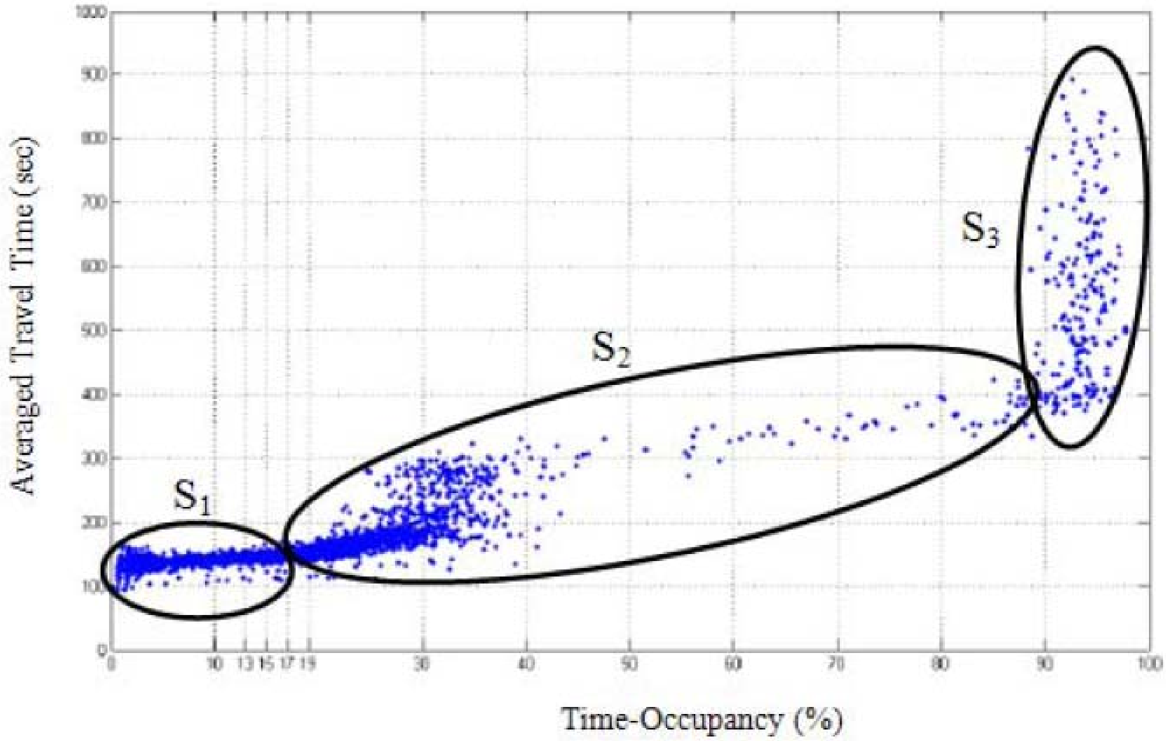

Figure 3. Averaged travel time vs. time-occupancy plot

In Figure.3, the graph could be clearly divided into 3 parts and each part is defined as each traffic state based on time-occupancy value which could be concluded in Table 1.

Table 1. Traffic state classification for static linear regression analysis

Traffic State	Time-occupancy (%)	Symbol
Freeflow (ff)	$0 \le O < 17$	S^{ff}
Saturate-flow (sf)	$17 \le O < 90$	S^{sf}
Over-sat flow (of)	$O \ge 90$	S^{of}

2.3 Static regression model with piece-wise linear method

Sisiopiku *et al.* (1994) applied this method to estimate travel time using time-occupancy

$$T = a + b_1 \times O + b_2 \times \delta \times (O - 17) + b_3 \times \kappa \times (O - 90) \quad (1)$$

$$T = a + b_1 \times O + b_2 \times KNOT1 + b_3 \times KNOT2 \quad (2)$$

Where

T: the travel time (T in second) ;

O : the percent time-occupancy;

a, b_1, b_2, b_3: regression parameters;

$KNOT1 = \delta \times (O - 17)$;

$KNOT2 = b_3 \times K \times (O - 90)$;

$$\kappa = \begin{cases} 1 & if\ O > 90;\ and \\ 0 & otherwise \end{cases}$$

$$\delta = \begin{cases} 1 & if\ O > 17;\ and \\ 0 & otherwise \end{cases}$$

"Note that the division points of time-occupancy in this static linear regression model are dependent on traffic condition and specific site, Sisiopiku *et al.* (1994)"

2.4 Results of applying Static linear regression model

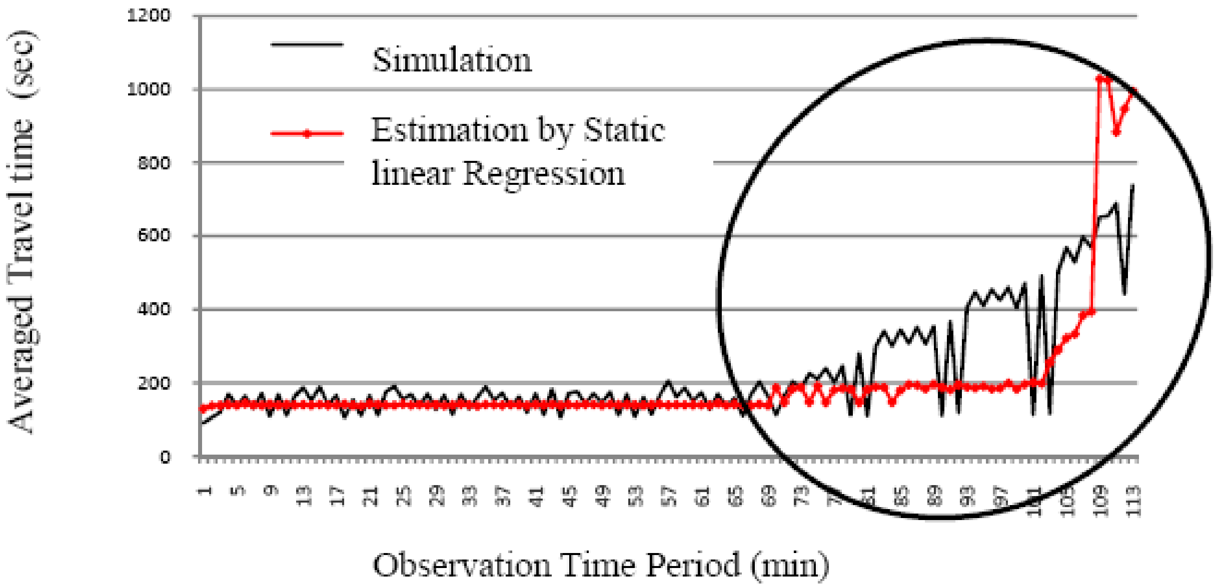

Figure 4. Result comparison between estimated travel time by static linear regression method and simulation

Time-occupancy value has been divided into three states as shown in Table 1 and they are independent of each other. This implies that the transition between states is unquestionably ignored. This paper proposed the separate state transition patterns by applying dynamic time series regression, i.e. Autoregressive Integrated Moving-average with External input series (ARIMAX), to improve the accuracy of travel time estimation especially the circle area as in Figure. 4.

3. DYNAMIC TIME SERIES REGRESSION

3.1 ARIMAX approach

As in references of Box *et al.* (1970), Daniel Billings *et al.* (2006) and Jing Fan *et al.* (2009), "ARIMAX approach allows us to combine linear regression and ARIMA process into one model. It broadens the applicability of ordinary least squares modeling. ARIMAX can be divided to 4 parts as followed:

- Autoregressive (AR) of order p is used for improving the current travel time estimation using previous value of travel time and a random noise.

$$T_t = \Phi_1 T_{t-1} + \Phi_2 T_{t-2} + \ldots + \Phi_p T_{t-p} + Z_t \qquad (3)$$

Where $\Phi = \{\Phi_1, \Phi_2 \ldots \Phi_p\}$ are autoregressive coefficients.
Z_t: the disturbance at time t. The process $\{Z_t\}$ modeled as an independent and identically distributed (*iid*) white noise with zero mean and variance $\sigma 2$.That is, $E[Z_t] = 0$ and $E[Z_t^2] = \sigma^2$ for all t and $E[Z_s Z_t] = 0$ if $t \neq s$

- Moving-average (MA) of order q is used for improving the current travel time estimation using previous value of travel time estimation error and then

$$T_t = Z_t + \theta_1 Z_{t-1} + \theta_2 Z_{t-2} + \ldots + \theta_q Z_{t-q} \qquad (4)$$

- Where $\theta = \{\theta_1, \theta_2 \ldots \theta_q\}$ are moving average coefficients. Normally, the term of ARMA (p,q) is always written in the back shift operator *'B'* where the back shift operator *'B'* operates on an element of a time-series to produce the previous element as $B^i X_t = X_{t-1}$, so ARMA(p,q) can be written as

$$(1-\Phi_1 B- \Phi_2 B^2-...- \Phi_p B^p)\ T_t = (1- \theta_1 B- \theta_2 B^2-...- \theta_q B^q)\ Z_t \qquad (5)$$

- Differencing (*I*) of order *d* is used for converting non-stationary travel time series data and time-occupancy series data to stationary data written in term of the back shift operator *'B '* i.e. $(1-B)^d T_t$, where *d* is the number of differencing order, *B* is the back shift operator, and T_t denotes the current travel time. For example $(1-B)^1 T_t = T_t - T_{t-1}$etc., Daniel Billings *et al.* (2006) "
- *r* in ARIMAX application is represented by the external input time series which is time-occupancy. It can be written in term of its previous and current value in order '*r*'.
- Finally, ARIMAX (*p,d,q,r*) can be written as followed,

$$T_t = \mu + \sum_{n=0}^{r} \beta_n O_{t-n} + \frac{(1+\theta_1 B+\theta_2 B^2+...+\theta_q B^q)}{(1-B)^d (1-\phi_1 B-\phi_2 B^2-...-\phi_p B^p)} Z_t \qquad (6)$$

where
T_t : travel time at the current time.
O_{t-n} : time-occupancy, for $n = 0$ to r.
μ : a constant.
d : the number of differencing of travel time and time-occupancy.
β_n: input coefficient at 'n^{th}', for $n = 0$ to r.
ρ_i : coefficient of previous value of travel time, for $i = 1$ to p.
Z_{t-j} : coefficient of previous value of travel time forecast error, for $j = 1$ to q.
Z_t : white noise with zero mean.

3.2 ARIMAX Steps

ARIMAX model can be divided into three steps. The first step is "Model Identification". The objective of this step is to define p, d, q and r which are the order of autoregressive, differencing, moving average and external input, respectively. The second step is "Model Estimation". The objective of this step is to estimate model parameters by using ordinary least square. The third step is "Diagnostic Checking". The objective of this step is to check the fitted models by "Serial Correlation" test. Then, we select the most fitted model by considering several statistical measurements such as Adjusted R2, SEE, SC, AIC, BIC, etc. For example, a good model should have small SEE, SC and AIC value and big Adjusted R_2 value.

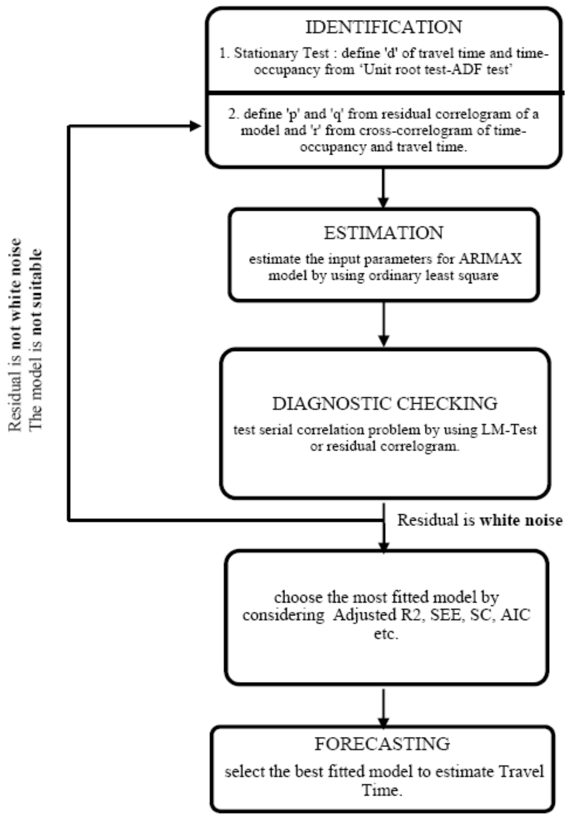

Figure 5. Analysis steps of ARIMA (p,d,q) with intput data series(r)

ARIMAX mechanism models the residual structure. Its concept is to minimise the residual of a model by combining the previous values of output (AR(p)), the previous values of the forecast error (MA(q)), the previous/current values of external input series (i.e. timeoccupancy) and the differencing (I(d)) for non-stationary time series data.

4. PROPOSED MODELS

4.1 Definition of State Transition Patterns

This paper focuses on the accuracy improvement of travel time estimation based on the change of time-occupancy, i.e. state transition dependent, especially from saturated flow state to over-saturated flow state as shown in Figure. 6.

From this figure, the transition has much significant effect to the accuracy of travel time estimation. However, the change from saturated flow state to over-saturated flow state also relates to free flow state in sequential form, namely free flow, saturated flow and over-saturated flow. Therefore, we proposed separate models to cover the four state transition patterns as followed:

- $\mathbf{S^{ff}_{t-1} \rightarrow S^{ff}_{t}}$

No change of state as the time-occupancy range of O_{t-1} and O_t are both within range of free flow state.

- $\mathbf{S^{ff}_{t-1} \rightarrow S^{sf}_{t}}$

The time-occupancy value within the range of free flow state at time (t-1) (O_{t-1}) changes to the saturated flow state at time t (O_t) i.e. $O_{t-1} < O_t$.

- $\mathbf{S^{sf}_{t-1} \rightarrow S^{sf}_{t}}$

No change of state as the time-occupancy range of O_{t-1} and O_t are both within range of saturated flow state.

- $\mathbf{S^{sf}_{t-1} \rightarrow S^{of}_{t}}$

The time-occupancy value within the range of saturated flow state at time (t-1) (O_{t-1}) changes to the over-saturated flow state at time t (O_t) i.e. $O_{t-1} < O_t$. From these four proposed models, we have applied Dynamic Time Series Regression (ARIMAX) to track travel time value which occurs during state transition. Details of state classification with time-occupancy range are shown in Table.2

Table 2. Proposed state classification for dynamic time series regression analysis

Previous State	Present State	Previous O_{t-1} range (%)	Present O_t range (%)	Symbol
Free flow(ff)	Free flow(ff)	$0 \leq O_{t-1} < 17$	$0 \leq O_t < 17$	$S^{ff}_{t-1} \rightarrow S^{ff}_{t}$
Free flow (ff)	Saturate-flow (sf)	$0 \leq O_{t-1} < 17$	$17 \leq O_t < 35$	$S^{ff}_{t-1} \rightarrow S^{sf}_{t}$
Saturate-flow (sf)	Saturate-flow (sf)	$17 \leq O_{t-1} < 35$	$17 \leq O_t < 35$	$S^{sf}_{t-1} \rightarrow S^{sf}_{t}$
Saturate-flow (sf)	Over-sat flow (of)	$35 \leq O_{t-1} < 90$	$35 \leq O_{t-1} < 90$	$S^{sf}_{t-1} \rightarrow S^{of}_{t}$

4.2 Data preparation for training sets

This part explains the data preparation plan for training sets in ARIMAX model. Time occupancy and travel time data were used as the training data sets. We then designed the separation of training sets which are suitable to each proposed state pattern. From the experimental results of varying flow as the deterministic system, it reveals that the observation time period has a significant effect on travel time especially in saturated flow state illustrated in Fig.6. Therefore, we have to define the observation time period optimally for each proposed state pattern due to the fact that the observation time period that affects travel time will be different from other proposed state patterns. Note that we defined the observation time period just only in the process of separating the training sets. Because the traffic states, i.e. the free flow, saturated flow and over-saturated flow sates occurred in sequential stage, we have to classify the data to the right model proposed in section 4.1 in order to calculate the parameter in ARIMAX model by using that already categorized data. The separation approach is categorized as followed (Figure. 6),

For free flow state, we use the data within the time range of 0^{th} to 30^{th} minute, i.e. before the state of changing to saturated flow state, namely Transition#1.

1. For Transition#1, the data between 30^{th} to 33^{rd} minute (the state of changing to saturated flow) is being chosen.
2. For saturated flow state, we picked the data that is within the range from 33rd to 53^{rd} minute before the state of changing to over-saturated flow state, namely Transition#2.
3. For Transition#2, we selected the data from 53^{rd} to 61^{st} minute (the state of changing to over-saturated flow).

From this design, it can be concluded into an appropriate observation time period of data separation for each state pattern illustrated in Table 3.

Table 3. Time period of each state for the training sets

States	Time Period (minute)
$S^{ff} \rightarrow S^{ff}$ (free flow)	30
$S^{sf} \rightarrow S^{sf}$ (saturated flow)	20
$S^{ff}_{t-1} \rightarrow S^{sf}_{t}$ (Transition #1)	3
$S^{sf}_{t-1} \rightarrow S^{of}_{t}$ (Transition #2)	8

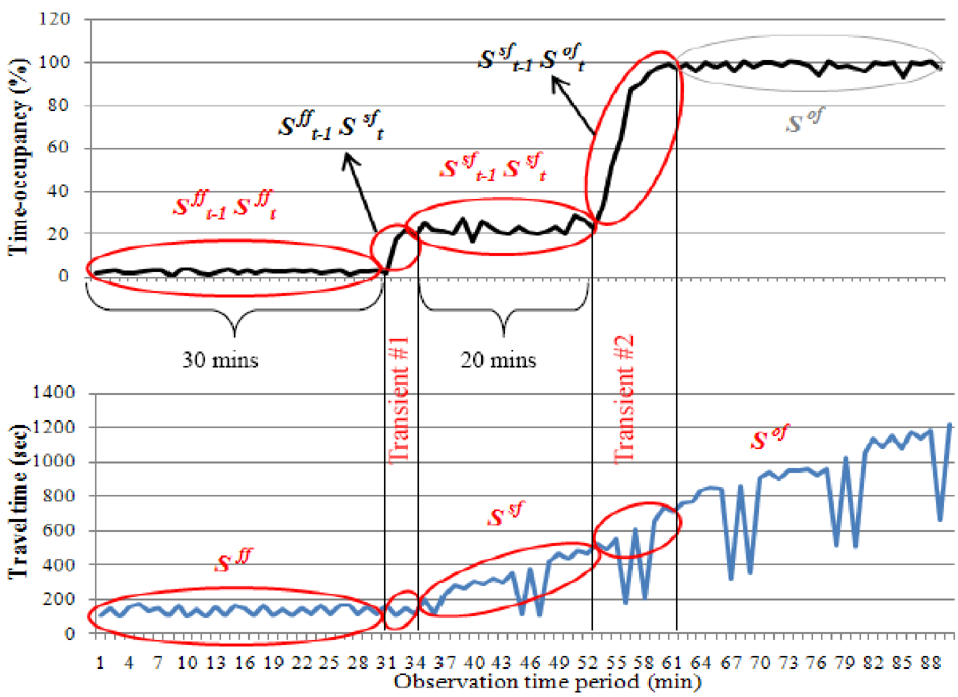

Figure 6. An example of the training data sets separation

4.3 Fitted Models for Proposed State Patterns

By applying Eq.6 with ARIMAX models in each state transition patterns, we finally get four equations represented by Table 4

Table 4. Proposed models applying ARIMAX

State Patterns	Proposed Fitted Models
$S^{ff}_{t-1} \rightarrow S^{ff}_{t}$	$T_t = 100.23+0.75O_t+1.07O_{t-2}+1.13O_{t-4}+\dfrac{(1-0.87B^{11})}{(1-0.05B-0.99B^{11})}Z_t$
$S^{ff}_{t-1} \rightarrow S^{sf}_{t}$	$T_t = 1.06-4.31O_t-5.39O_{t-2}+3.02O_{t-3}+\dfrac{(1+0.2B-0.8B^{5})}{(1-B)(1+0.98B+0.84B^{2}+0.93B^{3}+0.82B^{4})}Z_t$
$S^{sf}_{t-1} \rightarrow S^{sf}_{t}$	$T_t = 1.02-0.2O_t-1.8O_{t-6}-1.8O_{t-8}+\dfrac{(1-0.83B^{9})}{(1-B)(1-0.51B^{9})}Z_t$
$S^{sf}_{t-1} \rightarrow S^{of}_{t}$	$T_t = 304.94+12.4O_t-17.47O_{t-1}+9.36\,O_{t-4}+\dfrac{(1-0.98B^{8})}{(1+0.69B)}Z_t$

5. TEST DATA SET FOR PROPOSED SEPARATE MODELS

This part focuses on the accuracy test of our proposed models. First, we fed our test data, i.e. time-occupancy into the program of choosing models illustrated in Fig. 8. Then, the program processed and returned the sequence of 1, 1.5, 2 and 2.5 which means that we have to apply ($S^{ff}_{t-1} \rightarrow S^{ff}_{t}$),($S^{ff}_{t-1} \rightarrow S^{sf}_{t}$),($S^{sf}_{t-1} \rightarrow S^{sf}_{t}$),and ($S^{sf}_{t-1} \rightarrow S^{of}_{t}$)respectively.

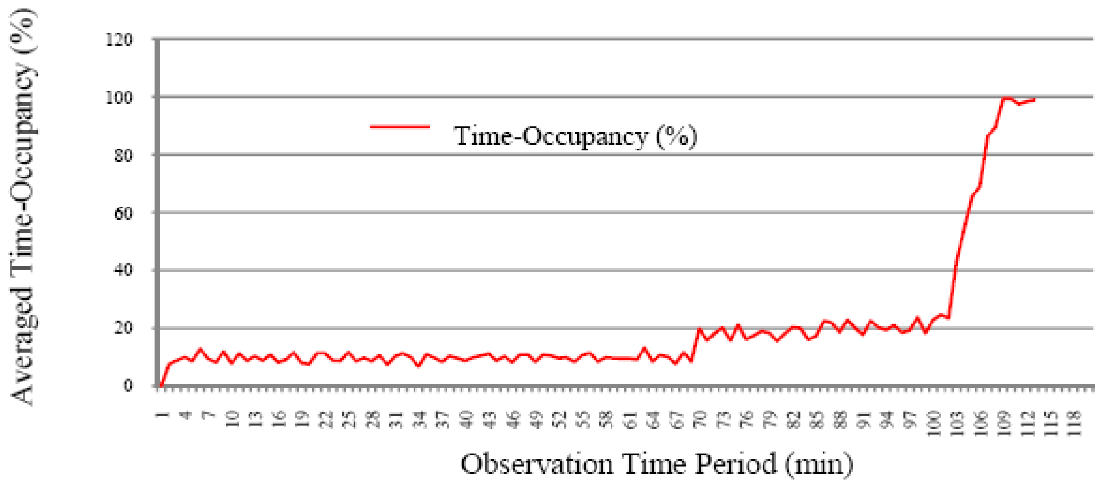

Figure 7. Test data set of the time occupancy data

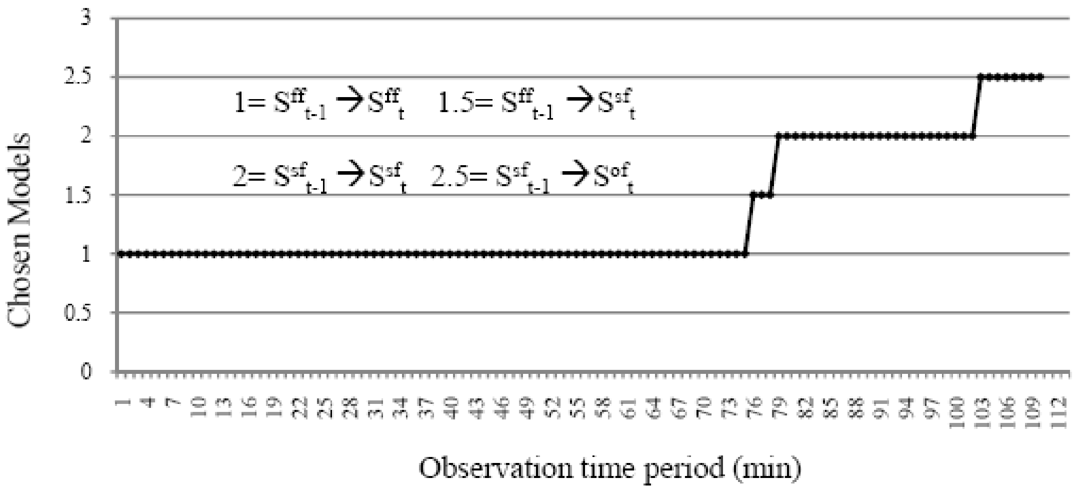

Figure 8. The models which are selected by checking the variance of time occupancy data

6. RESULTS

From the test data set in part 5, the result revealed that travel time estimation in free flow state using "Static Linear Regression Model" can estimate the travel time as accurately as our proposed model ($\mathbf{S^{ff}_{t-1} \rightarrow S^{ff}_{t}}$). This is because vehicles will not get disturbed by the others, so they could accelerate their speed up to maximum.

Considering the state transition, saturated flow state to the beginning of oversaturated flow state has some spikes occurred in simulated travel time. These spikes were caused by the traffic light that returned the travel time and time occupancy value when it was turned on. Travel time estimation with static linear regression model cannot estimate accurately when compared with our proposed models ($\mathbf{S^{ff}_{t-1} \rightarrow S^{sf}_{t}}$),($\mathbf{S^{sf}_{t-1} \rightarrow S^{sf}_{t}}$),and ($\mathbf{S^{sf}_{t-1} \rightarrow S^{of}_{t}}$) as shown in Fig. 9. This is because vehicles will be affected by the others especially the past residuals. Finally, we validate our proposed models by using mean absolute percent error as shown in Table. 5. This table shows that our proposed model ($\mathbf{S^{ff}_{t-1} \rightarrow S^{sf}_{t}}$),($\mathbf{S^{sf}_{t-1} \rightarrow S^{sf}_{t}}$),and ($\mathbf{S^{sf}_{t-1} \rightarrow S^{of}_{t}}$)can improve the accuracy of travel time estimation from the previous method by 19.91%, 24.67% and 20.69%, respectively.

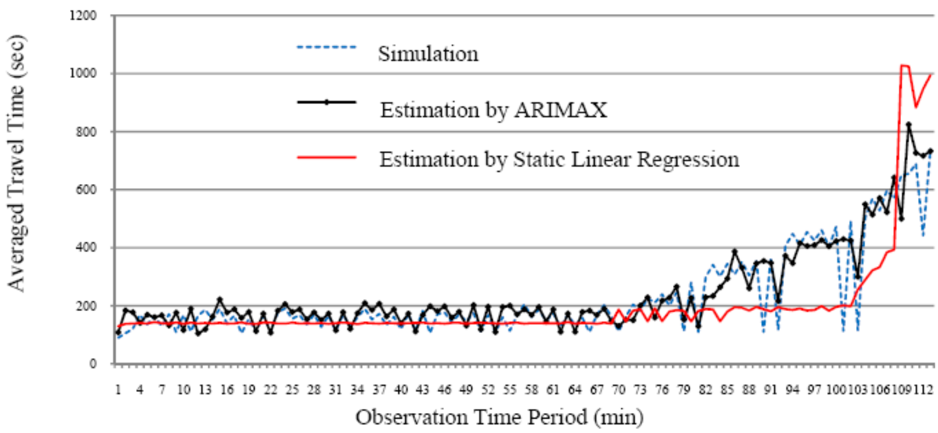

Figure 9. The result of estimated travel time series based on the proposed models

Table 5. Validation of the proposed models by mean absolute percent error (%)

Model types \ State Patterns	S^{ff}_{t-1} S^{ff}_{t}	S^{ff}_{t-1} S^{sf}_{t}	S^{sf}_{t-1} S^{sf}_{t}	S^{sf}_{t-1} S^{of}_{t}
Static Regression	17.9%	30.83%	51.7%	51.9%
ARIMAX	18.1%	10.92%	27.05%	30.21%

7. CONCLUSION

Travel time estimation based on time-occupancy using only static regression model is not sufficient for the case where past state has influence on the current state such as saturated flow state (S^{sf}) and over-saturated flow state (S^{of}). Transition period cannot be captured by Static Regression Analysis because it occurs during the state change from saturated flow state to over-saturated flow state. Therefore, this paper focuses on accuracy improvement of travel time estimation based on time-occupancy which depends on the state transition. We applied "Dynamic Time-Series Regression" instead of "Static linear Regression" and also proposed four state patterns i.e. ($\mathbf{S^{ff}_{t-1} \rightarrow S^{ff}_{t}}$),($\mathbf{S^{ff}_{t-1} \rightarrow S^{sf}_{t}}$),($\mathbf{S^{sf}_{t-1} \rightarrow S^{sf}_{t}}$), and ($\mathbf{S^{sf}_{t-1} \rightarrow S^{of}_{t}}$). The experiment results show that the vehicles move independently in the free flow state ($\mathbf{S^{ff}_{t-1} \rightarrow S^{ff}_{t}}$); as a result, the estimated travel time of our model and of the previous method (static linear regression) will not have much difference due to the fact that the past residual does not affect current travel time. In saturated flow state ($\mathbf{S^{sf}_{t-1} \rightarrow S^{sf}_{t}}$), the travel time will be increasing, as the number of vehicles left from the past increases. From the experiment, our proposed model for this state can improve the accuracy of travel time estimation because it is the time-dependent estimator. ($\mathbf{S^{ff}_{t-1} \rightarrow S^{sf}_{t}}$) and ($\mathbf{S^{sf}_{t-1} \rightarrow S^{of}_{t}}$) are the transition states which change from the free flow state to the saturated flow state and from the saturated flow state to over-saturated flow state, respectively. In this transition state, the travel time is affected by the residual from the past, therefore, the proposed model will be more efficient compared to the previous method (static linear regression) because the previous method can neither capture nor estimate the travel time in this transition state. However, the travel time estimation is not only affected by Time-occupancy alone, but it is also influenced by another parameter, i.e. Flow. In actual environment, Flow diversely occurs in many levels; as a result, it can have an impact on the accuracy of our estimation. Without considering Flow parameter, we focused on using only the available traffic data, i.e. Time-occupancy, in order to effectively estimate the travel time with more efficient method compared to the previous one. Therefore, the time series analysis was selected here because it is the statistical tool which depends on time. As for the actual implementation, variance of the time-occupancy data must be checked in order to select an appropriate model.

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TRENDY TRAVEL: EMOTIONS FOR SUSTAINABLE TRANSPORT

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Abstract: Trendy Travel: Emotions for Sustainable Transport is a project supported by the "Intelligent Energy – Europe" Programme of the European Community. The objective of the project is to achieve a major shift from the current travel behaviour that utilizes the personal car as the principal means of transportation towards more sustainable transportation modes, thereby ensuring substantial energy savings, considerable reduction of emissions and extensive cost savings. The main obtained and expected results are a change in perception and attitude towards sustainable transport and soft policies, integration of sustainable transport ideas and soft policies in city policy, utilization of promotion materials, dissemination of good practise results on a national and EU-wide level, energy savings, emissions reductions, cost savings. The paper elaborates the project objectives, implementation activities and results achieved so far. Besides, it also introduces how an EU-funded cooperative project involving several countries is structured and evaluated.

Key Words: Sustainable transport, Energy saving, Emissions reduction, Positive emotions

1. INTRODUCTION

The term sustainable transport stems from the term sustainable development. It is used to describe modes of transport that are consistent with wider concerns of sustainability. (Wikipedia, 2009) There are many definitions of the sustainable transport and of the related terms sustainable transportation and sustainable mobility. (Litman, 2009) Sustainable transport policies have their greatest impact at the city level. Many cities throughout the world have recognized to link sustainability and transport policies. The Local Governments for Sustainability, as an example, is an international association of local governments as well as national and regional local government organizations that have made a commitment to sustainable development. (ICLEI, 2009) The Partnership for Sustainable Urban Transport in Asia (PSUTA, 2009) has been collecting, reviewing, organizing, and disseminating information on sustainable transport in Asia.

At the European level the EU Commission has launched the Intelligent Energy Europe programme which is a tool for funding actions to save energy and encourage the use of renewable energy sources and move towards a more energy intelligent Europe. Among others there are several transport related projects so called STEER projects, such as the International Cluster for Mobility Management Development and Research Dissemination (MOVE), or Measures to Influence transport Demand to Achieve Sustainability (MIDAS). The Trendy Travel project is a three-year long research project funded by the Intelligent Energy Europe Programme (IEE, 2009). The project started in November 2007 and will end in 2010. The consortium consists of 13 project partners (municipalities, energy agencies, educational, mobility and health institutions) coming from 11 EU Member States (Figure 1).

- CCC - Cork City Council, Ireland (Coordinator)
- AGEAS - Salerno, Italy
- PMO - City Hall of Oradea, Romania
- FEMMO - Energy Agency in Aarhus, Denmark
- FGM-AMOR - Austrian Mobility Research, Austria
- Modellschule - Graz, Austria
- SIU - Szechenyi Istvan University Györ, Hungary
- EAP - Energy Agency of Plovdiv, Bulgaria
- NS - NS Nederlandse Spoorwegen, the Netherlands
- ÖKI - Ökoinsitut Südtirol, Italy
- MARTIN - City of Martin, Slovakia
- VHCB - Vilnius Health Bureau, Lithuania
- BUS -Consulting, Lisbon, Portugal

Figure 1. Project partners

The paper elaborates the objectives set by the project partners as well as the implementation activities and results achieved so far. Besides, the paper also introduces how an EU project involving several countries is structured and evaluated.

2. OBJECTIVES

The main objective of the project is to make sustainable travel more emotionally appealing, so as to affect a modal shift from the car to healthier, more eco-friendly transport modes.

This will be achieved by utilizing emotional approaches like:

- Storytelling: absorbing stories capture listeners, readers and viewers
- Rituals provide structure: bicycle events throughout the year
- Raising the image of cycling: particularly in the New Member States
- Pleasing the eye: good design for sustainable transport
- Parents are touched: how children can guide parents towards sustainable transport.

This objective will be achieved by completing various short-term and long-term goals. Shortterm goals are:

- Achievement of a positive perception and attitude towards sustainable transport
- Integration of sustainable transport and soft policies in municipal policy
- Utilization of promotion materials produced in Applications
- Creation of virtuous circles (upward spirals) for sustainable transport
- Dissemination with high impact on national and EU-wide level
- Energy savings through a modal shift in the order of 2 million litres fuel annually.

Long-term goal is the propagation and expansion of these policies throughout Europe and beyond.

3. IMPLEMENTATION

The consortium consists of individuals that are either key actors in the field of sustainable transport and mobility culture, members of one of the target groups or essential specialist professionals.

Orientation towards the New Member States is reflected in the fact that 5 of the 13 consortium members come from the New Members States.

3.1 Key actors

Partners come from 13 countries and 11 cities. They consist of municipalities, energy agencies, educational institutions, mobility and health agencies as well as one advertising agency. This is complemented by the involvement of several public transport companies and several design and fashion schools (from Aarhus, Cork and Graz), either as project partner, as subcontractor or as external partner. The structure and theme of the Applications guarantees the involvement of even more specialists and key actors.

3.2 Target groups

Target groups can be distinguished as follows:

- Current users and potential users of clean urban transport are the general public composed of different target groups, as public transport users, cyclists, school children etc.
- So called “multipliers” - people that influence other people with their opinion should be young professionals motivated at an early formative stage in their career to engage themselves in the topic of sustainable transport by using Trendy Travel approaches.
- Practitioners in public transport companies, energy agencies, educational institutions, municipalities and regions. Many of the practitioners with hands-on-experience take part in the project directly others are reached by the dissemination programme.
- Decision makers in public transport companies, energy agencies, educational institutions, municipalities and regions are part of the Trendy Travel project as coordinators and as part of the consortium.

3.2 Involvement of key actors and the target groups

Active involvement of key actors and the target groups is fundamental for the success of the Trendy Travel Project.

- Many key actors and target groups are involved directly in the project and therefore have a hand-on experience - learning by doing is the best way to communicate new concepts.
- General meetings always include a workshop section - providing practitioners with a platform to communicate their experiences.
- National workshops in local languages serve as an origin of a national network of initiatives emulating Trendy Travel applications.
- Through the various enquiries in the evaluation, extra contact has been made with decision makers and practitioners in order to get their direct opinion - before and after this also leads to involvement.

4. PROGRESS AND ACHIEVED RESULTS UNTIL 2009

So far, about 50 events, activities or promotion campaign have been carried on. The project website has been created and is regularly updated. A Dissemination Plan has been distributed within the partners. In addition, Trendy Travel has been accepted as an official member of the Sustainable Energy Europe Campaign (www.sustenergy.org).

4.1 WP1 “Project management”

The task “Preparing and organising the meetings” is in progress. During this interim period, four meetings have been organised with a specific support from the host partners: BUS Consulting, City of Martin, FGM-AMOR and VHCB. The quality assurance document and a risks analysis are regularly updated.

4.2 WP2 “Concept and Adaptation”

The task 1 “State of the art and categorisation” started in December 2007 and finished in June 2008. The lead partner is FEMMO, which realised and uploaded an optional template for describing different projects or marketing materials. All partners have contributed to the State of the art collection by uploaded descriptions of projects or marketing materials on the website leading to the “Toolbox of relevant State of the Art materials, Templates and Guidelines for application”.

The task 2 “Application Framework” started in January 2008 and finished in September 2008. The lead partner is FEMMO, which realised and uploaded a “Guideline on how to use the toolbox”.

The task 3 “Detailed implementation for all Applications” started in October 2007 and finished in March 2009 through the “Implementation plans for all applications”. The lead partner is FEMMO who has prepared a template for the “Reporting Structure”. Partners have uploaded their plans on the intranet.

4.3 WP3 “Trendy applications”

4.3.1 Storytelling

The task 1 “Storytelling” started April 2008 and was finished in June 2009. NS has developed three promotional campaigns: Health and Train campaign, Sustainability campaign and Infotainment. The last one is a storytelling competition on “positive travel experiences”. FGM AMOR organised a writing contest on the “positive emotions related with sustainable transport in urban areas”. In addition and as part of the “Set of movie clips”, two video clips, “The Exam” and “The Miracle”, have been produced with the objectives to be a dissemination tool and to make people think about transport. CCC as well organised a Storytelling competition based on "The joys of cycling. VHCB organised a poems competition for teenagers on "the most interesting weekend trip by my bicycle" in February 2009.

4.3.2 The bicycle event year

The task 2 "The bicycle event year" started in December 2007.

CCC has organised 11 events in 2008 and in 2009: a bike swap shop in March 2008, a bike to work week in May 2008, a training course for adults, a bicycle ballet, arts cycling festival, a rebel pedal parade, a cycle chic fashion show, a warm drinks for trendy commuter initiative, an awareness campaign, a training course and a bike flea market. In December 2008 CCC has published "Calendars to promote events in Cork" (figure 2).

Figure 2. Calendars to promote events in Cork, Ireland

AGEAS organised 15 cycling tours in 2008 and in 2009: Mozzarella in bici, I limoni della Costiera, Costiera Amalfitana Sud, Ciclamina in Pontecaganan, Costiera Cilentana, Capelli di Venere, Bagno nel fiume Calore, Punta Licosa, Cis Alentum, Alto Cilento, Nocera in bici, Tempo di Castagne, Sagra del fagiolo, The parks of the city of Salerno, Mozzarella in bici. Some events have been organised with the FIAB (Italian Federation of Bike-friends).

FEMMO has sorted its co-funding issues and is now able to fully implement its activities. As a result, one activity has been organised: Bicycle fair in March 2009.

SIU has organised 5 activities in 2008: Pilot project of a Bike rental leisure service, Bike competition, Alleycat, Recreational tours, Warm Drinks for cyclists.

VHCB organised seven events in 2007 and in 2008: a contest "My bicycle, me and my parents" held at schools and kindergartens, contest "My bicycle, me and my parents" held at schools and kindergartens a Training of children in 10 kindergartens "Safe cycling on bicycles", a fashion contest throughout schools "I am the best dressed cyclist in Vilnius city" a Bicycle carnival in Vilnius city "Bicycle the new fashion in Vilnius", a training "Children part of a safe traffic", a promotion campaign "To school on my bicycle!" and an exposition of children drawings "Clear air for all".

4.3.3 Raising the image of cycling

The task 3 "Raising the image of cycling" started in August 2008.

VHCB organised information meetings with the community of Vilnius city in 8 districts, kindergartens and schools, as well as a study on the activities organised within the Trendy Travel project.

SIU popularized the Trendy campaign in the University homepage website and marketing campaigns within the campus.

EAP has developed a video clip for local authorities in order to urge the creation of parking stations and safe lanes for bicycles. In addition, EAP renunced to promote cycling with famous local sportives as it could be conter productive.

FGM-AMOR has developed the "Brochure on 21 good reasons for cycling in 6 languages" in March 2009.

The "Template and guide to carry out the survey for "Bicycle climate test" has been delivered and uploaded by FEMMO in May 2008. All the partners have completed the bicycle climate test. The same test will have to be carried and delivered to SIU for March 2010.

The "Pictures books for kindergartens" prepared by the City of Martin has been translated in German, Italian and English (See figure 3).

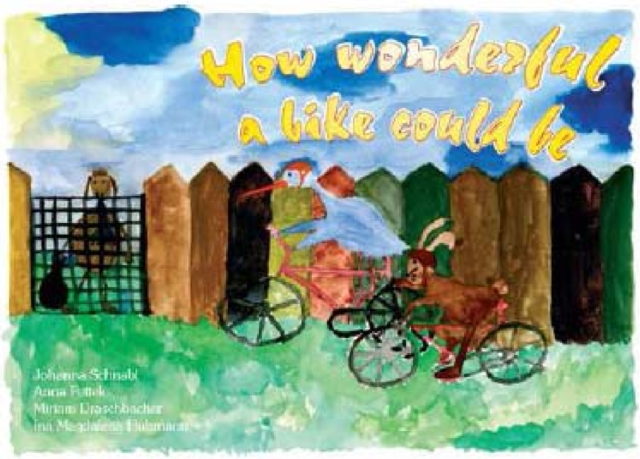

Figure 3. Picture books for kindergartens

4.3.4 Pleasing the eye

The task 4 "Pleasing the eye" started in February 2008.

NS has organised a Colour and Light experiment during the summer 2008.

FGM-AMOR has produced Piccolo Comics on walking, cycling and using public transport. A calendar has as well been delivered and won a prize on the national level. They have also produced a website called Emotions, where an international photo competition has been organised among others (figure 4).

Figure 4. Emotions website – Photo competition

MODELLSCHULE has worked with its students on 4 projects: Trendy Clip (video clip), Trendy T-Shirt, Trendy-Man, Exhibition of photographs. They have prepared a bicycle helmet design and illustrations, picture stories, newspapers, bicycle drawings (figure 5), graphic work, collages "traffic", photographs and paintings. These materials were used for the “Set of cartoons, illustrations & comic strips and photo stories” and the “Database on paintings, drawings & photos” (September 2009).

Figure 5. Pleasing the eye – artwork exhibition in Graz, Austria

OKI has produced 2 documents: A Guideline for Good Design in cycling with corporate design, logo, guidance system, information, communication and marketing activities, and An On-Line Toolkit to download.

4.3.5 Children guide parents

The task 5 “Children guide parents” started in March 2008.

In addition to the events organised in task 2, AGEAS organized “Bimbi in Bici” in May 2008 for children up to 11 years. OKI organised two meetings with politicians and decision makers of the city of Bolzano. With the assistance of the City of Bolzano and the police, OKI is now implementing four modules in 7 kindergartens (26 groups, 609 children, German and Italian): Kindergarten lotto, Learning to cycle, Bike rental system and Bike workshop.

OKI has translated in Italian the “Pictures books for kindergartens” prepared by the City of Martin but is as well developing a new book.

MARTIN worked on the education of children in kindergarten (traffic education at kindergarten Zaturcie, see figure 6) and bought 10 bicycles from for the Zaturcie kindergarten. In cooperation with JUS (bicycle group of Turiec region) and the City Architect Office, the City of Martin has so far implemented eight educational activities on traffic education: Martin’s bicycle day in May 2008. Cycling trip with kids and their parents, Traffic lights has two hands in October 2008, Interactive theatre about air pollution and Talking Semafor in November 2008, The best friends, Recycling train, Interactive theatre for kids in winter 2009, The traffic lights does not have fear in March 2009. Figure 6. Education of children in kindergarten, Martin, Slovakia.

VHCB is implementing its events calendar in 143 preschool and 150 schools.

4.4 WP4 “Evaluation”

The task 1 “Monitoring and Helpdesk” started in November 2008. The lead partner is SIU, which collected data for the indicators before implementation (also discussed in the table of chapter 3.7).

The task 2 “Guiding the learning process” started in November 2008 and is in progress.The task 3 “Evaluation” started in February 2008. All the concerned partners have completed the bicycle climate test. The same test will have to be carried on and delivered after implementation in March 2010. The “Report on the indicators or impacts of the project activities in each site” has been delivered and will have to be updated by each partner and delivered to SIU for March 2010 as well. Concerning the “Results of the survey on attitudes”

SIU will keep monitoring the project progress by using the Implementation plans and the Quality Assurance.

Survey on attitudes

The target group is constituted of citizens and transport users divided into two groups: citizens under and over 25 year, furthermore decision-makers/politicians, representatives of NGO-s, journalists, and transport experts. Opinions of 3-5 persons per each of the 6 above mentioned target groups has been surveyed in each partner cities. Altogether 216 persons have been asked to answer our questions. All polled was asked to rate the statements from 1 to 6, whether they agree absolutely (1) or do not agree at all (6) with them. Regarding the last statement as an example "If a choice has to be made between bicycle-traffic and car traffic, cyclists should get priority (infrastructure, regulations, funding)" the group of NGO was the most positive whereas the group of citizens over 25 and the politicians were less positive (see Figure 7).

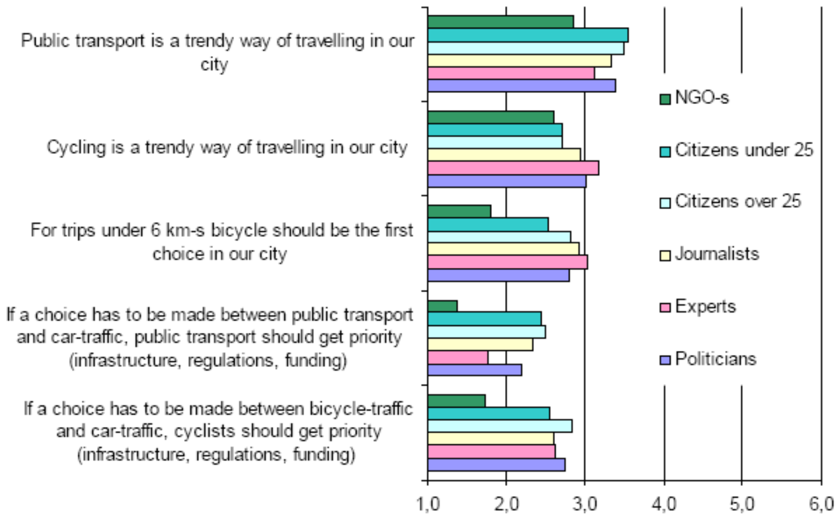

Figure 7. Survey on attitudes, example of the results

4.5 WP5 "Communication and Dissemination"

The task 1 "Dissemination plan" is finished. The lead partner was FGM-AMOR but contributions from all the partners were requested.

The task 2 "Website" is constantly updated by the lead partner FGM-AMOR. Contributions from all the partners are requested.

The task 3 "Merchandising and Dissemination materials" started in January 2008 and is in progress. The "Power Point Standard Presentation" to be used at the meetings during the project has been created by CCC and uploaded in March. The "Teaser postcards to promote the website" has been delivered in February 2009.

The task 4 "Piggyback dissemination through networking" started in April 2008 and is in progress. TRENDY TRAVEL has been accepted as an official member of the Sustainable Energy Europe Campaign (www.sustenergy.org). FGM-AMOR participated to Summer University in Stuttgart and Genoa in May and June 2008. Partners are encouraged to contribute to known platforms (Wikipedia and YouTube, News and case studies for the EU database ELTIS, TT in ELTIS-Newsletter, on Intelligent Energy Europe and Sustainable Energy Europe), to network with EU-wide networks (CIVITAS, ECF, UITP), to network with STEER projects and similar EU projects (EPOMM, MAX, Added Value,

Emotions), to investigate in which networks their city / organisation is involved (twinning cities, university networks, PT networks etc) and to provide the networks regularly with information.
The task 5 "Local Dissemination" started in January 2009. Partners have been asked to upload on the intranet their Local Dissemination Plans and to start preparing the National Dissemination Workshops.

4.6 WP6 "Common dissemination activities"

The task 1 "Online information" started in October 2007 and is in progress. In relation with WP5, task 2, online information on the website constantly updated by FGM-AMOR through CCC information. The lead Partner is CCC but contributions from all partners are required.

The task 2 "Event participation" started in December 2007 and is in progress. In March 2007, CCC as coordinator of TRENDY TRAVEL participated to a Joint SEC and STEER Workshop and Co-ordinators Meeting organised by the EACI, on March 12th and 13th 2008. In February 2009, AGEAS and FGM-AMOR took part in the European Sustainable Energy Week.

4.7 Interim review of performance indicators

During this period between 2007 and 2009 80% of the defined indicators are on progress to be fulfilled.

Performance indicator	Quantification of success	Results
Number of contributions to the Short story contest	20	Results in June 2009
Number of downloads of Video clips, cartoons, comic strips,	5000 downloads per year	In progress
Awareness of the benefits of physical movement in NL	Awareness Rising from 45% to 65% among train commuters of NL	In progress
Scheduling and implementation of Bicycle year / Bicycle events	At least 2 cities with 5 events and further 4 cities with 2 events per Year At least 2000 participants in the events	- 15 events per year in Salerno - 12 events per year in Cork - 5 events per year in Gyor - 7 events in Vilnius
Integration of Cycling Year activities in the normal routine of a city (budget, job description)	At least in 2 cities	In progress in Cork and Salerno
Number of cities/questionnaires for the Bicycle climate test	11 cities carry out at least 1000 questionnaires to evaluate the impact of WP3 cycling promotions	- 10 cities have carried out 180 questionnaires each - 10 cities have carried out 180 questionnaires each in Spring 2010
Uptake of Bicycle promotion events in Vilnius	Al least 25 events with more than 1500 participants Increase of demand and frequency of clients in bicycle shops of 10%	In progress, 7 events in Vilnius (VHCB)
Increasing interest in cycling resulting from testimonials of famous cyclists etc. in the city of Martin	Increase of demand and frequency of clients in bicycle shops of 5-10%	In progress
Increase in cycling arising from the Cycling year and image raising for cyclists activities	Increase in number of cyclists on representative road sections by 5-40% in involved sites.	In progress
Number of Kindergartens implementing cycling training,	At least 10 kindergartens in 3 different cities	OKI MARTIN VHCB FEMMO

Performance indicator	Quantification of success	Results
Number of Kindergarten lotteries	At least 3 kindergartens with more than 200 participants	3 kindergartens lottery in Bolzano with 609 participants 4 kindergartens lottery in Vilnius with 370 participants
Environmental indicator 1: Fuel/Energy savings	2.3 Million litres of fuel saved per year compared with the do nothing scenario	In progress
Environmental indicator 2: Emissions reductions.	7.000 tons CO2 saved per year compared with the do nothing scenario	In progress
Cost indicator: fuel cost savings	2.5 Million Euros saved in direct fuel costs per year compared with the do nothing scenario	In progress
Website, requests per month	7000 requests per month	3,500 requests per month in November 2008
No of national workshops to disseminate TRENDY TRAVEL know how in the language of potential applicators	Workshops in 10 countries 250 participants	1 workshop has been hold in Lisbon (BUS) 1 workshop is planned in the Netherlands (NS) 1 workshop is planned in Cork (CCC)
Rollup, Poster, ppt presentations	Trendy Travel materials disseminated at minimum 20 piggy back events	12 European events or networks
Media recognition	At least 50 media reports covering TRENDY TRAVEL applications	104 reports

5. LONG-TERM SYSTEM IMPACT

Direct outcomes will be: Energy savings at the demonstration sites in the order of 2 million litres of fuel against the trend, and a set of deliverables and dissemination material to promote sustainable travel habits.

Ideally, all EU cities can be reached. Thus, Trendy Travel will contribute to a substantial modal shift from single car use towards energy-efficient sustainable transport – thereby reducing energy consumption, reducing pollution and health problems, reducing accidents and enhancing the quality of life - especially in cities.

Some basic facts illustrate the motivation for the emotional promotion of clean urban transport:

- more than 50% of all human decisions are emotional - often against rational awareness
- most marketing campaigns for cars target human emotions
- more than 90% of all marketing expenses for transport comes from car manufacturers

Trendy Travel aims to ensure that Public transport, cycling and walking are associated with positive emotions like excitement, fun, being moved (in the heart), lust for life, pride etc.

Direct results of the various approaches - to be concluded by the end of Trendy Travel:

- A change in perception and attitude towards sustainable transport and soft policies
- Integration of sustainable transport ideas and soft policies in city policy
- Utilization of promotion materials created during Trendy Travel
- Creation of virtuous circles (upward spiral) for sustainable transport
- Dissemination of good practice results on a national and EU-wide level
- Energy savings, emissions reductions, cost savings

Long-term changes achieved by implementing the approaches - to be continued after the end of Trendy Travel:

- Ritualisation of events established through the bicycle calendar launched during Trendy Travel.
- Sustainable behavior modification through early education.
- Continued propagation of Trendy Travel approaches through integration in other networks like ELTIS and EPOMM.
- Financing of Trendy Travel tools with the maintenance budgets of respective partner cities.
- Integration of tasks for Trendy Travel measures into job descriptions of responsible municipal employees.
- Large scale transformation of policy decision regarding the implementation of sustainable transport modes.

6. CONCLUSION

The paper presents an EU-funded project supporting sustainable transport modes. It introduces the objectives and implementation activities of the Trendy Travel project. It mainly focuses on the implementation, evaluation as well as dissemination activities. A detailed overview of the performance indicators is given and also expected long-term impacts are highlighted.

The paper also demonstrates how a typical EU project is structured into work packages, what types of activities are performed and how the results are disseminated and evaluated.

The interim project results proved that soft measures – including education, marketing and information campaigns – can have productive roles in the essential work of making progress towards green and sustainable transport. Soft measures should complement hard measures (such as the provision of infrastructure) as they can contribute to a better acceptance. The Trendy Travel project is also a good example to demonstrate how emotional activities can make sustainable transport more appealing by illustrating the benefits of living without a car.

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APPLICATION OF MULTIPLE CRITERIA DECISION MAKING (MCDM) ON HIGH POTENTIAL CITY BUS ROUTES IN TAIWAN

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Abstract : The convenience of life comes from efficient transport. However, an improper public transport planning may decrease customers' satisfaction. This research shows the planning on intercity high potential bus routes is complex and closely linked with environment, energy and sustainable development. Private drivers cannot endure long bus headway and poor service quality. Bus companies are difficult in a trade-off dilemma between service quality and operation cost. In this research hybrid multiple criteria decision-making (MCDM) model is applied, with decision-making trial and evaluation laboratory (DEMATEL) method. An empirical case in Taichung Metropolitan is illustrated to show the advantage of MCDM model and discloses the important factors for bus route planning strategies.

Key Words: bus routes management, DEMATEL, multiple criteria decision making, MCDM

1. INTRODUCTION

Bus route system takes a very important part in urban public transport system. However, due to high competitive private vehicles in Taichung, the bus passenger rate declines annually. Low profit income of bus operator causes poor bus service quality. Poor service quality causes low passenger rate, and then makes the profit lower again. The vicious spiral seriously deteriorates the bus service. How to find out potential bus line routes and carefully manage them becomes a chance to improve the situation.

This research aims to unfold key factors of bus passenger satisfaction. It is believed that these key factors can contribute to operation strategies carried out on the selected potential bus line experts, government officers, and academic professors. Four scopes of passenger, operator, manager, and socioeconomic were considered to give insights to bus operation management. We hope this research can provide practical and feasible solutions to alter the vicious spiral into a virtuous circle and create a sustainable transport environment in Taichung. The paper summarizes in Section 2 important researches regarding the hypotheses, effects, and influence of evaluate planning on high potentiality city-bus routes. In Section 3, DEMATEL technique is introduced and a model is established using these techniques. In Section 4, there is an empirical study showing the high potentiality city-bus routes environmental evaluate planning in Taichung, Taiwan. The results are compared with the traditional additive evaluation model. Section 5, summarizes and give conclusions.

2. MEASUREMENTS OF CITY BUS ROUTE PLAN

This research analyzed the planning of urban bus line route with respect to passenger (user), operator (bus company), and controller (government). The three scopes proposed by Kuo (2000) would be considered to cover demands for government policies. Chu (1995) and Wang (2000) think that the selection of bus line routes should follow three principles: (1) analysis to concerned layers, (2) preference to quantitative indices, and (3) index independence. In practice work, Huang (2000) mentioned that the planning goal of bus route will differ according to roles of commuter, operator, or controller. This research integrated the advantages and proposed 22 representative criteria from scopes of passenger, operator, controller and the socioeconomic.

3. PROPOSED MODEL: MCDM MODEL

In Section 2, this research organizes and sets up the evaluate planning on high potentiality city-bus route system that will exert an influence in high potentiality city-bus route efforts. Impact will be made when the government, educational circles, and industries make coordinated plans and efforts, researching the relations and different literary composition dimensions and criteria of the high potentiality city-bus route.

Thus, the great user of the city-bus evaluate plan is to consider things in detail. This great user includes average traveling time, travel cost, waiting time, transfer frequency Transfer frequency. It can be difficult to quantify precise values in complex evaluation systems. A complex evaluation environment can, however, be divided into subsystems to facilitate differentiation and score measuring. Thus, the relationship between route structures and their degree of interdependence are determined from the result of DEMATEL technique.

3.1 Clarifying interrelations between criteria discussion and conclusion

In a complex system, all criteria are related, either directly or indirectly, making it difficult to define a specific objective/aspect in isolation. While the vision of an interdependent system can lead to passive positioning, a clear hierarchical structure can lead to linear activity, with no dependence or feedback, which may create new problems (Tzeng et al., 2007).

Study for explore nature and research that quantize, so-called quantization it studies to be every problem quantity, probe into issue their through difference of quantity, and method, question of quantity, research this utilize way of questionnaire go on. Quality research requires probing into the characteristics of the definition, way, or metaphor and researching the quality that is designed to be a problem for every criterion, go on through way, expert interviews to analyze. Its purpose lies in that it is relevant for the bus route plan program to probe into that residents' comfort as impacted by the bus route plan as seen through documents, user, operation, maintain, and society. The influence continues in the local bus system by looking for and going against its influence degree, and then we must set up some basic concept tactics with these questions. Our research utilizes, comments, and allows the decision method to be the main analysis tool.

In Section 2, we discussed bus system program and bus system development to construct dimensions and 20 criteria with four dimensions to influence as we have seen through previous research. Through the research of quantization, it influences the weight in the bus system program and assesses the comprehensive performance to influence degree and every criterion which the bus system program probes into every criterion, is it construct dimensions is it is it improve four based on scheme direction of research basically to put forward to set up after the pluses and minuses to understand. The main analysis tool that this research institute uses is DEMATEL method; the purpose of using its analytical method is as follows: 1) use DEMATEL to construct the affirmation that influences the relationship among criteria; 2) probe into and look for an offering to influence the resident's life to be compatible with the bus system plan through documents, the bus system in some urban areas now fall into “The market shrinkage, operator passive improvement, and the lower level of service,” and makes the mark getting worth and worth.; and 3) point out in previous research the bus system management it’s necessary to figure out some important criteria of bus routes’ planning and operating about users, operators and the government and find the relationship of all criteria to make it better and make a three-way win for users, operators and the government that connects with each dimension and criterion. However, the part mentioned in documents has not been completed yet. Thus, we utilized DEMATEL to construct the affirmation of the influence relationship among the dimensions and criteria (Tzeng, 2007; Huang et al., 2005; Liou et al., 2007; Chiu et al., 2006; Liou et al., 2008; Chen et al., 2008a, 208b; Chen et al., 2010).

3.2 DEMATEL technique

The DEMATEL technique was used to investigate and work out the complicated problem group. DEMATEL was developed with the belief that the pioneering and proper use of scientific research methods could help illuminates specific and intertwined phenomena and contribute to the recognition of practical solutions through a hierarchical structure. The methodology, according to the concrete characteristics of objective affairs, can verify interdependence among variables/attributes and confine the relationship that reflects the characteristics with an essential system and evolution trend (Chiu et al., 2006; Huang and Tzeng, 2007).

DEMATEL has been successfully applied in many situations, such as marketing strategies, e-learning evaluations, control systems, and safety problems (Hori and Shimizu, 1999; Liou et al., 2007; Tzeng et al., 2007; Ou Yang et al., 2008; Chen et al., 2008a, 208b; Chen et al., 2010)

The method can be summarized as follows:

Step 1: *Calculate the direct-influence matrix by scores.* Based on experts’ opinions, evaluations are made of the relationships among elements (or variables/attributes) of mutual influence. Using a scale ranging from 0 to 4, with scores representing ‘no influence (0),’ ‘low influence (1),’ ‘medium influence (2),’ ‘high influence (3),’ and ‘very high influence (4),’ respectively. The digraph can portray contextual relationships between the elements of the system as shown in Figure. 1. For example, an arrow from *b* to *a* signifies that *b* affects *a*, and its influence score is 2. They are asked to indicate the direct effect they believe a factor *i* will have on factor *j*, as indicated by a_{ij}. The matrix *A* of direct relations can be obtained.

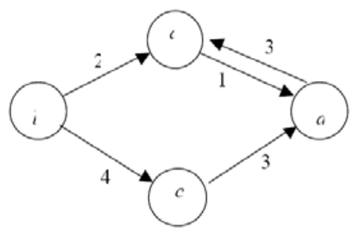

Figure 1. The directed graph

Step 2: *Normalizing the direct-influence matrix.* Based on the direct-influence of matrix ***A*,** the normalized direct-relation matrix ***D*** is acquired by using formulas (1) and (2).

$$\boldsymbol{D} = k\boldsymbol{A} \quad (1)$$

$$k = \min\left\{1/\max\sum_{j=1}^{n} a_{ij}, 1/\max_{j}\sum_{i=1}^{n} a_{ij}\right\}, \quad i,j \in \{1,2,\ldots,n\} \quad (2)$$

Step 3: *Attaining the total-influence matrix T.* Once the normalized direct-influence matrix ***D*** is obtained, the total-influence matrix ***T*** of NRM can be obtained through formula (3), in which ***I*** denote the identity matrix.

$$\boldsymbol{T}=\boldsymbol{D}+\boldsymbol{D}^2+\boldsymbol{D}^3+\ldots+\boldsymbol{D}^k=\boldsymbol{D}(\boldsymbol{I}+\boldsymbol{D}+\boldsymbol{D}^2+\ldots+\boldsymbol{D}^{k-1})$$

$$[(\boldsymbol{I}-\boldsymbol{D})(\boldsymbol{I}-\boldsymbol{D})^{-1}]= \boldsymbol{D}(\boldsymbol{I}-\boldsymbol{D}_k)(\boldsymbol{I}-\boldsymbol{D})^{-1}$$

Then,

$$\boldsymbol{T}=\boldsymbol{D}(\boldsymbol{I}-\boldsymbol{D})^{-1}, \text{ when } k \rightarrow \infty, D^k = [0]_{n\times n} \quad (3)$$

where $\boldsymbol{D} = [d_{ij}]_{n\times n}$, $0 \leq d_{ij} < 1$, $0< \sum_{j=1}^{n} d_{ij}, \sum_{i=1}^{n} d_{ij} \leq 1$. If at least one row or column of summation, but not all, is equal to 1, then $\lim_{k\rightarrow\infty} D^k = [0]_{n\times n}$.

Step 4: *Analyzing the results.* In this stage, the sum of rows and the sum of columns are separately expressed as vector $r = (r_1,\ldots,r_i,\ldots, r_n)'$ and vector ₁ $c = (c_1,\ldots,c_j,\ldots, c_n)'$ by using formulas (4), (5), and (6). Let $i=j$ and $i,j\in\{1,2,\ldots,n\}$; the horizontal axis vector ($r+c$) is then made by adding r to c, which illustrates the importance of the criterion. Similarly, the vertical axis vector (r-c) is made by deducting r from c, which may separate criteria into a cause group and an affected group. In general,

when (r-c) is positive, the criterion is part of the cause group. On the contrary, if the (r-c) is negative, the criterion is part of the affected group. Therefore, the causal graph can be achieved by mapping the dataset of the (r+c, r-c), providing a valuable approach for decision-making.

$$\boldsymbol{T} = [t_{ij}]_{n\times n}, \qquad i,j = 1,2,\ldots,n \quad (4)$$

$$r = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = [t_{i.}]_{n\times 1} = (r_1,\ldots,r_i,\ldots, r_n)' \quad (5)$$

$$c = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} = [t_{.j}]_{n\times 1} = (c_1,\ldots,c_j,\ldots, c_n)' \quad (6)$$

where vector ***r*** and vector ***c*** express the sum of rows and the sum of columns from total - influence matrix $\boldsymbol{T} = [t_{ij}]_{n\times n}$ of respectively, and superscript denotes transpose.

4. AN EMPIRICAL CASE: HIGH POTENTIAL BUS ROUTES IN TAICHUNG

In Taiwan, the study case is the high potentiality city-bus in Taichung. Evaluation plan systems are complex organisms, comprised of environmental, software, hardware, and human factors. It is clear that high potentiality city-bus evaluation plan measures must be context-dependent and based on real operations, and each dimension having three to ten criteria. A survey was conducted through giving questionnaires to three groups comprising 15 experts, five of them from university domain expert scholars (including Transportation Technology and Management, Land Management, Urban Planning, Environment Technology, and Traffic Management), another five from government departments, and the last five from related industry. Their ratings of each criterion, with respect to sustainable development, used a 5-point scale ranging from 0 (no influence) to 4 (very high influence) as defined in section 3.2. The highest scoring three criteria from each dimension were extracted to construct the system for measuring the high potentiality city-bus evaluation plan. Since comprehensive conservation rates in the high potentiality city-bus evaluation plan systems are important factors in plan measurements, they were used as a further criterion (Table 1).

Table 1. Dimensions and criteria for the high potentiality city-bus evaluation plan system

Dimensions	Criteria
User ($D1$)	Average traveling time (C_1) Travel cost (C_2) Waiting time (C_3) Transfer frequency (C_4)
Operation ($D2$)	Operating cost (C_5) Revenue (C_6) Service standards (C_7) Average turnaround time (C_8)
Maintain ($D3$)	Operating region (C_9) Operations (C_{10}) Fare (C_{11}) Finance (C_{12}) Facilities (C_{13}) Traffic network transport efficiency (C_{14}) Traffic network density (C_{15}) Traffic network service efficiency (C_{16}) Route coverage and repetition rate (C_{17}) Route directness & circuitry (C_{18})
Society and economy ($D4$)	Pollution cost (C_{19}) Congestion cost (C_{20}) Budget excluding by subsidies (C_{21}) Social Welfare (C_{22})

4.1 Building influence relationship matrix of the high potentiality city-bus evaluation plan analysis

The aim is not only to determine the most important plan criteria but also to measure relationships among criteria. A questionnaire was used to gather these assessments from three groups of 15 academic, government, and industry expert scholars (including university experts. Their ratings of each criterion, with respect to sustainable development, were based on a 5-point scale ranging from 0 (no effect) to 4 (very high influence). The highest scoring three criteria from each dimension were extracted to construct a system for measuring a bus route plan. Since comprehensive conservation in bus route plan systems rates has important factors in plan measurements, they were used as a further criterion. The aim is not only to determine the most important plan criteria, but also to measure relationships among criteria. The watershed experts were thus asked to determine the importance of the relationships among the dimensions. The average initial direct-relation 4×4 matrix A, obtained by pair-wise comparisons in terms of influences and directions between dimensions, is shown as Table 2.

Table 2. The initial influence matrix *A*

Dimensions	User (D_1)	Operation (D_2)	Maintain (D_3)	Society and economy (D_4)
User (D_1)	0	3.4	3.6	3.8
Operation (D_2)	3.0	0	2.6	2.6
Maintain (D_3)	2.4	3.2	0	2.4
Society and economy (D_4)	2.4	2.2	3.0	0

As matrix A shows, the normalized direct-relation D is calculated from Eqs. (1) and (2). Then, using Eq. (3), total influence T can be derived as Table 3 and 4. By using Eqs. (5) and (6), the sum of the total influence given and received by each dimension can be derived as Table 5.

Table 3. The direct of influences given and received on dimensions

Dimensions	Sum of raw $\{r_i+c_i\}$	Sum of Column $\{r_i- c_i\}$	Sum of Column and raw	Ranking
User (D_1)	1.000	0.722	1.722	1
Operation (D_2)	0.759	0.815	1.574	3
Maintain (D_3)	0.741	0.852	1.593	2
Society and economy (D_4)	0.704	0.815	1.519	4

Table 4. The total influence matrix *T*

Dimensions	User (D_1)	Operation (D_2)	Maintain (D_3)	Society and economy (D_4)	Total influence normalized
User (D_1)	0.9056	1.2348	1.2804	1.2526	**4.6734**
Operation (D_2)	0.9554	0.8112	1.0333	1.0022	3.8021
Maintain (D_3)	0.8985	1.0158	0.8118	0.9633	3.6894
Society and economy (D_4)	0.8677	0.9260	0.9987	0.7503	3.5427

Based on this, the IRM of the DEMATEL method can be obtained and is shown in Figure 2 by using Table 4. It is shown in Figure 3 by using Table 5.

Table 5. The sum of influences given and received on dimension

Dimensions	Sum of raw $\{r_i\}$	Sum of Column $\{c_i\}$	Column $(r_i\ c_i)$	Column $(r_i- c_i)$
User (D_1)	4.673	3.627	8.301	1.046
Operation (D_2)	3.802	3.988	7.790	-0.186
Maintain (D_3)	3.689	4.124	7.814	-0.435
Society and economy (D_4)	3.543	3.968	7.541	-0.426

Table 6. The result of criteria analysis

Criteria	D	R	D+R	D-R
Average traveling time (C_1)	20.916	26.174	47.090	-5.258
Travel cost (C_2)	23.152	23.050	46.202	0.102
Waiting time (C_3)	23.515	21.649	45.164	1.866
Transfer frequency(C_4)	24.071	20.782	44.853	3.289
Operating cost (C_5)	11.152	14.400	25.552	-3.248
Revenue (C_6)	12.770	12.828	25.598	-0.058
Service standards (C_7)	12.663	10.402	23.065	2.261
Average turnaround time (C_8)	12.044	11.000	23.044	1.044
Operating region (C_9)	6.425	5.846	12.271	0.578
Operations (C_{10})	5.790	4.784	10.574	1.006
Fare (C_{11})	5.759	5.415	11.174	0.344
Finance (C_{12})	6.161	6.699	12.859	-0.538
Facilities (C_{13})	4.440	5.147	9.587	-0.708
Traffic network transport efficiency (C_{14})	5.732	5.382	11.113	0.350
Traffic network density (C_{15})	5.321	5.523	10.844	-0.202
Traffic network service efficiency (C_{16})	5.114	5.812	10.926	-0.698
Route coverage and repetition rate (C_{17})	4.931	5.993	10.924	-1.061
Route directness & circuitry (C_{18})	5.407	4.478	9.885	0.929
Pollution cost (C_{19})	7.577	10.261	17.838	17.838
Congestion cost (C_{20})	8.947	7.614	16.561	16.561
Budget excluding by subsidies (C_{21})	8.323	8.020	16.343	16.343
Social Welfare (C_{22})	8.603	7.554	16.157	16.157

as the criterion, “user” right “society after surface” the influence to affect highly; But “society right “the user” presents the low influence relations after the surface”. In addition, the user is in four construction surface the most important influence construction surface, is also in the structural relation influence chart mainly only affects the construction surface; Otherwise, society is in the structure connection influence chart is affected mainly after the surface the construction surface. Change of along with the social economy environment structure, Taiwan area private transports has rate climbs year by year, although improved a people line of convenience, but follows the transportation which and the environmental protection question comes also day by day is actually serious, therefore, promotes the populace transportation while carrying rate already for the Governmental agency key point diligently. But the public vehicle system manages for a long time, loses money the situation to be day by day serious, causes the market to fall into the vicious circle for a long time in the difficult position, therefore, discovers in the public vehicle system the important influence criterion, and draws up the suitable strategy, leads the public vehicle system's transport business situation, can improve the overall populace to transport the environment.

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EXPLORING SUSTAINABLE URBAN FORMS: A CASE STUDY IN JABOTABEK METROPOLITAN AREA, INDONESIA

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Abstract: To explore sustainable urban forms for developing countries, this study conducts a stated preference survey in Jabotabek metropolitan area, Indonesia, to examine households' preferences for different types of urban forms focusing on the integration of land use and transportation. The alternatives in the survey include nine types of urban forms defined by the combinations of three residential areas (compact city, transit-oriented city, and modern suburbs) and three commuting modes (car, bus, and train). SP survey shows that living in compact city and commuting by train is the most preferred urban form, followed by the compact city and transit-oriented city supported by bus system. To incorporate heterogeneity in household's stated choice behavior, a random-coefficient logit (RCL) model is established to represent household's choices about the nine alternatives. The RCL models and simulation analyses suggest that sustainable urban forms mostly support transit services.

Keywords: Compact city, transit oriented development, SP survey, heterogeneity, RCL model, sustainability, Jabotabek metropolitan area.

1. INTRODUCTION

To reduce environmental loads and energy consumption from human activities, various concepts and policies have been proposed and practiced around the world. In line with such thinking, it is becoming more and more important how to realize sustainable urban forms by implementing effective and efficient urban/transportation planning. Sustainable urban forms generally share some common characteristics such as controlling car ownership and use, encouraging use of transit systems and non-motorized travel modes (e.g., walking and biking), and motivating effective use of existing land resources (e.g., Banister, 1992; Kenworthy and Laube, 1996; Newman and Kenworthy, 1999; Jenks *et al.*, 1996, Cervero, 2002).

Dieleman *et al*. (2002) report that defining the relationships between urban forms or land use composition and travel mode as well as vehicle kilometers traveled is a complicated task as very diverse sets of factors come into play: firstly, travelers hold different personal and household attributes, income, household composition, and participation in the workforce, which have strong impacts on mobility and modes employed; secondly, residential location, residential environment and the transportation services the residential location is endowed with affect travel behavior; and thirdly, trip purpose, space-time constraints and land use affect the chaining of trips, which strongly affects mode(s) utilized. Built environment at residential areas also influences household residential choice behavior. Examples of comprehensive reviews on built environment and travel behavior are Anderson *et al.* (1996), Badoe and Miller (2000), Crane (1999), Ewing and Cervero (2001), Handy (1996), Steiner (1994) and Stead *et al.* (2000).

It is generally recognized that motorized transportation, especially automobile transportation have caused air pollution, high energy consumption, and uneven urban development, which have become the main problem areas of studies about sustainable development. Heavy use of automobiles in low density urban areas is closely related to the phenomenon termed as automobile dependency. One reason for automobile dependency is the urban sprawl. Because, in low density and sprawled urban areas, public transit systems remain in poor accessibility to most residents; contrary to public transit systems, automobile is flexible and offers increased accessibility and mobility. This phenomenon is seen in developed countries in line with the suburban development which is associated with low density, bedroom communities. In this regard, planners in recent years have been struggling to tackle suburban sprawl and its negative social, economic, and environmental effects. It is expected that increases in energy shortage and air pollution will require actions to reduce motorized passenger and fright transport (Goodwin, 1996; Sperling, 1995).

To reduce motorized transport in urban areas, a series of interrelated policies and ideas have been developed mainly in developed countries. These range from downtown revitalization projects to new urban growth strategies such as New Urbanism, Smart Growth, Compact City, and Transit-Oriented Development (TOD). Application of such sustainable urban development schemas also shows difficulties in the pre-established cities of the developed world, where most of the neighborhoods and transportation infrastructure are already in place and are more difficult to change (Cervero and Landis, 1997). On the other hand, cities in developing countries are growing rapidly and are expected to become major contributors to environment emissions and energy consumptions in the future. Therefore, it is much more crucial to establish and promote environmentally sustainable policies to accommodate urban growth in these cities. Unsustainable development related to transportation in developing cities is caused by not only high use of automobiles, but also poor service quality of transit systems. Especially regarding transit systems, policies to encourage construction of Bus Rapid Transit (BRT) or exclusive bus lanes might allow the developing cities to develop extensive, affordable and sustaining transit systems. But, as developed countries once experienced, increase of income leads to the increase of automobile ownership, which further encourages the urban growth with low-density, speeds up the progress of homogeneous land use and worsens the improvement of accessibility by transit systems in these developing countries. With similar development paths, it is highly probable that developing countries might also enter the vicious cycle of motorization and urban sprawl.

Under such circumstances, it is becoming more and more important how developing countries could realize sustainable urban development, and consequently, it is necessary to understand how people in developing countries would prefer different types of sustainable urban forms. Needless to say, people in most of developing countries have not experienced any sustainable urban forms. As a result, it is difficult to expect that revealed preference data could provide useful insights about policies of sustainable urban development. Therefore, this study applies a stated preference (SP) approach to investigate households' preferences for different urban forms under hypothetical situations. The SP survey was conducted in Jabotabek metropolitan area of Indonesia, in 2003. In the SP survey, to reduce answer burdens of the surveyed households, each household is presented with four SP profiles, each of which consists of one of three residential areas and one of three commuting modes. Thus, choice is made with respect to nine alternatives in each SP profile. Based on the above hypothetical information, each household is asked to choose one residential area and one relevant commuting mode. The choice tasks are repeated four times for each household. In addition to SP data, information about current residential areas is also investigated. Furthermore, a choice model suitable to the collected SP data is also established to especially represent the heterogeneity in household choice behavior. In the choice model, some of the parameters of alternative-specific attributes are assumed to follow normal distributions. Simulations related to some sustainable urban development scenarios are conducted.

2. A METHODOLOGICAL ISSUE: HETEROGENEITY

It is known that choice behavior changes across decision makers. Such heterogeneity can be classified into two major categories: the observed and unobserved heterogeneity. The observed heterogeneity is caused by the observed attributes of decision makers (e.g., gender, age, income and household composition) and the unobserved heterogeneity takes place when some of important attributes, especially psychological attributes (e.g., taste, attitude, character and motivation), are omitted in the model. On the other hand, careful review suggests that heterogeneity seems a more broad and general concept to describe people's decisions.

Segmentation approach is the most popular and easiest method to represent the observed heterogeneity, based on the above-mentioned observed attributes of decision makers. On the other hand, Bock and Uncles (2002) argue that such heterogeneity can take place at least regarding preference of product characteristics, effect of interaction among consumers (social interaction), choice barrier, negotiation ability and perceived benefit of suppliers, and all the information should be used to segment the consumers. Such segmentation approach assumes that decision makers belonging to each segment show homogeneous behavior. In the SP survey, if one can collect multiple responses from a respondent, a complete individual behavior model can be estimated. Of course, sample size is another issue. In addition, due to the progress of technology, pre-paid cards or IC cards have been widely used in developed world. These smart cards can automatically record each passenger's trip information across space and over time. Such data can be also used to estimate individual behavior model. In this sense, technological development opens new ways to model people's behavior and provides new methods to make transportation planning and policy decisions. Compared with the observed heterogeneity, the unobserved heterogeneity is more complex. Such unobserved heterogeneity affects various aspects of behavior models, such as taste variation, error structure, dynamics (state dependence and initial condition of panel survey) and choice set.

It is usually known as alternative-specific constant term. According to variation patterns of the alternative-specific taste, two types of choice models can be established. The first is called fixed-effect model, which assumes that the alternative-specific taste does not change randomly; the second is called random-effect model, which assumes that the alternative-specific taste follows a random distribution (Zhang *et al*, 2001). The random-effect model can be further sub-divided into parametric and non-parametric models, where the former assumes a continuous probabilistic distribution and the latter does a discrete probabilistic distribution (usually called Mass Point approach). On the other hand, many models have been proposed to describe such attribute-specific taste. Mixed logit/probit model is the most popular one, where all the attribute-specific taste terms are assumed to follow multivariate normal distribution and can be estimated using maximum simulated likelihood estimation method (see Hensher and Greene, 2003). Recently, Bhat and Guo (2004) proposed a mixed spatially correlated logit model to represent residential choice behavior.

In order to represent heterogeneous covariance error structure, Bhat (1997) defines the parameter of logsum variable derived from a nested logit model as a function of individual attributes in the context of inter-city travel model choice. Bhat (2001) adopts a mixed logit model to represent heterogeneity in taste parameters and error structure.

In the analysis of road pricing policy, Bhat and Castelar (2002) represent three types of heterogeneity (preference, taste about level-of-service and state dependence) in a mixed SP/RP combined model. As described by Heckman (1981) and Degeratu (1999), heterogeneity in initial condition of panel survey can be mainly incorporated into the model based on a fixed initial condition method and a correlated initial condition method. The former method ignores the influence of unobserved heterogeneity; in contrast, the latter takes it into account. Degeratu (1999) further confirms that the correlated initial condition method is more effective by estimating a discrete choice model, which incorporates the state dependence derived from first-order Markov chain process.

Concerning the choice set, Chiang *et al* (1999) proposed a new choice set generation model, which incorporate the heterogeneity in both choice set and taste parameter. Swait's (2001) GenL model can be also applied to represent such heterogeneity.

3. STUDY AREA: JABOTABEK METROPOLITAN AREA, INDONESIA

The Jabotabek metropolitan area is one of the largest metropolitan areas in the world. The whole metropolitan area is comprised of the capital city of DKI Jakarta and its three neighboring provinces called as Bekasi, Bogor and Tangerang. According to JICA SITRAMPII study conducted in 2002, the whole Jabotabek area, with an area 6,580km^2 has a population at around 21.5 million, which constitute 10% of the population of Indonesia and is concentrated on the axes between Bekasi-Tangerang and Bogor-Jakarta axes, reaching the highest values in the central areas of Jakarta city.

In the region, the rapid urbanization has been experienced by Tangerang, urbanization in the other areas of Botabek has remained at moderate levels. The average household size in the area has decreased from 4.7 to 3.8 and the number of households has been increased (Pacific Consultants International and ALMEC Corporation, 2003), which point to additional housing need and residential development. On the other hand, economy of the whole area corresponds to 20% of the GDP with the total employed population in Jabotabek is about 7.5 million, concentrated in mainly the center of Jakarta and centers of Bogor, Bekasi and

Tangerang.

Report by Pacific Consultants International and ALMEC Corporation in 2003 divides the whole Jabotabek metropolitan area into four density groups of residential areas: very low density (20-50 persons/ha), low density (50-100 persons/ha), medium density (100-200 persons/ha) and high density (over 200persons/ha). The very low areas are located far from central Jakarta and only constitute 5% of the whole Jabotabek area. Urban infrastructure and services are in poor supply conditions in these areas. In low density areas, it is noted by JICA (2003) study that the transit services are supplied in acceptable margins to the residents. In medium density areas, transportation alternatives increase including the para-transit options. In high density areas of DKI Jakarta, the traffic congestion is one of the prime problems in the daily urban life, thus development of mass transit services becomes desirable in these regions.

4. STATED PREFERENCE SURVEY

4.1 Design of SP Questionnaire

As mentioned previously, SP approach is adopted here to explore how households in Jabotabek metropolitan area (JMA) show their preferences for different types of urban forms. To design the SP questionnaire suitable to the situations in developing cities, a pilot survey was conducted first with respect to about 70 students in Hiroshima University from developing countries. The pilot survey shows that ideal residential environment does not change drastically across countries of origin, and provided basic inputs for the SP survey in this study. These inputs are the candidates of alternative-specific attributes, as shown below.

A) Factors of layout of residential area: distances to supermarket (place to buy everyday groceries), department store, park or open space, railway station and bus stop.
B) Factors of travel to work: travel time and cost for car, bus and train

As the survey is geared toward long-term urban development, to reflect respondents' potential choice behavior, the following assumptions were made.

1) All respondents have a high income: Without this assumption, the choice exercise would heavily constrain the SP answers. As most of the respondents in Jabodetabek (and developing countries in general) have a low income. To discard this constraint on choice, respondents were asked to assume a high income.
2) All respondents own an automobile: Because this research is based on the assumption of increased car ownership in the remote future in order to analyze travel mode choice, it becomes inherent to include this assumption. At present car ownership in developing countries is low, and for them no "choice" exists in a mode choice scenario. Therefore to be able to make long-term forecasts for policy guidance, this assumption must also be included.
3) All respondents work in Jakarta City: This assumption was necessary to simplify the survey, and also to ameliorate any inconsistencies concerning the definition of the residential land use patterns (compact city, transit-oriented development (TOD), and modern suburbs)
4) Travel by public transport is comfortable and safe: Public transport systems in Jabodetabek (and in most developing countries) are notoriously unsafe, un-hygienic, and have generally very poor levels of service. They are usually looked at as modes used by the poor. In order for the respondents to discard this image of public transport, it was necessary to make this assumption, otherwise public transport would, in all likelihood, not be able to

compete with selection for the private automobile.

Each hypothetical residential area is situated at a pre-defined distance from urban core and defined in terms of their respective distances from activity sites, as well as travel times and costs of potential travel modes to urban core, as shown below. The urban core is defined as the work location for the head of household.

i. Transit-Oriented Development (TOD): Transit stations are near residential locations and residential area is 9~18 kilometers far from urban core.
ii. Compact City Development (CC): Major urban activity centers are close to residential locations and residential area is 3~8 kilometers far from urban core.
iii. Modern suburban development (MS): Only recreational activity centers are close to residential location, which is 19~30 kilometers far from urban core.

Residential areas that are compact and transit oriented contain all of the activities including the transportation facilities within 2 kilometers; the radius for all of the activities reachable from the residential location is assumed to be 3 kilometers radius from the residential location in suburban residential area. The first alternative, TOD puts a residence within 500 meters of both of a bus stop and a train station. In the other alternatives, the train station is within 1 kilometers in CC and within 2 kilometers in MS from residential locations. Commuting modes are also subject to variation based on the residential area. In fact, each of the commuting trip times and costs changes with respect to the distance from the urban core. In terms of travel times and costs, the most expensive residential area alternative becomes the MS and the cheapest one becomes TOD. For the TOD, the focus is on the quality of transit system. Hence, the distance to the rail station does not extend beyond 1000 meters.

Also, as residential TOD is generally defined as an area where all daily activities can be done within walking distance of the residence, the supermarket is also always within 1000 meters. Distances to restaurants and shops are not given priority and therefore they are not located as near as the other sites. Open space is also located near the residence. The CC places a restriction on the area expansion of the city. Therefore the residence is located nearest the urban core. Distances to restaurants and shops as well as supermarkets are given priority, while open space and railway station are not, hence these latter two are situated at least 1000 meters from the potential residence. The MS is patterned after the typical western automobile suburb, where open space in direct proximity to the residence is given highest priority, while other activity sites are not. The fundamental concept behind this is that passenger cars are dominating travel mode supported by a strong highway network. The transport level of service variables include travel time and cost, which are calculated based on the actual values of the selected survey districts of Jabotabek metropolitan area to central area of Jakarta city.

Based on the pilot survey mentioned above and the person-trip survey conducted by JICA with the help of Pacific Consultants International and ALMEC Corporation in 2002 (SITRAMPII study), the alternative-specific attributes and their levels for SP survey are determined, as shown in Table 1. As seen from Table 1, all the attributes have two levels, respectively. An orthogonal fraction of the $L_{32}(2^{31})$ factorial design consisting of 32 profiles is constructed. To reduce the respondents' burden, the 32 profiles were grouped into 8 balanced blocks. Each respondent received only one block of 4 profiles and was asked to choose one alternative from the nine pre-defined alternatives. The questionnaire is designed in a visual format that displays the characteristics of all the attributes. The alternatives within each SP profile were re-ordered on different pages to reduce reporting biases.

The survey consists of two parts: in the first part, households report information on demographic and socio-economic characteristics as well as attributes of the actual residential area. In the second part of the survey, households are asked to answer the given four SP questions.

4.2 Results of SP Survey

The number of respondents to the questionnaire displays decreasing order with respect to the population of the constituent cities of the Jabotabek metropolitan area (Figure 1). Basically from the data set, it is understood that most of the activity centers and transit services are in close reach from the location of residence in DKI Jakarta (Figure 2). The non-central areas of the Botabek region have activity centers generally far from the location of the residence. Botabek region is in poor supply of the transit services, although the central areas in Botabek have supermarket and restaurants close to the residences.

Table 1. Alternative-specific attributes and their levels for SP survey

Land Use Pattern	Residential Area			Commuting Mode		
	Activity Sites	Distances		Travel Mode	Values	
(1) Compact City Development (CCD): 3 - 8 km from urban core	Supermarket	near far	500 meters 1000 meters	car travel time	fast slow	35 min 65 min
	Park	near far	1000 meters 2000 meters	car travel cost	low high	11000 rup 20000 rup
	Department store	near far	500 meters 1000 meters	bus travel time	fast slow	45 min 80 min
	Railway station	near far	1000 meters 2000 meters	bus travel cost	low high	2200 rup 4000 rup
	Bus stop	near far	500 meters 500 meters	rail travel time	fast slow	40 min 55 min
				rail travel cost	low high	1600 rup 2000 rup
(2) Transit-Oriented Development (TOD) 9-18 km from urban core	Supermarket	near far	500 meters 1000 meters	car travel time	fast slow	60 min 110 min
	Park	near far	500 meters 1000 meters	car travel cost	low high	15000 rup 28000 rup
	Department store	near far	1000 meters 2000 meters	bus travel time	fast slow	70 min 125 min
	Railway station	near far	500 meters 1000 meters	bus travel cost	low high	3000 rup 5500 rup
	Bus stop	near far	500 meters 500 meters	rail travel time	fast slow	70 min 100 min

Table 1. Alternative-specific attributes and their levels for SP survey (Cont'.)

Land Use Pattern	Residential Area		Commuting Mode		
	Activity Sites	Distances	Travel Mode	Values	
(2) Transit-Oriented Development (TOD) 9-18 km from urban core			rail travel cost	low high	3400 rup 4500 rup
(3) Modern suburban development (MSD) 19-30 km from urban core	Supermarket	near far	2000 meters 2000 meters	car travel	fast slow
	Park	near far	5 meters 5 meters	car travel	low high
	Department store	near far	3000 meters 3000 meters	bus travel	fast slow
	Railway station	near far	2000 meters 2000 meters	bus travel	low high
	Bus stop	near far	500 meters 500 meters	rail travel	fast slow
			rail travel cost	low high	4400 rup 5700 rup

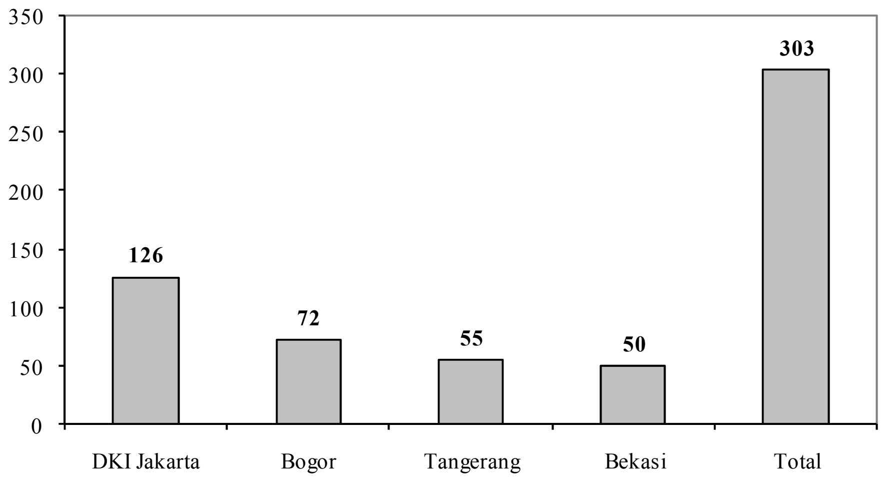


Figure 1. Distribution of surveyed households in the Jabotabek region

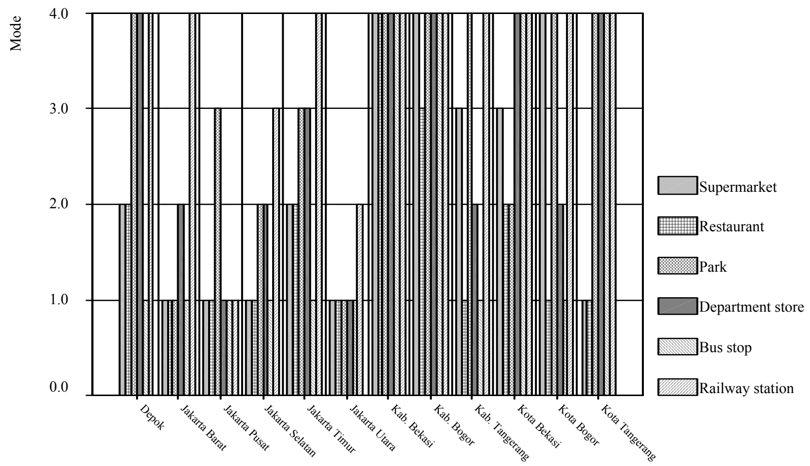
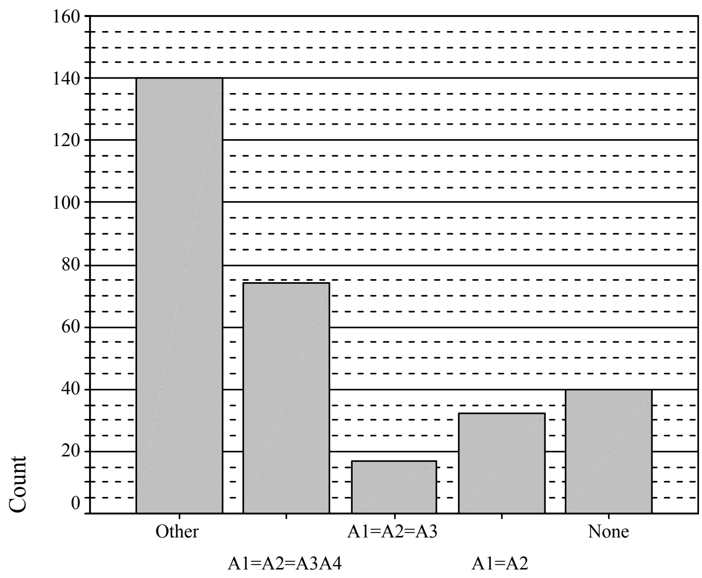


Figure 2. Distances of basic activity centers and transit services from residential location

In the survey form, we ordered three residential area alternatives (and commuter modes alternatives nested in residential area alternatives) on one page. So there might be expected some random effects of heterogeneity caused by the ordering of the alternatives on a page. For example, a respondent might be inclined to see the first alternative in a more positive than the second alternative. We control for this type of heterogeneity by reordering three residential alternatives and have respondents make choice again. As shown in Figure 3, most of the 303 surveyed households choose different alternatives under all of the four SP profiles with different attributes and levels. Some of the households choose the same alternative on some different occasions. Such consistent responses might be caused by two major reasons: one is that some alternatives might be captive to those respondents; another is that respondents might feel fatigue to repeatedly answer the similar SP questions. Unfortunately, it is difficult to distinguish between these two reasons. This is left for the future research.



(A: Alternative)

Figure 3. Consistency in responses

Figure 4 shows the SP choice results. It is obvious that compact city is the most preferred urban form in the sense that choice share of compact city is 52% (=10%+19%+23%), followed by TOD (29%) and modern suburbs (18%). Concerning choices of commuting modes, bus shows the highest share (42%), and train is positioned at the second place (39%). With respect to the combination of residential area and commuting mode, living in compact city and commuting by train is the most preferred urban form, followed by the compact city and transit-oriented city supported by bus system. Respondents show the lowest preference for car-commuting under any SP profiles. It is also obvious that income shows large influence on the choice of urban form (see Figure 5). As a general trend, households with income larger than 4.0 million Rupliahs show quite different preferences for different urban forms from other households.

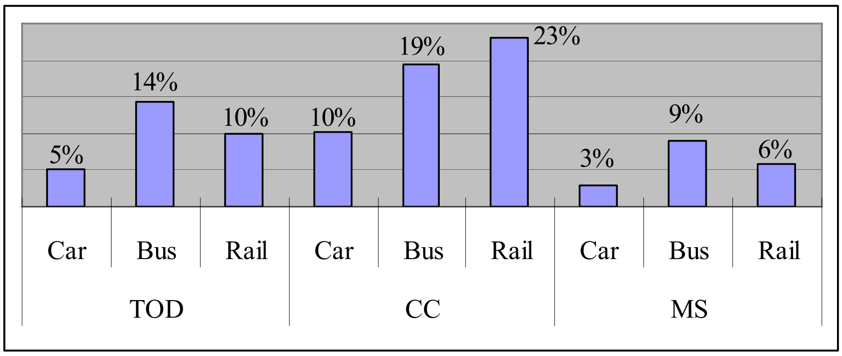


Figure 4. SP Choice results

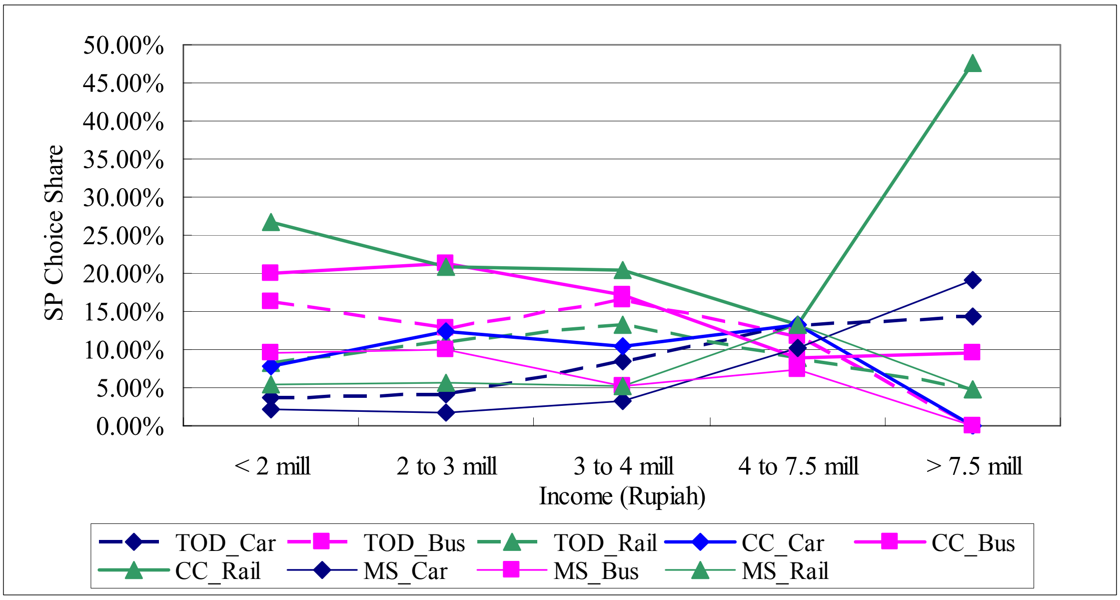


Figure 5. SP choice shares of residential areas by income

5. CHOICE MODEL

In the SP survey, it is assumed that all commuting modes are available to all households in all hypothetical residential areas; thus, choice set is composed of all nine alternatives (three residential areas and three commuting modes) in this study. A typical choice made by the household *h* on alternative *i* at an incidence *t* (refers to a SP profile in this study) can be formulated as follows:

$$y_{hit} = \begin{cases} 1, & if \quad U_{hit} \geq U_{hjt} \\ 0, & otherwise \end{cases}, \forall j \neq i \qquad (1)$$

$$U_{hit} = V_{hit} + \varepsilon_{hit}, \quad V_{hit} = \beta' X \qquad (2)$$

where $U_{hit}, V_{hit}, \varepsilon_{hit}$ are the utility, its deterministic term and the probabilistic error term, respectively; X, β are vectors of explanatory variables and their parameters; y_{hit} is a dummy variable indicating the choice result of alternative *i*, i.e., if *i* is chosen, then $y_{hit} = 1$, otherwise, it is equal to zero. The formulation given in equations (1) and (2) leads us to the well-known Multinomial Logit Model (MNL) as given in equation (3) (Ben-Akiva and Lerman, 1985).

$$P_{MNL}(y_{hit} = 1) = \frac{e^{V_{hit}}}{\sum_{j=1}^{n} e^{V_{hjt}}} \qquad (3)$$

As discussed in the Section 2, choice behavior shows heterogeneity among decision makers. However, the MNL cannot reflect such heterogeneity properly. Therefore, to represent households' heterogeneous choice behaviors in this study, instead of the MNL model, we suggest applying one of its extensions, Random Coefficients Logit (RCL) model. Both RCL and MNL model assume that the error term, ε_{hit} follows an identical and independent Gumbel distribution. A significant difference between MNL and RCL arises in the nature of the parameters: MNL assumes the parameters are fixed, RCL assumes that at least some of the parameters are random (for a detailed explanation of the RCL model, see Ben Akiva and Lerman, 1985; Train, 1997 and 2003; and McFadden and Train, 2000). In other words, RCL model allows that different households might show different responses to the attributes characterizing the urban forms in the SP survey. Suppose that parameter β is distributed with a probability density function, *f(β)*. Then, the probability of choosing an alternative *i* is obtained by integrating the distribution of the parameter values:

$$P_{RCL}(y_{hit} = 1) = \int_{\beta_{1h}} \cdots \int_{\beta_{Kh}} \frac{e^{\beta_h X}}{\sum_{j=1}^{n} e^{\beta_h X}} f(\beta_{Kh}) \cdots f(\beta_{1h}) d\beta_{Kh} \cdots d\beta_{1h} \qquad (4)$$

Here, β is replaced by β_h in order to reflect the households' heterogeneous choice behaviors. Equation (4) shows a formula of choice probability which assumes that all the introduced parameters are random. The formula for the case that only a part of parameters are random is straightforward.

Note that in the SP survey, each household is asked to answer the same set of alternatives for four times. Usually, the resultant four SP choices are dealt with as the choice results from different households. However, since these four SP choices come from the same household, it is natural to assume that β_h should be the same in choosing different SP profiles for that household. In this sense, it is necessary to extend the RCL model to accommodate such multiple occasions of choice. Such extension is straightforward (see Fowles and Wardman, 1988). Suppose that a household makes a choice on the same set of alternatives T times, then the probability becomes as follows:

$$P_{mRCL}(y_{hi}=1)=\int_{\beta_{1h}}\cdots\int_{\beta_{Kh}}\left[\prod_{t=1}^{T}\frac{e^{\beta_h X}}{\sum_{j=1}^{n}e^{\beta_h X}}\right]f(\beta_{Kh})\cdots f(\beta_{1h})d\beta_{Kh}\cdots d\beta \tag{5}$$

The estimation is carried out by using LIMDEP 8.0 (Econometric Software, 2002)

6. MODEL ESTIMATION AND SIMULATION

6.1 Model Estimation

Based on preliminary analyses, household size, car ownership and household income are introduced into the choice model to represent the observed heterogeneity in household choice behavior. Car ownership is a dummy variable, equal to 1 if household owns a car, 0 otherwise. To reflect the non-linear relationship between household income and SP choice behavior, a dummy variable indicating high income level (larger than 4.0 million Rupiahs) is adopted. Concerning the alternative-specific attributes, most of them are introduced into the model. Estimation results of RCL model (equation (5)) are shown in Table 3.

Model accuracy
Observing model accuracy, compared with the RCL model with no variables (i.e., assuming choice probabilities are the same across all the alternatives), and the RCL model with only constant terms, the McFadden's Rho-squared are 0.1791 and 0.2127. All the standard deviation parameters of RCL model are statistically significant. Most of the parameters of explanatory variables also show significant values. These facts suggest that the established RCL model is acceptable.

Table 3. Estimation results of RCL model

Explanatory Variables	Estimated		t-score
Household attributes			
Household size			
Transit-oriented city	0.14	*	2.18
Compact city	0.12		1.46
Car ownership			
Transit-oriented city	-0.67	**	-2.72
Compact city	-0.78	**	-2.70
High income			
Transit-oriented city	-0.73	+	-1.79
Compact city	-1.60	**	-3.33
Alternative-specific constant terms			
Transit-oriented city	1.28	*	2.04
Compact city	1.97	**	2.80
Alternative-specific attributes			
Travel time (car)	-0.01	*	-2.10
Travel time (transit)	2.68E-03		0.95
Travel cost (car) (1/1000)	-0.02		-1.11

Table 3. Estimation results of RCL model (Cont'.)

Explanatory Variables	Estimated		t-score
Travel cost (transit) (1/100000)	-0.04		
Distance to supermarket	-0.64	+	-1.73
Distance to department store	-0.08		-0.52
Distance to bus stop	-0.84	*	-2.23
Distance to rail station	-0.35	*	-2.42
Standard deviation for the parameters with random distributions			
Constant term of transit-oriented city	0.57	**	3.48
Constant term of compact city	1.45	**	9.95
Distance to supermarket	0.25	+	1.91
Distance to department store	0.68	**	8.48
Distance to bus stop	5.91	**	13.21
Distance to rail station	1.53	**	11.54
Sample size	303		
Model accuracy indicators			
Converged log-likelihood: RCL model (df =12)	-2,096.64		
Restricted log-likelihood			
RCL model with only constant terms (df =2)	-2,554.21		(0.1791)[a)]
RCL model with no variables	-2,663.04		(0.2127)[a)]

Note: + 90% level of significance; * 95% level; ** 99% level; [a)] McFadden's Rho-squared

Parameters of alternative-specific attribute

For commuting mode specific attributes, only travel time of car shows that its parameter is statistically significant and has an expected sign. In other words, people do not prefer long travel time in commuting. As for the parameters related to distances to various neighborhood facilities, parameters of distances to bus stop and rail station, and supermarket are significant. Except for travel time of transit systems (bus and rail), parameters of other alternative-specific attributes all have a logical sign. In other words, people prefer cheaper commuting mode with shorter access distances to transit stops, and like to visit department store and supermarket close to their residential areas. All the standard deviation parameters of the distances are statistically significant. These results support the introduction of household heterogeneity using RCL model.

Parameters of household attributes

Most of household attribute parameters are statistically significant. Households with more members prefer living at transit-oriented city (TOD) and compact city (CC), while households with cars and high income prefer living at modern suburban area.

6.2 Simulation

As shown in Figure 6, RCL estimation results show that the estimated choice probabilities approximate the observed choice shares well in the sense that correlation between observed and estimated shares are 0.8504. Hereafter, using the above-mentioned estimation results, simulation analyses are conducted with respect to layouts of residential areas. Concretely speaking, simulation scenarios are set with respect to distances to some facilities at residential areas. Here, transit stops and department stores are targeted and relevant scenarios are shown in Table 4. In total, 5 scenarios are assumed. Since this study attempts to explore sustainable urban form for developing cities, scenario analyses are carried out with respect to TOD and CC. The simulation results are shown in Figure 7.

Concerning distances to bus stop and rail station, it is found that increase of choice probability of TOD_Bus is larger than that of TOD_Rail, based on comparison between S1 and S3. In case of reducing distance to bus stop, increase of choice probability of TOD_Bus mainly comes from decreases of choice probabilities of compact city (CC). In contrast, in case of reducing distance to rail station, increase of choice probability of TOD_Rail mainly comes from decrease of choice probability of TOD_Car. Observing simulation results of S1 and S2, it is obvious that simultaneously reducing the distance to bus stop for both TOD and CC leads to competitive change of choice shares within both TOD and CC. This is similar to the case of reducing distance to rail station (S3 and S4). By reducing the distances to bus stop and department store at TOD scenario at the same time (S%), considerably large increase is observed with respect to choice probability of TOD_Bus, as well as almost equal reductions of choice probabilities of CC scenarios.

7. CONCLUSION

To explore sustainable urban forms for developing countries, this study applies a stated preference (SP) survey to examine how households choose different types of urban forms under hypothetical situations. Considering rapid urban growth in developing countries, it is very important for policy makers to properly understand both future trend and potential changes of urban growth under the implementation of different types of policies. SP survey method is especially effective to deal with such not-yet-existing choice situations. This study assumes three residential areas, i.e., compact city, transit-oriented city and modern suburb, and three commuting modes, i.e., car, bus and rail. In total, nine alternatives from the combination of residential areas and commuting modes are defined in the SP survey, and as a result, 32 SP profiles are constructed. Attributes introduced in the SP survey are related to layouts of residential area and travel service levels, where the former is defined using distances to different facilities (including transit stops, supermarket, department store, open

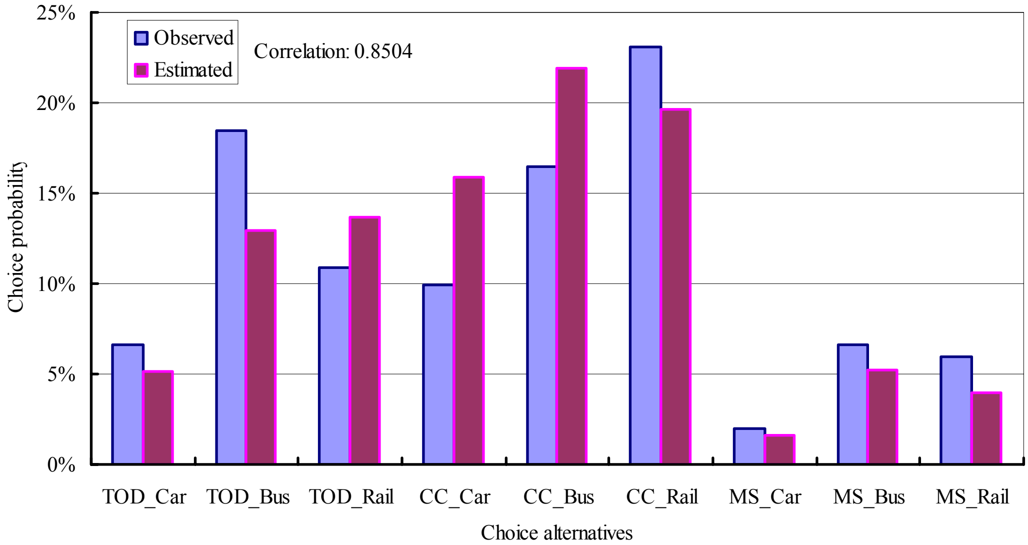
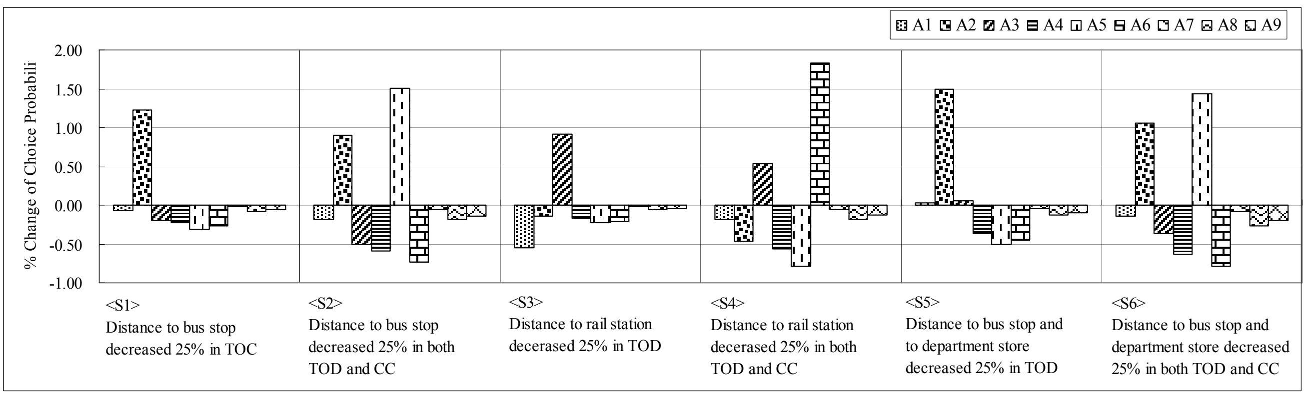


Figure 6. The observed choices and their estimated values by RCL model

Table 4. Policy scenarios for simulation analyses

Scenarios	Contents
S1	Distance to bus stop decreased 25% in TOD
S2	Distance to bus stop decreased 25% in both TOD and CC
S3	Distance to rail station decreased 25% in TOD
S4	Distance to rail station decreased 25% in both TOD and CC
S5	Distance to bus stop and to department store decreased 25% in TOD
S6	Distance to bus stop and department store decreased 25% in both TOD and CC

TOD: Transit-oriented development; CC: Compact city



A1:	A2:	A3:	A4:	A5:	A6:	A7:	A8:	A9:
TOD_Car	TOD_Bus	TOD_Rail	CC_Car	CC_Bus	CC_Rail	MS_Car	MS_Bus	MS_Rail

Figure 7. Simulation results

Space and park and latter includes travel time and cost. In the SP survey, each household is asked to answer four SP profiles. Taking Jabotabek metropolitan area as a case study area, 303 households participated in the survey and 1212 (=303*4) valid SP answers were obtained. SP survey shows that living in compact city and commuting by train is the most preferred urban form, followed by the compact city and transit-oriented city supported by bus system. To represent heterogeneity in household's stated choice behavior, a random-coefficient logit (RCL) model is built, by assuming that some of alternative-specific attributes are randomly distributed. Especially, since each household is asked to answer the same set of SP profiles for four times, the resultant SP responses behaviorally share some common characteristics. The established RCL model also accommodates such multiple choice situations. The RCL model also remedies the IIA inefficiency of the traditional Multinomial Logit model and increases the ability to locate elicitation of more flexible models. Empirical analyses show that the RCL model is good enough to describe household's choice behavior about different types of urban forms. It is also found that most of the alternative-specific attributes have statistically significant parameters and signs of these parameters are also logical. Simulation results support the role of transit services in shaping sustainable urban forms.

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SPEEDING IN THAILAND: DRIVERS' PERCEPTIONS

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Abstract : The paper presents results from a part of the study on speeding in Thailand. The whole study was divided in various aspects including the perceptions and attitudes toward speeding in Thailand to find out why people speed knowing that it is dangerous. Using the framework of perception leads to behavior, the study research methodology for this part used both quantitative and qualitative approaches. For the quantitative approach the questionnaire survey was used to collect data from 407 respondents from the three sites selected in Bangkok, Chiangmai (the north) and Phuket (the south) of Thailand. Focus group discussions were carried out in all three sites for qualitative method, drivers of various types of vehicles were chosen for the focus group. The results showed that people speed because of haste, bad planning, recklessness, and personal habits. Most people were not safety conscious. All agreed that the process of socialization could create better driving attitudes and skills as the standard of driver training and licensing in Thailand is well below that of developed countries like Australia or Japan. Notwithstanding the standard of licensing, socializing agents like school, peer group and mass media have important parts in educating and raising awareness regarding speeding attitudes and skills.

Key Words : Speed, Drivers' Perception

1. INTRODUCTON

This paper is part of a project on Safe Driving Speed funded by the National Health Foundation of Thailand, carried out from February 2008 – June 2008. The author worked as a behavioral scientist in the project. The project is a collaborative work between Asian Institute of Technology and Prince of Songkla University.

Road accidents in Thailand kill some 13,000 people, and injured about 1 million people with the resulting economic and social costs of 243,000 million Baht (2008 value) annually (about 10,000 million Australian dollars) (Department of Highways 2007 Study of Traffic Accident Cost in Thailand: Final Report) a huge loss that Thailand needs to address in order to develop on a sustainable basis. The data from the Office of Thai National Police indicates that, speeding ranks first as a cause of accidents in Thailand. This research project on Safe Driving Speed was funded by the National Health Foundation of Thailand in 2008 to carry out a study on Speeding in Thailand. The objectives are to study the effects of speeding on road crashes, enforcement of the laws and drivers' attitudes regarding speeding. The outcomes of the research were used to make recommendations for policies and measures to manage vehicle speed in Thailand.

2. CONCEPTUAL FRAMEWORK

The research used the conceptual framework of perception leads to behavior in this case perception of driver leads to behavior = speeding as shown below:

People (Basic Factor) ---------**Perception** -------------------**Behavior= Speeding**

3. SCOPE OF THE STUDY

Since the study has to be on nationwide basis so the area chosen to cover the whole of Thailand were Bangkok and its vicinity, Chiangmai province to represent the north of Thailand and Phuket province to represent the south of Thailand. These selected areas were also based on the high percentages of accidents caused by speeding and where there are large numbers of tourists. The sampling chosen were purposive and represented various types of drivers of different kinds of vehicles such as taxi, small buses, trucks, cars and motorcycles to assess their attitudes and perceptions toward speeding.

4. RESEARCH METHODOLOGY

The research methodologies used were quantitative and qualitative approach. The quantitative method used questionnaire interview of different drivers in three selected areas Bangkok, Phuket and Chiangmai. A total of 407 samples were collected. The results were sum up as percentages. The qualitative approach used focus group discussion and in-depth interview. For each region, the focus groups were conducted by the research team at two different sites to find out the motives that make people speed.

In the focus groups the questions were asked:

1. Why do most people speed?
2. Why do you speed?
3. Do you think killing people on the road is a crime?
4. Who taught you how to drive? (Or where did you learn your driving?)
5. What are the reasonable measures for punishment of speeding?
6. What do you suggest should be done to prevent speeding?
7. What do you think of the road signs? What color should be appropriate?

5. RESULTS OF THE STUDY

5.1 Quantitative Results

Most of the respondents (drivers) were male 90% only 10% were female drivers. The age ranged between 25-50 years old. 71% were single and those married had 1-2 children on average. Most respondents were drivers by occupation and 64% had primary and secondary levels of education. Only 15.72% had university degrees.

When asked how the respondents learnt to drive, it was found that 64.13% taught themselves, 30% had learnt driving from someone such as family (mostly father) friends, colleagues and relatives (brother, sister). Only 5% went to learn at driving school (Table 1).

Table 1. The way drivers learn to drive

Learning methods	**number**	**%**
Self taught	261	64.13
Friend/colleague	122	29.98
Driving school	20	4.91
Others	2	0.49
Not specified	2	0.49

The majority learnt driving by themselves because they were professional drivers so most might have been bus boys before. As a study on Bus Safety Situation in Thailand (2007) reported most bus drivers learnt driving from being bus boy and had lessons from the bus driver during their free time.

Regarding driving experience, 98.77% had been driving more than one year. The maximum was 30 years. One fifth (21.13%) of the drivers had more than 10 years experience of driving. To be taken into consideration with the speeding, the respondents were asked about the main purpose of the driving which more than half (54.55%) stated that it was their occupation and 32.19% drive for work and business purpose. Also, 62.65 % of the drivers drove their vehicles everyday.

5.1.1 Causes of Speeding

As for the causes of speeding 74.20% stated that it was haste followed with age 36.86%, 32.43% said it was personal liking, sex of drivers, driving experience and vehicles' familiarity resulted in 20% for each category (Table 2).

Table 2. Factors relating to drivers

Drivers' factors	**number**	**%**
Age	150	36.86
Sex	81	19.90
Driving experience	76	18.67
Worry about possible accidents	32	7.86
Personal liking	93	22.85
Haste	302	74.20
Vehicle ownership	11	2.7
Vehicle familiarity	73	17.94
Route familiarity	132	32.43
Mood and mind conditions	68	16.71
Sleepiness and fatigue	33	8.11
Trip planning	18	4.42
Activities whilst driving (music, chatting)	8	1.97

Regarding the environmental factors which were conducive to speeding, the weather conditions came first at 60.2% traffic conditions (such as no cars on the road) came second at 52.83%. Fuel saving came third at 31.94% and the time of driving scored 29.73%. Passengers in the vehicle had some effects at 25.55% whereas the behavior of other drivers on the same route did not have much impact (Table 3).Vehicles' factors and safety equipments such as seatbelts or helmets had impacts at 32.68% and the readiness of the safety equipments such as airbags had impacts at 16.95% on speeding.

However, road factors are considered to be important factors on speeding such as physical conditions of roads namely: the straight road, the winding road or uphill and downhill roads, 46.19% of respondents stated that these conditions had effects on speeding. 43.24% considered road surface such as gravel, concrete, have some effects as well as types of roads such as highways, expressways had some effects at 36.16%. Warning traffic signs against speeding had 30.47% impact on speeding. This number confirmed the importance of warning signs on speeding

Table 3. Environmental factors relating to driving

Environmental factors	number	%
Weather conditions	245	60.20
Traffic conditions	215	52.83
Time (day/night)	121	29.73
Driving behavior of other drivers	34	8.35
Passengers in vehicles	104	25.55
Fuel saving	130	31.94

5.1.2 Road Factors

One of the important factors for speeding is the geometry of the roads such as straight road, curve or uphill-downhill roads. 46.19% of respondents agreed that these had impacts on speeding. Also, type of pavement such as gravel, asphalt and concrete and type of roads such as highway, expressway had impacts on speeding 43.24% and 36.61% respectively (Table 4).

Table 4. Road factors

Road factors	number	%
Type of roads	149	36.61
Numbers of Lanes	121	29.73
Type of pavement surface	176	43.24
Lanes Divisions (with Median or without)	23	5.65
Geometry or alignment of Roads	188	46.19
Crossing/U turn/Connecting points	83	20.39
Speed enforcement signs	124	30.47

As far as ownership of vehicles are concerned 50.37% of respondents stated that it made the difference on speeding because of unfamiliarity. Only 4.39% or 9 persons out of 205 admitted that it helped slow down the speeding.

Regarding the size of the vehicle engine, 28%of drivers said it made them speed because the engine power enabled them to speed and they would like to try the efficiency of the vehicles. 15.47% of drivers said the speeding depended on the behavior of drivers more than engine power the same as 14.34% who answered that they did not drive any faster regardless of the engine power due to the fear of accidents.

The followed question asked was if the drivers would drive faster if it was a new car only 22.36% said they drove faster and 70.76% said they drove normally. From the above results it indicated that among the three factors: people, road and vehicle which contributed to accidents vehicle had the smallest impact.

5.1.3 Opinions and Suggestions Concerning Speed Laws

The third section of the questionnaire asked about the opinions and suggestions of the speed law including the enforcements' measures. The results showed that 90% of the respondents knew the legal for maximum speed mostly (24.04%) from the speed signs on the roads and media such as newspapers and radio. Only 10% or 39 drivers responded that they did not know almost 41% said they never saw nor heard of the laws, on this point, publicity should play important part here. 91.65% agreed with the maximum speed law for safety reason and it helped decrease accidents and its severity as well as it was a standard to comply to. Those who disagreed said the maximum speed set should be realistic, should have no speed limit as the drivers were well aware of safety on the road, and sometimes speeding was necessary(Table 5).

Table 5. Opinions on maximum speed limit law

Opinions	number	%
Agree with	373	91.65
Do not agree	23	5.65
Others	11	2.70
Total	407	100
Reasons for agreeing	**number**	**%**
Safety	179	47.99
Reduce crash severity	41	10.99
Have a rule to follow	35	9.38
Saving fuel	5	1.34
Others & non specified	103	27.61
Total	373	100
Reasons for disagreeing	**number**	**%**
Maximum speed should be realistically set	7	30.43
Free speed limit should be allowed	7	30.43
Sometimes one need to drive fast	5	21.74
Not stated	4	17.39
Total	23	100

On the answers on the maximum speed limit outside the city areas, there were 31.7% of those who knew, 22.36% did not know and 45.95% others. Those who knew mostly learnt from the speed signs beside the roads which showed the crucial importance of effect of the road speed signs on speeding.

As for the fine fees and punishments for "driving beyond speed limit" almost 60% (57.49%) stated that they knew. Those who knew because they had been caught speeding (41.45% of those who knew). For those who did not know 54.37% said they had never been caught speeding so they did not know and 9.38% never heard nor seen about the maximum speed law. These answers indicated that most drivers did not pay attention to the risk of being arrested or speeding nor being punished or fined which would have resulted in them becoming more careful not to speed beyond the law limit (Table 6).

Table 6. Knowledge about maximum speed limit law

Drivers' knowledge	number	%
No. of drivers who know speed limit	366	89.93
No. of drivers who do not know	39	9.68
Others	2	0.49
Total	407	100
Source of information	**number**	**%**
Roadside speed limit signs	113	30.87
Media (newspapers, TV, radio)	64	17.49
Driving lessons	60	16.39
Land Transport Provincial Office	49	13.39
Department of Land Transport	11	3.01
Police	11	3.01
Have been fined for speeding	9	2.46
Others	49	13.39
Total	366	100

On the level of fines in Thailand at 400 baths ($AUS13.79, 29 baths/one dollar) for the punishment of "speeding over the legal limit" the majority thought that they were acceptable.

The respondents also suggested that the law should be seriously enforced by the responsible officers, the law was not up to date, not clear and not strict, should have more check points, the confiscation of driver's license was not suitable, should correct the people not the law and more.

5.1.4 Opinions and Suggestions toward the Speed Signs

83.05% thought that the warning speed signs had effects on drivers and caused them to reduce speed whereas 10% thought it had no effects. Those who slowed down did so for safety reason, to prevent accidents and believed that there must be danger to have the warning signs installed.

60% thought that the wording, length, size of letters, color and position of signs were suitable. 40% thought there should be some improvements especially should increase number of the signs.

The suggestions were as follows: there should be more signs in the small lanes, should maintain signs and repaint some, the letters on the speed signs were too small, in some dangerous positions there should be more warning signs and so on.

5.1.5 Opinions on the Publicity to Reduce Speeding

70.52% of drivers thought the publicity had some effects and 23.83% thought it did not. For the types of media which has effects on speeding, the 72% thought road signs had most effects, followed with television and the least effects (15.72%) was the internet since most people had no access to internet. To improve the publicity, the respondents suggested that it should be done consistently and by and through the community.

5.1.6 Opinions on the Social and Cultural Conditions Affecting Driving

When asked if speeding was a suitable behavior or not, 77.64% said one should not do it 2.95% said should, as it was something necessary, 19.41% who gave answers as others, said it depended on the situation and necessity.

The reasons for speeding are haste 46.93%, excitement 16.95%, and personal habits 13.51%. Of the respondents, 74.945 learnt about safety in driving from school and other educational outlets, 25.06% never learnt from anywhere. For those who learnt, 57.38% learnt from the Department of Transport, 9.51% from school, office and others, only 2% stated they learnt it from the driver's license training.

Among the respondents, 83.78% had experienced accidents or been involved with accidents caused by speeding. The experience made them more careful in driving and speeding. 11.73% admitted the accidents scared them, almost the same percentage as those who stated they felt nothing.

On the question that speeding caused some deaths and if it was a crime or not, 43% of the drivers thought it was NOT A CRIME, they said it was more an accident and it was not controllable. In fact, it could be controlled which will lead to less damages for lives and property. However, 39.31% of respondents thought the punishment should be imprisonment and 17.4% thought that the existing laws were reasonable.

5.2 Qualitative Results

The qualitative results corresponded with the quantitative study. The qualitative study used the method of focus group discussions in three selected provinces. The drivers were purposively chosen to represent the various drivers' types. They were drivers of truck, taxi, van, motorcycles, bus, pick-up trucks, and housewives. The housewives were a necessary component of the focus group to balance the point of view of ordinary people in the community.

In the focus groups, questions asked were: cause of speeding, killing people on the roads is a crime or not, method of learning to drive, opinions toward advertisement, law punishment, road signs. The most important question is ***why people speed.***

5.2.1 Cause of Speeding

Most answers were "haste" and it is common practice in Thai society.

"Time" Housewife, age 41, Chiangmai

"To make it for the destination as it is nearly dark" hire motorcyclist, male, Phuket

"It is something others people do as common practice. It is normal social phenomenon" Car driver, male, age 42, Chiangmai

As for driving habit of Thai people:

"It is bad habit, it is (Thai) nature" Bus tour driver, male, age 42, Chiangmai

For most Thais, religious beliefs are important:

"Yes, I will honk (to show respect to the religious shrines or statues)" Van driver, 48, Chiangmai.

"It is for the security of the mind" Passengers mini van driver, 53, Chiangmai.

Researches on speeding in western countries indicated that people in the western societies regarded killing people on the road was a stigma and was a crime. On this issue, the Thai drivers thought it was more an accident because they did not mean it.

"It is a crime if you intended to hit a person but on the road, it is unavoidable cause did not mean it to happen, it is considered an accident" Tour bus driver, male, 42, Chiangmai.

"Different from murdering a person, it should be an accident cause did not intend it to happen" Car driver, male, 35, Phuket.

It seems the Thai people considered killing people on the road more an accident than a crime. This notion made the drivers in the study think it is uncontrollable whereas in fact the death from an accident could be controlled by decrease the driving speed or drive within the legal limit.

5.2.2 Driving Methods

In the focus group discussion, drivers were asked how they learn to drive which most of them answered:
"Dad taught me (to drive)" Motorcyclist, female, 19 years old, Chiangmai.
"Self taught. I learnt it from being a bus boy. The old driver also taught me". Two rowed passengers van (Song Taew) driver, male, 53, Chiangmai.
"I taught my children both son and daughter" Mini van driver, 48, Chiangmai.

The results from the focus group discussions corresponded with the results from the quantitative survey where 65% of the respondents learnt to drive by themselves by having close relatives or friends or other drivers taught them. Very few people (5%) went to driving school. Thus, this led to the important question if they have learnt or been educated about the danger of speeding or speeding was not a desirable behavior one ought not to do from any source or any one or not. The answers were:
"Yes, I was trained on this but not interested. But if you fell down you would know. Cause I had an accident. I drove motorcycle and hit someone due to drunkenness. I had to be hospitalized". Pick-up driver, male, 21, Phuket)
"In school, friends told me" Motorcyclist for hire, male, 43, Phuket.
"I taught my children not to drive fast. But when they drive beyond our sight, they drive fast as usual".Car driver, female, 41, Chiangmai.

The above answers show that there is teaching about driving and speeding embedded in the socialization process in Thai society from school, parents and peer groups.

However, the process of socialization about speeding and driving could be strengthened from the childhood stage as almost all participants in the focus groups expressed their concerns about the teenagers as far as speeding is concerned. For the road signs on speeding, the participants felt that the number of signs could be increased and should be in English especially in tourist cities such as Chiangmai and Phuket. The Color of the signs should be yellow and reflective so they could be seen at night. The Letter size should be larger so it can be seen clearly.

As far as punishment and law enforcement are concerned, the opinions are various but all agreed that laws should be stricter so as to make people slow down their driving speed.

On the whole, all participants in the focus group discussions in the three provinces namely: Chiangmai, Phuket and Bangkok agreed that most people realized the effects of speeding and have been taught that it was not desirable behavior. But the answers were that it was something normal which most Thai drivers do in Thai society. It is considered Thai phenomenon, it is a social norm which people behave accordingly. The perception of the drivers was that to hit someone dead on the road was an accident not a crime meant that it was something uncontrollable whereas they could have controlled by reducing the speed or drive within the legal limit. Haste was the main reasons people speed reflects the habit of Thai people who (are well known to) lack planning and estimation of the time needed for traveling.

6. CONCLUSION

The paper recommends as results of opinions and attitudes toward speeding studied teaching about safe driving in the socialization process from an early age. The campaign against speeding should be well publicized. The improvements of road signs on speed should be carried out. The short term measures which could be done immediately are the increase of punishment and the increase of law enforcement as well as the use of speed camera.

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IS SMEED'S LAW STILL VALID? A WORLD-WIDE ANALYSIS OF THE TRENDS IN FATALITY RATES

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Abstract: Professor R J Smeed published his famous formula for predicting road deaths in 1949. Later on, other authors tried to validate or update the formula based on newer data. Most of these publications emphasized the encouraging finding that the increase of vehicle ownership leads to a decrease in fatalities per vehicle. Less attention was paid to the other and less encouraging – interpretation of Smeed's formula, namely that the increase of vehicle ownership leads to an increase in fatalities per population and in the total number of fatalities. Fortunately, the increasing trend of the total number of fatalities started to change towards a decreasing trend in some countries from the 60's. The paper analyses GDP, vehicle ownership, population and road fatality data from 139 countries. Relationships between these variables are shown. Using cluster analysis, countries are grouped according to their safety performance trends.

Key Words: Smeed, road safety, vehicle ownership, fatality rate, cluster analysis

1. INTRODUCTION

In his famous paper, Smeed published his formula for predicting road deaths as an empirical rule relating traffic fatalities to motor vehicle registrations and population (Smeed, 1949).

$$D = 0.0003\ (N \cdot P^2)^{1/3} \quad (1)$$

where D is the number of annual road deaths, N is number of registered vehicles and P is population. His paper is mostly cited emphasizing that the increase of vehicle ownership leads to a decrease in fatalities per vehicle (Figure 1).

$$D/N = 0.0003\ (N/P)^{-2/3} \quad (2)$$

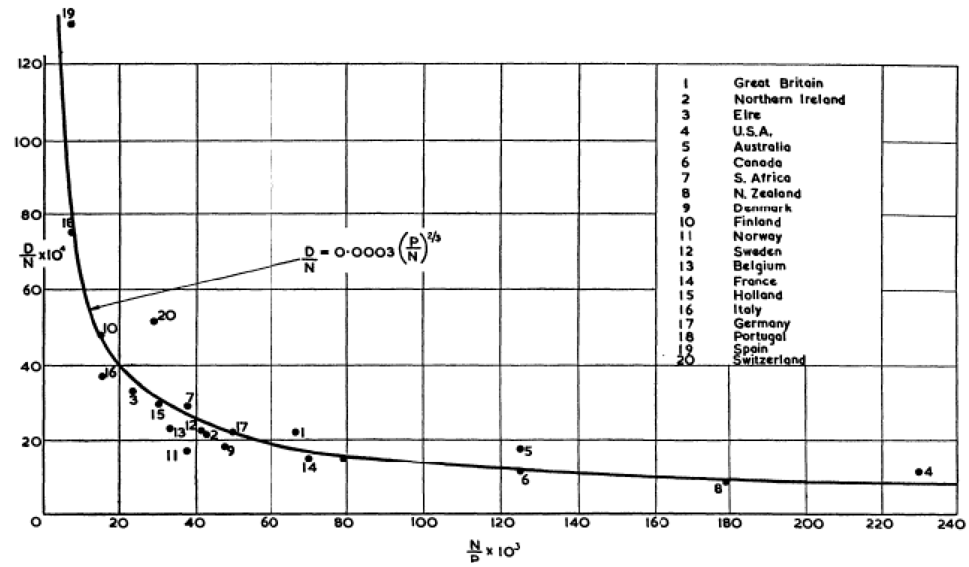

Figure 1. Relation between number of deaths per 10 000 registered motor vehicles and number of vehicles per 1 000 population for 1938

Less attention was paid to the other – and less encouraging – interpretation of Smeed's formula, namely that the increase of vehicle ownership leads to an increase in fatalities per population and in the total number of fatalities (Figure 2).

$$D/P = 0.0003\ (N/P)^{1/3} \tag{3}$$

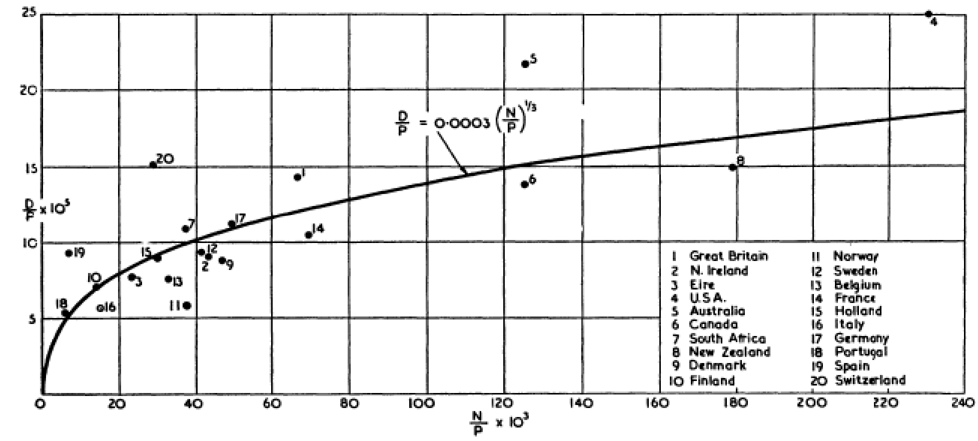

Figure 2. Relation between number of fatalities per 100 000 population and number of registered vehicles per 1 000 population for 1938

Later on, other authors tried to validate or update the formula based on newer data. The law was found to be valid with some changes in parameters (e.g. Adams, 1987). Fortunately, the increasing trend of the total number of fatalities started to change towards a decreasing trend in some countries from the 60's. For the UK, the Smeed prediction was moving correctly and had approximately the right magnitude until about 1966. Since 1966 the Smeed prediction continues to rise, while the real road deaths have fallen quite reliably. By 2000, the Smeed prediction was about 4 times too high (Safe Speed, 2004).

The models describing the changes in road fatalities are using among others vehicle kilometres travelled and Gross Domestic Product.

Research carried out by Oppe (Oppe, 1991 cited in Elvik & Vaa, 2004, p. 38) found that the long-term development of traffic fatalities in the highly motorised countries follows a law-like pattern determined by the growth of motorisation and the decline of the fatality rate per vehicle kilometre of driving.

The change from the increasing to the decreasing trend could be observed in several countries. Kopits and Cropper have found that the income level at which traffic fatality risk (F/P) first declines is $8600 (1985 international prices), regardless of how the time trends are specified. This is the approximate income level attained by countries such as Belgium, the United Kingdom, and Austria in the early 1970s, South Korea in 1994, and New Zealand in 1968 (Kopits, Cropper, 2005).

2. SCOPE OF THE PAPER

This paper presents a world-wide analysis that addresses the verification of Smeed's law. Chapter 3 gives an overview of the data used during the analysis. Chapter 4 and Chapter 5 focus on the validation as well as the review of the two interpretations of Smeed's law. In Chapter 5 the authors propose a new function that better describes the evolution of fatality rate per population in the function of level of motorization. In Chapter 6 countries are grouped into 6 clusters according to their GDP, vehicle ownership rate and fatality rate per population based on their 2007 data. In Chapter 7 a detailed investigation of Asian data is provided and finally Chapter 8 summarizes the conclusions.

3. DATA USED IN THE ANALYSIS

For our analyses we used fatality, population, vehicle ownership and GDP figures. The data used in Chapter 4 and Chapter 5 of this paper, namely the number of fatalities, number of registered motor vehicles and population stem from a global report on road safety for the year 2007 (WHO, 2009). Those countries that have less than 100 road deaths were excluded from the analysis, thus 139 countries were considered.

In Chapter 6 dealing with the cluster analysis along with the previously mentioned data the GDP per capita was added. The gross domestic product based on purchasing-power-parity (PPP) per capita was derived from the World Economic Outlook Database of International Monetary Fund (IMF, 2009).

In Chapter 7 focusing on Asia the data come from various sources. These were the online database of United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP, 2009), the global report on road safety for the year 2007 (WHO, 2009), the ASEAN Statistical Yearbook (ASEAN, 2005) as well as data rows for China and Thailand from the NICE on RoadS EU-Asia project (Koren & Borsos, 2006).

4. FATALITIES PER VEHICLES

Figure 3 and Figure 4 contain fatality rates per vehicle as well as vehicle ownership rates for the 139 countries in 2007, together with Smeed's relationships. Looking at Figure 3, we see that the number of fatalities per vehicles fits well into the trend Smeed found. This is remarkable, considering that the vehicle ownership rates at the time of his study were between 0.01 and 0.23, while some of these figures exceed 0.8 now.

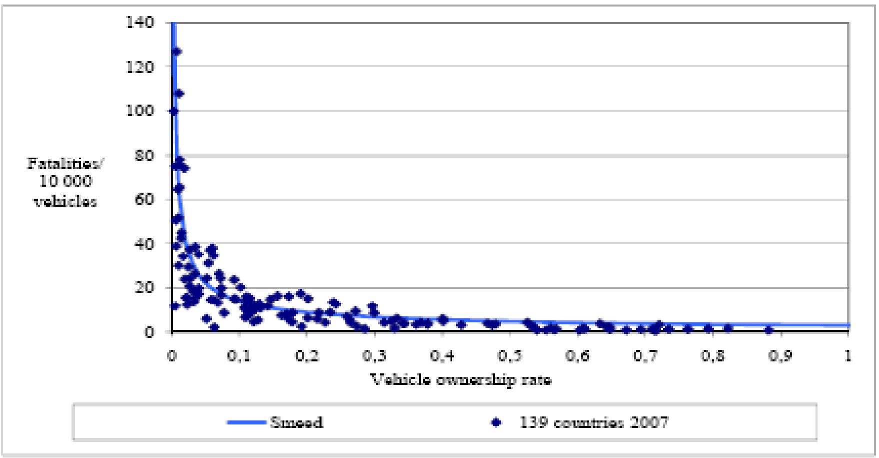

Figure 3. Vehicle ownership and fatality rate per vehicles in 2007 compared with Smeed

However, if we have a closer look of the area below 10 fatalities per 10 000 vehicles (Figure 4, log scale), we see that almost all data lie below the curve, especially for vehicle ownership rates higher than 0.2 which are well out of the range of Smeed's data from 1938. Also the logarithmic scale contributes to the visibility of the differences from the curve.

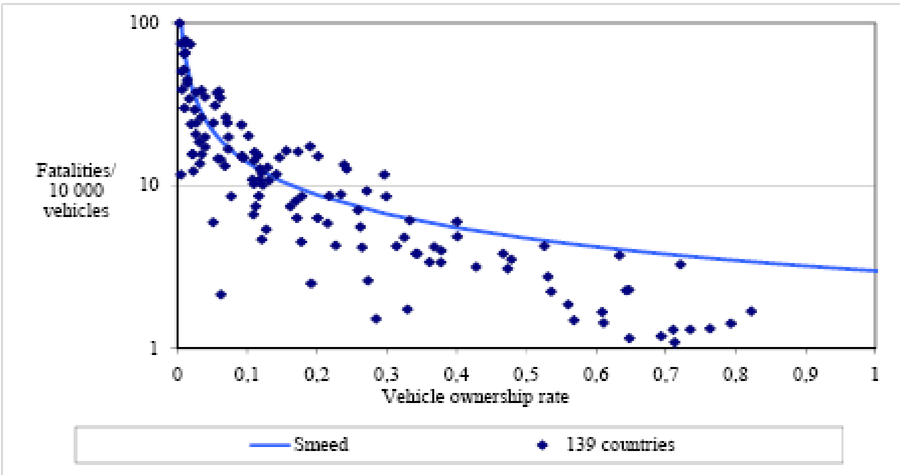

Figure 4. Vehicle ownership and fatality rate per vehicles in 2007 compared with Smeed (log scale)

5. FATALITIES PER POPULATION

As an overall strategic indicator, the most widely used variable to describe the road safety level of a country is the fatalities per population. As it is shown in Figure 5, these data are very much dispersed, the ratio of the highest and lowest values being up to 7:1 for a given vehicle ownership level in 2007. This dispersion is apparently much higher than it was in 1938, with the ratio of about 3:1 between the highest and lowest fatality rates for ownership levels of 0.02 and 0.04. The increase in dispersion is most probably due to the difference in the set of countries studied: Smeed's survey covered a relatively homogenous group of the most developed 20 countries of the world, while the 2007 data come from 139 countries in five continents with huge differences in their economic power, vehicle fleet, road network, social attitude, education and enforcement culture.

Looking at the dispersed "cloud of points" of Figure 5, or trying to find usual regression curves and correlation coefficients, one might come to the conclusion that there is no relationship between vehicle ownership and fatality rates. This is certainly true if we follow the "try several curves until the best fit and then find an explanation" method.

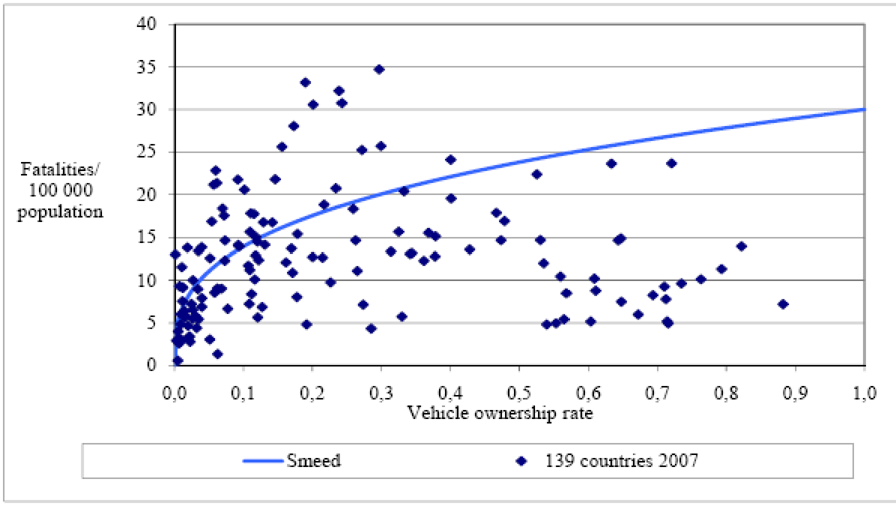

Figure 5. Vehicle ownership and fatality rate per population in 2007 compared with the Smeed formula

The authors followed a different approach: find a formula which explains the phenomenon and then try to fit it. For the description of the relation between vehicle ownership rate and fatalities per population the following formula was used here:

$$D/P = a \cdot N/P \cdot e^{-b \cdot N/P} \quad (4)$$

The term $a \cdot N/P$ is expressing the growing exposure with the increase of the vehicle numbers. While N/P is very low, $e^{-b \cdot N/P}$ is about 1, so the first part of the formula, i.e. the growth in vehicle numbers is dominant.

The second part of the formula, $e^{-b \cdot N/P}$ is a negative exponential function, expressing that the growth of vehicle ownership generally goes together with the increase in vehicle and infrastructure safety as well as with an improvement in education and enforcement.

The formula was fitted to the 2007 data of 139 countries, finding a and b to minimise the square of differences between actual and expected D/P.

From the data, "a" was found to be around 230, which means that for the ownership figure of 0.1 vehicles per person $0.1 \cdot 230 = 23$ fatalities per 100 000 population are expected.

From the data, "b" was found to be around 4.4, which means that for the ownership figure of 0.1 vehicles per person the impact of safety improvements is a correction factor of $e^{-4.4 \cdot 0.1} = 0.64$, for 0.3 vehicles per person $e^{-4.4 \cdot 0.3} = 0.27$, while for 0.6 vehicles per person $e^{-4.4 \cdot 0.6} = 0.07$. Thus, with higher motorisation rates the second term of the formula becomes dominant.

Though the least square method was used to find the best fit, the curve should not be considered as a regression line and therefore no correlation coefficients are given here.

The formula used is appropriate to describe the phenomenon that with low motorization the number of fatalities is increasing. Once reaching a certain threshold, the society will devote and can afford more efforts to turn the previous trends in road safety. The turning point of the fitted curve is about 0.20-0.25 vehicles per person and 20 fatalities per 100 000 population (Figure 6). Apparently there are huge differences among countries. These differences are mainly due to the considerable variations between countries' characteristics such as geographical features, economic and political background.

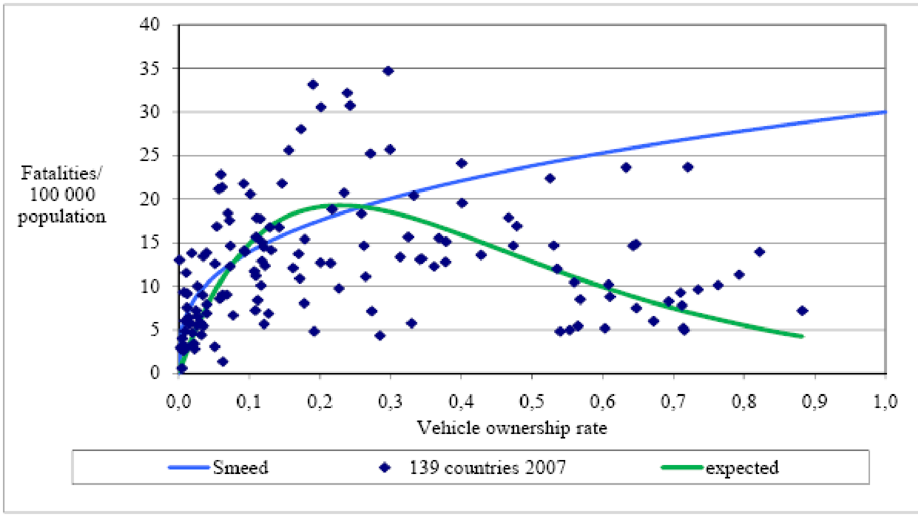

Figure 6. Relationship between vehicle ownership and fatality rate per population for 2007

Although the above data represent a cross-section from one year, the relationship between vehicle ownership and fatalities can be also explained as a change over time (see also section 7.3).

The change in the number of fatalities per population is influenced by the following driving forces:

- Increase in vehicle ownership rate goes together with an increase in accident exposure.
- Increase in vehicle ownership rate goes together with economic growth and technological development (better infrastructure, better equipped cars, better emergency services etc.).
- Social attitude against road safety changes (evaluation of accident costs, acceptance of restrictions etc.).

The combined impact of the three driving forces leads to three stages of development:

- Declining road safety situation

Increasing fatality rate per population dominates due to growing traffic volume and exposure, the economy is weak, and there is no social attention to road safety.

- Turning point

The road safety situation is quite bad; however, the economic performance makes the change possible, if there is adequate social and political will.

- Long-lasting improvement

The pace of economic and technological development as well as the change in social attitude is higher than the growth in traffic volume.

It has to be mentioned here that the number of vehicles is far from being a perfect measure of accident exposure. Vehicle kilometers travelled on a countries road network would describe the exposure much better. In the above explanations the term "vehicles" could be replaced by "vehicle kilometers" as well. Probably the dispersion of the points in the figures would be considerably less. Similar studies were performed earlier for cases when there is a good data set of vehicle kilometers. This is usually possible for individual countries with consistent vehicle kilometer data over the years (e.g. Safe Speed, 2004). Unfortunately, the international statistical data collections contain vehicle kilometer data only for a very limited number of countries and even for those countries which provide such data, the difference in definitions and calculation methods reduces the possibility of international analyses.

6. CLUSTER ANALYSIS

In order to arrange countries by their 2007 data into clusters, three variables were chosen: GDP per population, vehicles per population and fatalities per population. Because of their different magnitudes, all variables were normalized, i.e. their values were divided by their respective means. Then the countries as cases were clustered according to the three variables using K-Means Cluster Analysis in SPSS software. Among others tables of cluster membership and distance from cluster centre were produced as outputs. After several runs it was found that the choice of 7 clusters gives a reasonable description of each cluster. The number of cases (countries) in each cluster and the cluster means of the three variables are shown in Table 1. Clusters were numbered according to their growing GDP/P means. Except for Clusters 5 and 6, the Vehicles/P means are growing parallel to the GDP/P means. The Fatalities/P means generally follow the findings before; they are low at low and high vehicle ownership rates, while the highest fatality rates were found for medium ownership figures. In

Figure 7 clusters are illustrated with different markers in the vehicle ownership – fatality rate coordinate system.

Table 1. Main data of the clusters

Cluster No.	Number of countries	Cluster means		
		GDP/P	Vehicles/P	Fatalities/P
1	44	0.15	0.15	0.53
2	38	0.50	0.53	1.22
3	12	1.04	0.96	2.21
4	15	1.26	1.51	1.06
5	9	1.73	2.59	1.20
6	20	2.99	2.58	0.70
(7)	(1)	(6.66)	(2.99)	(1.20)

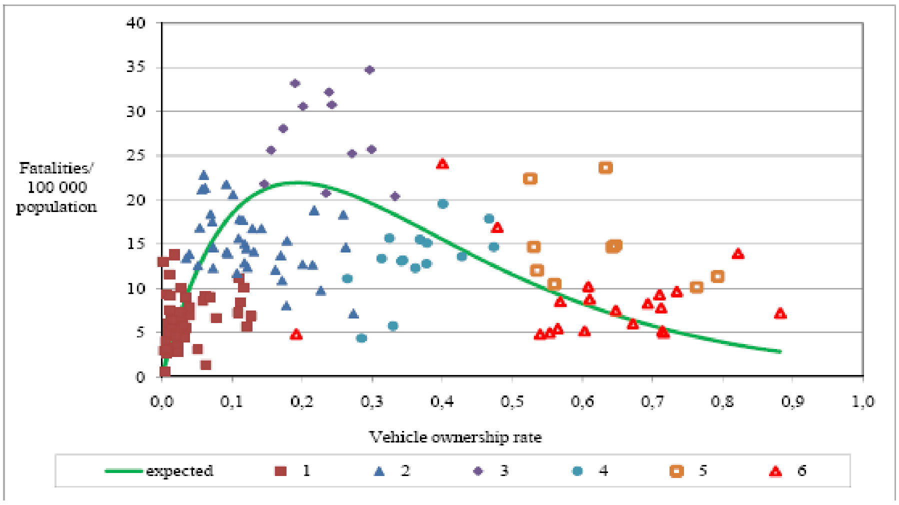

Figure 7. Clusters of countries according their GDP, ownership and fatality rates

Cluster 1 contains the poorest countries. Their vehicle fleet is similarly low. Fatalities per person in these countries are half of the average of all countries. Most of these countries are in Africa but other countries like Tajikistan and Afghanistan belong also to this group.

In Cluster 2 the average GDP is higher but still only half of the average of all countries. Their vehicle fleet is closely proportional to their income. Despite their relatively low vehicle fleet, fatalities per person in these countries are 1.2 times the average of all countries. Countries in this cluster are distributed on 4 continents.

Only 12 countries belong to Cluster 3 which contains the most dangerous ones. Their GDP and vehicle fleet is around the average of all countries, but their fatalities per person figure is 2.2 times more than the average of all countries. Also 4 continents are represented in this group and in several of these countries a large number of population is exposed to a high risk (Russia, Kazakhstan, Iran, Mexico, South Africa, Venezuela).

Cluster 4 contains countries with slightly higher income than the average. Their vehicle fleet is higher than it would be expected from the GDP figures. Fatalities per person in these countries are around the average of all countries. Besides some new EU member states (Bulgaria, Hungary, Poland, Slovakia) countries like Argentina, Korea, Thailand, Uruguay belong to this group.

Cluster 5 is an outlier in some sense. Here the average GDP is 1.7 times higher than the average of all countries and their vehicle fleet is much higher in proportion to their income (or the other way round: their GDP is lower than it would be expected from their vehicle fleet). Probably this discrepancy leads to the result that fatalities per person in these countries are 1.2 times of the average of all countries. Countries in this cluster are the lower income old EU member states (Greece, Portugal) some higher income new member states (Czech Republic, Estonia, Slovenia) as well as three other countries from three continents.

Cluster 6 contains the 20 most developed countries with a GDP three times than the average. Their vehicle fleet is slightly lower than it would be expected from the GDP figures. Fatalities per person in these countries are only about 70% of the average of all countries. Most of the old EU member states as well as Australia, Canada, Japan and the USA belong to this group. Cluster 7 has only one element, this outlier is Qatar with its very high GDP and moderately high fatality rate.

Table 2 shows the first ten countries in each cluster closest to the cluster centre

Table 2. The first 12 countries in each cluster closest to the cluster centre

1	2	3	4	5	6
Tajikistan	Albania	Russian Fed.	Hungary	Estonia	Canada
Sudan	Tunisia	Kazakhstan	Croatia	Portugal	Belgium
Benin	Turkmenistan	Botswana	Argentina	Slovenia	Austria
Afghanistan	Jordan	Iran	Trinidad	Czech Rep.	Sweden
Cameroon	Georgia	Mexico	Lebanon	Greece	France
Tanzania	Azerbaijan	South Africa	Slovakia	New Zealand	UK
Burkina Faso	Jamaica	Venezuela	Bulgaria	Lithuania	Australia
Ghana	Namibia	Libya	Poland	Puerto Rico	Germany
Mali	Paraguay	Montenegro	Belarus	Malaysia	Ireland
Chad	Armenia	Oman	Latvia	-	Netherlands
Malawi	Moldova	Guyana	Korea	-	Switzerland
Congo	Honduras	Saudi Arabia	Thailand	-	Japan

7. ANALYSIS OF ASIAN TRENDS

7.1 Fatalities per vehicles – 2007 data

In order to have a better view on Asia we collected the 2007 data for the Asian countries.

As far as the fatalities per vehicles are concerned, the countries are quite dispersed along the Smeed curve due to their different vehicle ownership rates.

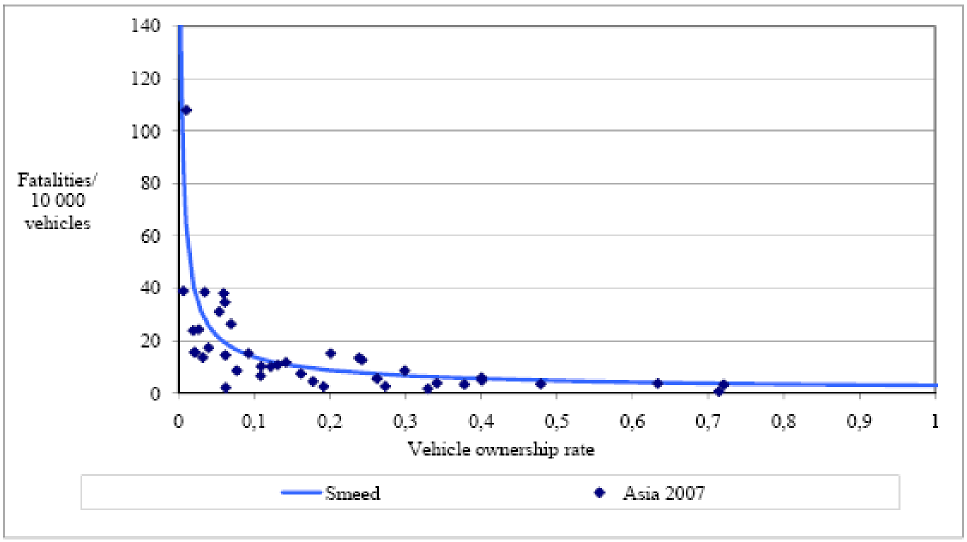

Figure 8. Relationship between vehicle ownership and fatality rate per vehicles for Asia

7.2 Fatalities per population – 2007 data

From the point of view of the fatalities per population even stronger differences can be perceived among Asian countries. Most of them are still in the upward trend, but the downward section is also significant (Figure 9). The high dispersion of fatality rates between countries is due to the fact that Asia is the most divergent continent: countries with low, medium and high income, with widely different geographic conditions, road networks, vehicle fleets and social systems can be found here.

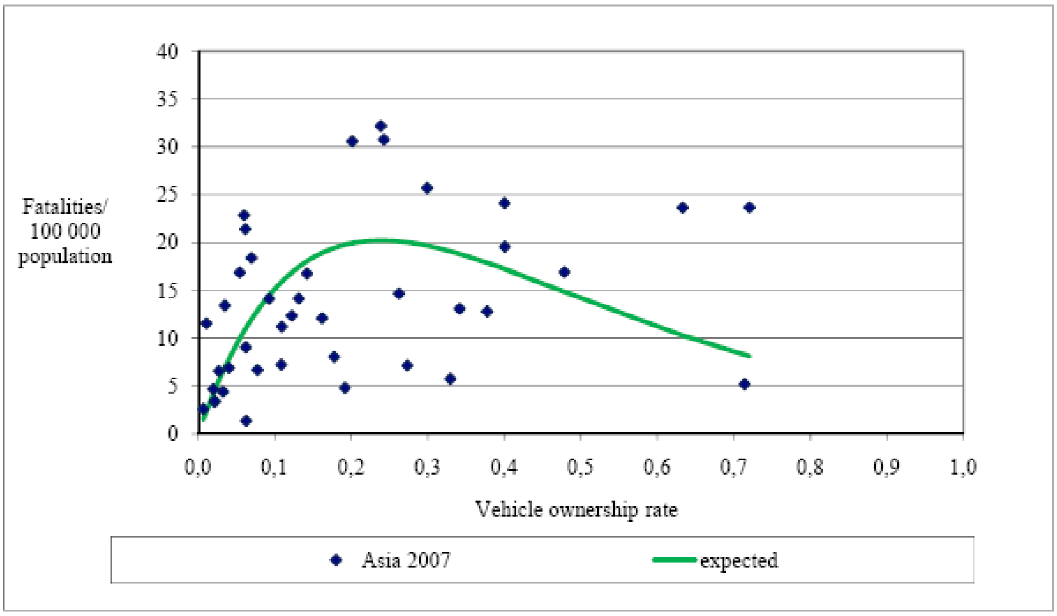

Figure 9. Relationship between vehicle ownership and fatality rate per population for Asia

Unfortunately, in some countries the fatality rate is over 30 per 100 000 inhabitants. Oman, Kazakhstan, Iran are the worst-performing countries with a motorization level of 200~300 and a fatality rate higher than 30 fatalities per 100 000 population. On the contrary there are some well-performing countries, such as Singapore (4,82 fatalities per 100 000 population, 191 vehicles per 1 000 population) or Japan with quite high level of motorization (5,18 fatalities per 100 000 population, 714 vehicles per 1 000 population).

The difference in fatality rates between countries is quite high, and also the ownership levels have a very wide range. The latter is due to the high share of two-wheelers in several countries.

7.3 Fatalities per population – time series

For some Asian countries time series of cars per population and fatalities per population were analyzed. For seven out of eight countries the number of registered vehicles (ASEAN, 2005), in case of Japan the passenger cars in use (UNESCAP, 2009) were used. Owing to lack of data the length of these time series differs, the following list gives an overview of the years included in the analysis:

- China: 1994-2003, 2007
- Malaysia: 1997-2003, 2007
- Myanmar: 1997-2000, 2007
- Philippines: 2003, 2007
- Singapore: 1997-2003, 2007
- Thailand: 1994-2003, 2007
- Lao People's Democratic Republic: 1997-1999, 2007
- Japan: 1990-2002, 2007

The overall picture is similar to the previous cross sectional figures but in Figure 10 the changes for each country can be observe.

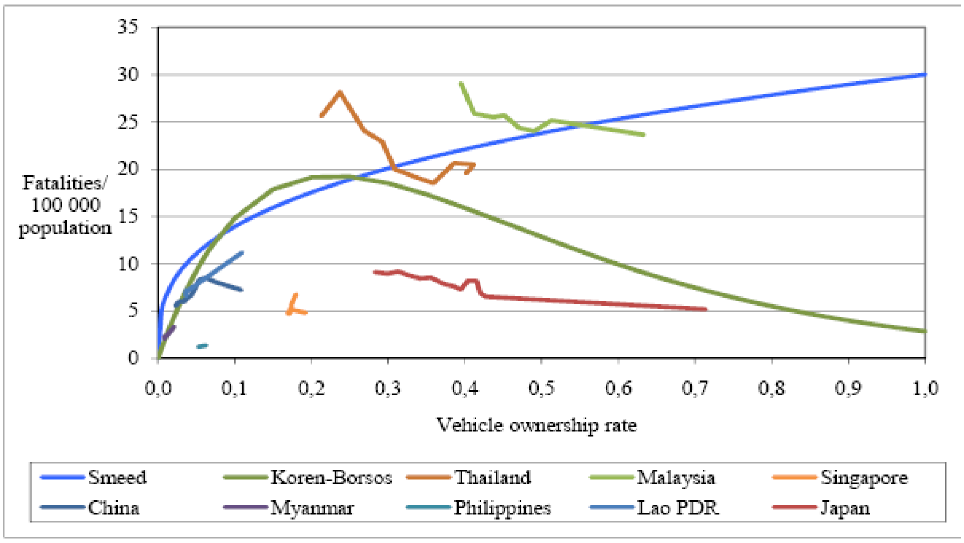

Figure 10. Changes of fatality rates versus vehicle ownership in some Asian countries

Some countries in the lower motorization phase have low fatality numbers but these figures have steadily been increasing in the last decade (China, Myanmar, Philippines, Lao PDR). Some others (Malaysia, Thailand) suffer from much higher fatality rates but these rates are decreasing, especially in Thailand. The low Japan fatality rates show a further decrease.

Fatalities of low vehicle ownership countries (e.g. China, Philippines, Myanmar) are still low but unfortunately rapidly increasing. Countries with medium vehicle ownership (like Thailand, Malaysia) have quite high fatality rates but these are decreasing remarkably. In these countries, the high share of two-wheelers contributes to the high fatality figures. Japan's data are very much similar to that of the high income countries in Cluster 6.

8. CONCLUSIONS

It was found that Smeed's formula is describing reasonably well the changes (increase) in fatalities up to the 0.2-0.3 vehicles/person ownership level, whereas above this level the formula is too pessimistic, the fatalities are fortunately tending to decrease in reality.

For the description of the relation between vehicle ownership rate and fatalities per population a new formula was found combining a linear function showing the growth of vehicle ownership with a negative exponential function explaining the improvements in safety level. The formula can be used both for cross sectional data of a given year to describe difference between countries and for time series of given countries.

In terms of road safety, three stages of development can be identified all over the world. In the first phase the road safety situation is declining. At a second phase, countries come to a turning point. The third phase can be a lasting improvement.

The range of fatality figures between countries for a given car ownership level is quite large.

These differences underline the fact, that the trends found are not like laws of nature. A country will not automatically follow the trend, but a lot has to be done to follow it; it is a result of many efforts in vehicle design, infrastructure safety, enforcement and education.

The cluster analysis identified six clusters of countries with similar fatality rates, car ownership and GDP levels within each cluster but huge differences between clusters. Countries within the same cluster should preferably follow similar road safety strategies.

The Asian countries show a very much dispersed picture in terms of fatality rates and their trends.

Many of them are in a declining road safety situation, where an increasing fatality rate per population due to growing traffic volume dominates, and there is not enough social attention to road safety.

Some other countries are around the turning point, their road safety situation is quite bad, and however, the economic performance makes the change possible, if there is adequate social and political will. There is also the chance for a long-lasting improvement, if the pace of economic and technological development as well as the change in social attitude is higher than the growth in traffic volume.

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COMPETITIVENESS OF CONTAINER PORTS IN A REGION WITH COOPERATION AND INTEGRATION

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Abstract: In order to cope with the ever-increasing competitive environment and enhance the overall competitiveness of ports in a region, cooperation between adjacent container ports as well as integration of regional ports is emerging. The main purpose of this paper is to explore causal relationships between influential factors, types of port cooperation (i.e. complementary cooperation and coopetition), integration of ports, and the overall competitiveness of ports in a region. The results indicate that complementary cooperation, coopetition and integration of ports are all positively influence the overall competitiveness of ports in a region. Overall speaking, the competitive intensity toward competitiveness of regional ports through either complementary cooperation or integration is better, and innovation of ports toward the competitiveness of regional ports through coopetition is better than other ways. Therefore, it is suggested that port authorities can choice either cooperation or integration to enhance the overall competitiveness of ports in a region.

Key Words: Container Ports, Port Cooperation, Port Integration, Competitiveness, Structural Equation Modeling

1. INTRODUCTION

Keen competitions between ports are often observed in a region even within a country. Increasing ship size, greater negotiating power and greater market share of shipping companies through alliances may heighten the competition. This changing environment has posed challenges for the port authorities and led them to seeking new strategies. Therefore, cooperation of adjacent container ports might be adopted as a counter-strategic option against shipping lines in order to survive on the ever-increasing competitive business environment (Avery, 2000). Wang and Slack (2004) also pointed out that in view of the competition unleashed by globalization, the constituents of a regional port system need to be organically integrated for achieving a win-win solution for all concerned.

Sanchez (2006) stated that since many main ports are directly located within cities or agglomeration networking, and combined planning would be an important step towards a more integrated development of ports in the region and would be fundamental to mitigate negative effects from port development. In view of competition between adjacent ports in a region, or in a country with small area like Taiwan sometimes leads to a waste of resources and could be detrimental to the economy, it is very important to integrate adjacent ports through inter-port cooperation to enhance the overall competitiveness of all ports in same region and/or country. For instance, port authorities in a region could get together or finance facilities in one port, and this port could then act as the nodal point of the transport networks reaching the region and, therefore could avoid unnecessary over-investments in each port (UNCTAD, 1996). Recently, more and more practical cases in port cooperation/integration have been found in the real world; such as Osaka and Kobe in Kansai of Japan; Vancouver, Fraser River and North Fraser in British Columbia of Canadian; Ningbo and Zhoushan port in Zhejiang of Mainland China etc., which reveals that regional integration and cooperation of ports in a proper area could be beneficial to all ports concerned.

This study began with literature reviews, followed by the conduction of a questionnaire survey to collect data required for the following main purposes of analysis: (1) to explore factors influence on competitiveness of ports, (2) to examine causal relationships between influential factors, types of port cooperation, integration of ports, and port competitiveness in a region. Quantitative methods such as factor analysis and structural equation modeling were used to analyze the data. Although the survey was conducted in Taiwan, where four international container ports are located in fairly short distances between each others, it is expected that most results of this study can also be reasonably inferred to other similar circumstances, i.e. where several ports existed in a small region and/or country with certain extent of overlapped hinterland or market.

The rest of the paper is organized as follows: The relevant literature is reviewed in section 2. Section 3 describes research design and methods. Section 4 presents empirical results of structural equation modeling, followed by conclusions in section 5.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Cooperation and Integration of Regional Ports

Bird (1980) developed a conceptual perspective on port development, in which three levels of functional integration are identified in the port development process as: setting, expansion and specialization. Notteboom and Rodrigue (2005) considered the recent rise of seaport terminals act as transshipment hubs in extensive maritime hub-and-spoke as a driving factor in port development dynamics, and proposed "regionalization" as the fourth step of the port development process. The regionalization phase and associated integrated hinterland networks promote the formation of discontinuous hinterlands. With a more efficient access to the hinterland, regionalization has become a new phase in the development of port systems to improve their competitiveness (Notteboom and Rodrigue, 2005; Verhoeven, 2009). Thus, more and more countries are cooperated and/or integrated their ports in a region to cope with changing environment and competing with other adjacent countries.

Yap and Lam (2006a) also presented port complementarity as feasible alternatives to strengthen a port's competitive position. Port coopetition through collaborating with partners may achieve the benefits of increased and spare capacity as well as improved capacity utilization (Song, 2003).Hwang and Chiang (2009) also found that complementary cooperation and coopetition would positively influence the overall competitiveness of ports in a region. In addition, a regional port system needs to be integrated to unleash the competition of globalization (Wang and Slack, 2004). Both cooperation and merger are to adopt collaboration as the way to achieve a competitive advantage and synergy. Unlike cooperation, integration can be regarded as merger, the combining of two or more companies into a single corporation.

One practical example of ports integration in a region was Canada. Fraser River, located in North Fraser, which is headquartered in Richmond under the Arthur Lang Bridge, is the smallest of the three ports. The Vancouver Port is already the biggest in Canada. These three western Canadian ports of Vancouver have agreed to integrate to form a single entity – which would in effect become the second largest port in North America. After merging, each port has a specialized area, although there is overlap between them. The port in Vancouver is dominated by container traffic and Fraser River Port receives automobiles arriving from overseas. North Fraser Port, which includes the Vancouver International Airport, is used primarily for shipping logs. They expect this merge would be significant in attracting higher volumes from the fast-expanding Asian markets and they would thereby be able to compete more effectively with US gateways (C.I., 2007). Another example is Osaka and Kobe in Kansai of Japan. The Japanese ports of Osaka, Kobe and Sakai-Senboku Amagasaki- Nishinomiya-Ashiya are merged. This combination was primarily aimed at improving international competitiveness and luring liner services (Fairplay, 2008).

Regarding with cooperation of ports in a region, one practical example is the complementary cooperation on Shanghai and Ningbo port in the past. Shanghai didn't have sufficient water depth so Ningbo was arranged as a complementary port; on the other hand, this complementary cooperation helped Ningbo to gain awareness from the shipping companies.The other type of cooperation is called "coopetition". It takes place when companies work together for parts of their business might not the competitive advantage, and where they think they can share common costs while remaining competitive in other areas. For example, while port of Seattle and Tacoma have competed with each other for cargoes in the overlapped hinterland, they did cooperate on infrastructure, transportation, regional promotion and environmental issues. The port commissioners for Seattle and Tacoma indicated that joint planning and cooperation was vital and increasing competition from Canada western ports (Pacific Shipper, 2008). In short, it also shows that there are intense competitions among ports in North America. Ports of Seattle and Tacoma are coopetition in U.S., and the Vancouver Fraser Port Authority was formed by the merger of three ports in Canada. The purpose of both cooperation and integration is to enhance the overall competitiveness of the region in order to cope with ports of adjacent countries.

Port of Ningbo and Zhoushan is another special example. The two ports had been operated under different administrations, which had resulted in separation of planning and greatly undermined their competitiveness. Therefore, Ningbo and Zhoushan began with cooperation initially, since Zhoushan can complement the disadvantage of the water front development in Ningbo, and Ningbo can complement the disadvantage of hinterland and port development in Zhoushan. Two ports were finally merged into "Ningbo-Zhoushan Port" and started formal operation on Jan. 1 of 2006.(China business council for sustainable development, 2006). Thus, cooperation of ports might be thought as a preliminary step of ports integration in a region.

2.2 Overall Competitiveness of Adjacent Ports in a Region

Ports in same region can be regarded as a single organization. When several ports located in same region and not managed by one same authority, competition may be expected (Wang and Slack, 2004). Therefore, ports competition in same region is essentially similar to intrafirm competition, which has positive and negative consequences for the organization. Positive consequences include the development of a greater number of strategic options, shorter time to market for new products, and broader market coverage. Negative consequences include

duplication, waste of resources, and the potential to engender noncooperative behavior among organizational units (Birkinshaw and Lingblad, 2005). Thus, it can be inferred that cooperation of adjacent ports in same region could influence the overall port competitiveness of the region. Furthermore, cooperation of regional ports can also be regarded as horizontal cooperation. Horizontal cooperation is concerted practices between companies operating at the same level(s) in the market in order to increase performance. Cruijssen *et al*. (2007) pointed out that the potential benefit of horizontal cooperation is to increase their profitability, or to improve the quality of their services. Bartlett and Ghoshal (2000) described three ways in which strategic alliances allow participating firms to reap the benefits of scale economies by pooling their resources and concentrating on core activities, sharing and leveraging the specific strengths and capabilities of the other participating firms, and trading different or complementary resources to achieve mutual gains and eliminate the high cost of duplication.
One of such examples is the set up of the Yangtze River Delta International Shipping Center by the China government, in order to group container terminals and allocate its capacities properly to prevent duplicated constructions, and raise the international competitiveness of Chinese ports as a whole (Wang and Slack, 2004).

2.3 Influential Factors of Port Competitiveness

The two key ideas that are highlighted in the European Commission's proposal for boosting competitiveness and attractiveness of peripheral port cities are cooperation and innovation (City of Göteborg, 2007).Yap and Lam (2006b) pointed out that the load centers also face intense competition from ports located in close proximity due to sharing their hinterlands. Nevertheless, intrafirm competition had potential benefit of increasing the speed to market for new products, enhancing the range of strategic options open to the firm, and broadening the firm's coverage of the different segments in the market (Sorenson 2000, Kalnins 2004, Birkinshaw and Lingblad 2005). For ports, innovation encompasses not only techniques and technology but also the innovation strategies (i.e., product/process-innovations), new approaches to marketing, new forms of logistics and new concepts of scope (Burroughs, 2005; Allaert, 2007). Innovation is an important competitive attribute at the port (Tosh, 2006). Today, ports must rapidly innovate to meet new environmental obligations for material disposal in order to enhance organizational capabilities necessary to maintain competitive advantages (Burroughs, 2005). In addition, cooperation would be helpful to complement one another's competitive advantage and thereby help to boost performance (Yap and Lam, 2006a). Cooperation is also a business strategy used by port operators, as in any industry, to obtain resources from the market. Therefore, if ports intend to innovate in port operations and development, cooperation/integration with adjacent ports would be the important ways.

Most country also tried to cooperate and/or integrate their ports in a region, because cooperation and/or integration strategies of ports can counter fierce intra-and inter-port competition and better serve the general economic interests of their hinterland (Lam, 2002; Yap and Lam, 2006a). Williams (2005) stated that conflict and competition between members of interorganizational networks may create pressures to change the network's structure so that it supports desired levels of cooperation. Competitive intensity itself is a major factor driving firms pursues a strategy of cooperation (BarNir and Smith, 2002).Ang (2008) also stated that firms facing high levels of competitive intensity have greater pressures to collaborate to reduce competition. It is also inferred that competitive intensity would influence on competitiveness through cooperation. Moreover, the creation of competitive advantage is an act of innovation through ports cooperation or/and integration to develop new and better ways of competing. In short, it might be concluded that competitive intensity and innovation of ports would positively influence on cooperation and integration of ports in a region. Moreover, competitive intensity, innovation of ports, cooperation and integration would positively influence on the overall competitiveness of ports in a region, and competitive intensity and innovation of ports also would influence ports competitiveness in a region through cooperation and/or integration.

3. RESEARCH DESIGN AND METHODOLOGY

Questionnaire design and survey, factor analysis, reliability and validity testing, and structural equation modeling are the methods adopted in this study. An exploratory factor analysis was performed for reducing the number of variables and combining these variables into a factor as a measure construct. This procedure would help to minimize multicollinearity or error variance correlations among indicators in the confirmatory factor analysis of the measurement model. Such errors should be avoided as much as possible in structural equation modeling procedures. Finally, structural equation modeling was used for testing the hypothesis and exploring causal relationships.

3.1 Questionnaire Design and Survey

The questionnaire was divided into two parts. The first part of the questionnaire contains 25 designed questions for measuring competitive intensity, innovation of ports, two types of cooperation, integration of ports in a region, and port competitiveness. All the variables were selected and modified on the basis of reviewing literatures related to port operation, port cooperation, port integration, and port competitiveness etc.. The first part of the questionnaire is to ask the degree of agreement of these twenty-five statements, using a six point Liker scale from 1 being "strongly disagree" to 6 being “strongly agree”. The respondents are advised to answer the 25 questions based on the situations of the four adjacent container ports in the west coast of Taiwan, and/or other similar conditions they are familiar with. These four ports, namely Keelung, Taipei, Taichung and Kaohsiung, are located in order from north to south in the west coast of Taiwan, with port pair distance of 34, 87, 110 nautical mile respectively. Therefore, the hinterlands of these ports are overlapped with each others. Part two is the socio-economical attributes of the respondents. Initial questionnaire was pre-tested and revised before sending out to the selected professors, experts, officials of port authorities and managers of shipping companies. Out of the 380 surveyed samples in total, 259 questionnaires were returned with a response rate of 68%. The profile of the respondents is summarized in Table 1.

Table 1. Respondents profile

Item	Keelung Harbor Bureau	Taichung Harbor Bureau	Kaohsiung Harbor Bureau	Shipping Company	Professors and Experts
Top managers	6	3	7	11	24 (10%)
Managers	11	4	4	54	
Front-line managers	7	2	4	30	
Senior Clerks	6	20	22	44	
Total Sample	30 (12%)	29 (9%)	37 (14%)	139 (55%)	

The respondents in Table 1 are divided into several groups. Experts and professors are those who have devoted to studies of port industry. Top managers of port authority include directorgeneral, harbor master, deputy harbor master, chief engineer and deputy chief engineer; managers include department director and deputy director; front-line managers include section chiefs, and senior clerks are those with at least fifteen years experiences in port management, operation and planning. As to shipping companies, top managers include the chief executive officer, deputy general manager/ assisting general manager etc.; managers include department manager and associate manager etc.; front-line managers include chief of section, officer; senior clerks of shipping companies are those with at least fifteen years experiences in operation, planning department.

The survey was conducted in the above-mentioned way, with the consideration that respondents of port authorities may reflect the viewpoints from port management and operations, respondents of shipping companies may reflect the viewpoints of port users, whereas professors and exports are assumed to be more neutral. By combing those different characteristics of respondents together, the overall results of the survey can be expected to be less biased.

3.2 Results of Factor Analysis

Exploratory factor analysis (EFA) is a variable reduction method usually used to identify groups of observed variables, and was used to reduce 25 variables to extract the crucial dimension in this study. EFA was used to analyze variables separately for each facet with varimax rotation, and the latent root criterion of 1.0 was used for factor inclusion in this study. A factor loading of 0.50 was also used as the benchmark to include items in a factor. V11 and V12 are deleted due to those loadings on F3 less than 0.5. Six interpretable factors were extracted and named as: (1) competitive intensity, (2) shipping and terminal operators' strategy, (3) complementary cooperation, (4) coopetition, (5) integration of ports in a region and (6) competitiveness of regional ports (means overall competitiveness of adjacent ports in same region).

Competitive intensity in the region refers to the level of competition of the ports and is related to the number of local competitors, the frequency of using certain marketing actions. Innovation of ports refers to the adaptation of new techniques and strategies in port operation and management etc. Complementary cooperation refers to where ports complement one another's competitive advantage and thereby help to boost performance (Yap and Lam, 2006a). Coopetition refers to a way of collaborating to compete which is compatible and mutually benefited strategies with different objectives can be strengthened (Song, 2003). In short, complementary cooperation focuses on increasing advantages by complementing to each other, whereas coopetition focuses on coordinating each other to reduce unnecessary inter-ports' competition. The results are listed in Table 2. These procedures were performed using SPSS 12. Subsequently, these composite variables (factors) were treated as indicators to measure a construct in structural equation modeling of section 4.

Table 2. Results of exploratory factor analysis

Variable	Statements of Variable	Named Factor	Factor Loading	Cronbach's α
V1	The port has many competitors in local market.	F1 Competitive Intensity in a Region	0.595	0.723
V2	Temporary price discounts are used in local market.		0.571	
V3	Price discounts are very often used in local market.		0.854	
V4	The range of price discounts in local market is very high.		0.840	
V5	Ports should continuously try to serve the needs of port users, such as shipping companies.	F2 Innovation of Ports	0.558	0.809
V6	Ports should continuously develop and bring in new advanced technologies, such as Information Technologies.		0.707	
V7	Ports should continuously add new values and functions.		0.781	
V8	Ports should continuously reinforce marketing strategies and customers' service.		0.812	
V9	Ports should continuously bring in diversified service in port operation.		0.649	
V10	Ports are complemented to each other with its advantages.	F3 Complementary Cooperation	0.614	0.771
V11	Disadvantages of ports are remedied by each other.		0.738	
V12	Ports differentiate their roles based on advantages of each other.		0.363	
V13	Ports help each other to increase performance.		0.415	
V14	Ports coordinate with each other in operations and development.	F4 Coopetition	0.721	0.837
V15	Ports coordination can reduce competition with each other.		0.641	
V16	Proper integration of ports' characteristics.		0.759	
V17	Ports differentiate its development based on different functions.		0.761	
V18	Ports are developed together in which roles and functions of each port are properly differentiated.	F5 Integration of Ports in a Region	0.532	0.859
V19	Resources of ports are integrated together to increase efficiency of utilization.		0.669	
V20	Ports are coordinated to develop and/or enhance the cluster effect.		0.813	
V21	Ports are cooperated to provide new & better service for the customers.		0.810	
V22	Improvements in operating performance.		0.727	
V23	Improvements in response to demand of market.	F6 Competitiveness of Regional Ports	0.789	0.871
V24	Improvements in adaptability to environmental changes.		0.775	
V25	Improvements in providing new services.		0.686	

3.3 Hypothetical Framework and Hypothesis

According to the above-mentioned literatures, competitive intensity in a region and innovation of ports are the significant influential factors to the regional competitiveness. Firms that face high levels of competitive intensity have a greater desire to collaborate due to their need to reduce competitive pressures (Ang, 2008). Thus, it also implies that port authorities might tend to cooperate with other ports in a region when faced severe competition in the market. Innovation has also become a key factor in the development of ports to stimulate cooperating or integrating with other adjacent ports to enhance capabilities of ports. In addition, cooperation and integration can also be the important medium between the influential factors and the overall competitiveness in a region. Accordingly, the following hypotheses were proposed and the hypothetical framework is shown as Figure 1.

Hypothesis 1: Competitive intensity in a region positively influences complementary cooperation of ports.

Hypothesis 2: Competitive intensity in a region positively influences coopetition of ports.

Hypothesis 3: Innovation of ports positively influences complementary cooperation of ports.

Hypothesis 4: Innovation of ports positively influences coopetition of ports.

Hypothesis 5: Complementary cooperation of ports positively influences the integration of ports in a region.

Hypothesis 6: Coopetition of ports positively influences the integration of ports in a region.

Hypothesis 7: Complementary cooperation of ports positively influences the competitiveness of regional ports.

Hypothesis 8: Coopetition of ports positively influences the competitiveness of regional ports.

Hypothesis 9: Competitive intensity in a region positively influences the integrations of ports in a region.

Hypothesis 10: Innovation of ports positively influences the integrations of ports in a region.

Hypothesis 11: Competitive intensity in a region positively influences the competitiveness of regional port.

Hypothesis 12: Innovation of ports positively influences the competitiveness of regional port.

Hypothesis 13: Integration of ports in a region positively influences the competitiveness of regional ports.

Hypothesis 14: Competitive intensity and innovation of ports in a region toward the competitiveness of regional ports is positively influenced through complementary cooperation and integration of ports.

Hypothesis 15: Competitive intensity and innovation of ports in a region toward the competitiveness of regional ports is positively influenced through coopetition and integration of ports.

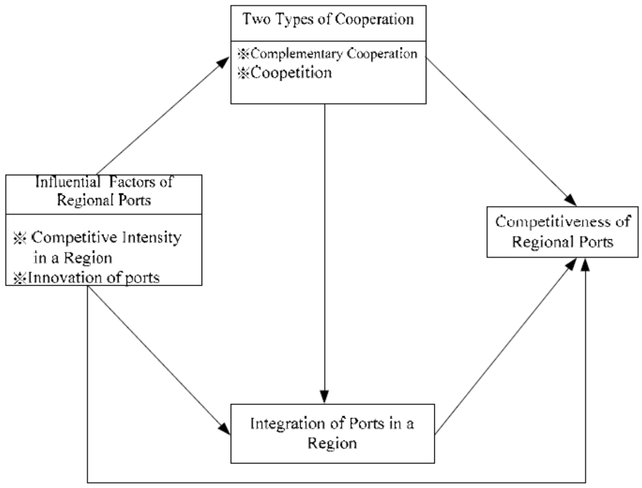

Figure 1. Hypothetical framework

4. STRUCTURAL EQUATION MODELING

The process of structural equation modeling includes two steps: validating the measurement model and fitting the structural model. The former is accomplished primarily through confirmatory factor analysis, while the latter is accomplished primarily through path analysis with latent variables. Both steps were performed using SAS 9.0.

4.1 Validation of the Measurement Model

The confirmatory factor analysis (CFA) is used to develop an acceptable measurement model, and to provide evidence that the indicator variables are measuring the underlying constructs of interest, and that measurement model demonstrates an acceptable fit to the data. At this stage of the analysis, this measurement model does not specify any causal relationships between the latent constructs of interest (Anderson and Gerbing, 1988). Confirmatory measurement models should be evaluated before measurement and structural equation models are examined simultaneously. Thus, each construct in the model was analyzed separately. These procedures provide evidence concerning the extent to which the indicators used in the study are producing reliable data and are measuring what they are intended to measure.

Coefficient alpha is a reliability index of internal consistency. Moreover, it also needs to compute a composite reliability index for each latent factor included in the model, which can reflect the internal consistency of the indicators measuring a given factor. The results of the measurement model with six constructs and 14 indicators derived from confirmatory factor analysis are showed in Table 3. The construct reliability values for all the latent constructs in this study exceeded the commonly accepted threshold value of 0.70 (Nunnally, 1978). As to convergent validity, it is assessed by the t-tests. Factor loading for all the indicators measuring the same construct are statistically significant and this is viewed as evidence supporting the convergent validity of those indicators. The measurement model describes the nature of the relationship between latent constructs and the manifest indicators to measure those latent constructs. Goodness of fit indices in Table 3 indicates that the overall measurement model is acceptable. Finally, the results of chi-square difference test reveal that the correlations between the measures of these different constructs are relatively weak as shown in Table 4

Table 3. Results of convergent validity and composite reliability

Factor	Index	Cronbach's α	Srandardiaed Loading (t-value)	Composite Reliability
F1	V3	0.831	0.6363(5.5586)	0.803
	V4		0.9780 (6.2224)	
F2	V6	0.778	0.7117 (11.9762)	0.810
	V7		0.8321(14.5464)	
	V8		0.7532 (12.8458)	
F3	V10	0.771	0.8204(13.0191)	0.766
	V11		0.7551(11.9941)	
F4	V16	0.831	0.8532(14.9746)	0.824
	V17		0.8214(14.3975)	
F5	V18	0.830	0.7886(14.2744)	0.854
	V20		0.8565 (16.0481)	
	V21		0.7926 (14.3747)	
F6	V23	0.861	0.8646(15.3000)	0.851
	V24		0.8569(15.1339)	
Goodness-of-fit indices		N=259 X^2/df=1.098 NFI=0.960 NNFI=0.995 CFI=0.996 GFI=0.964 RMSR=0.022		

Table 4. Results of discriminatory validity

Factor Sets	Unrestricted Model $\chi^2(62)$ = 68.0443	
	$\chi^2(63)$	χ^2 difference
(F1,F2)	323.3707	255.3264
(F1,F3)	185.6640	117.6197
(F1,F4)	238.4376	170.3933
(F1,F5)	244.2215	176.1772
(F1,F6)	268.7743	200.73
(F2,F3)	169.6349	101.5906
(F2,F4)	181.3845	113.3402
(F2,F5)	245.4888	177.4445
(F2,F6)	233.4622	165.4179
(F3,F4)	145.8740	77.8297
(F3,F5)	148.8409	80.7966
(F3,F6)	143.3529	75.3086
(F4,F5)	164.7975	96.7532
(F4,F6)	180.3097	112.2654
(F5,F6)	191.5146	123.4703

4.2 Results of Structural Model

A measurement model can't specify any causal relationships between each latent constructs, therefore, a structural model is required to specify causal relationships between the latent constructs themselves. The process of hypothesizing structural causal model was guided by theoretical considerations, and the final structural model derived from the framework of Figure 1 as shown in Figure 2 had acceptable goodness of fit indices. The chi-suqare value is not significant (χ^2 (63) =92.308, $p<0.05$), and the χ^2/df ratio is 1.465. A criterion that χ^2/df ratio less than 5 has been suggested as the threshold of an acceptable fit between the hypothesized model and the sample data (MacCallum, Brown & Sugawara, 1996). Root mean square residual (RMSR) of 0.031 is less than 0.050, goodness-of-fit index (GFI) of 0.952,nonnormed fit index(NNFI) of 0.974, normed fit index (NFI) of 0.946, and comparative fit index (CFI) of 0.982 all exceed 0.900.

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4.2.1 Hypothesis Testing

The hypothesized causal model was tested by structural equation modeling, which included a test of the overall model as well as individual tests of the relationships among the latent constructs. The results offered support for the relationship between influential factors, the port cooperation, port integration, and port competitiveness at a significant level of 0.05(Figure 2). As shown in Figure 2 and Table 5, both complementary cooperation and coopetition of ports are positively affected by competitive intensity and innovation of ports. Integration of ports in a region is positively affected by complementary cooperation and coopetition of ports. Moreover, overall competitiveness of regional ports is positively affected by complementary cooperation, coopetition and integration of ports. However, hypothesis H9, H10, H11 and H12 are not supported by the data.

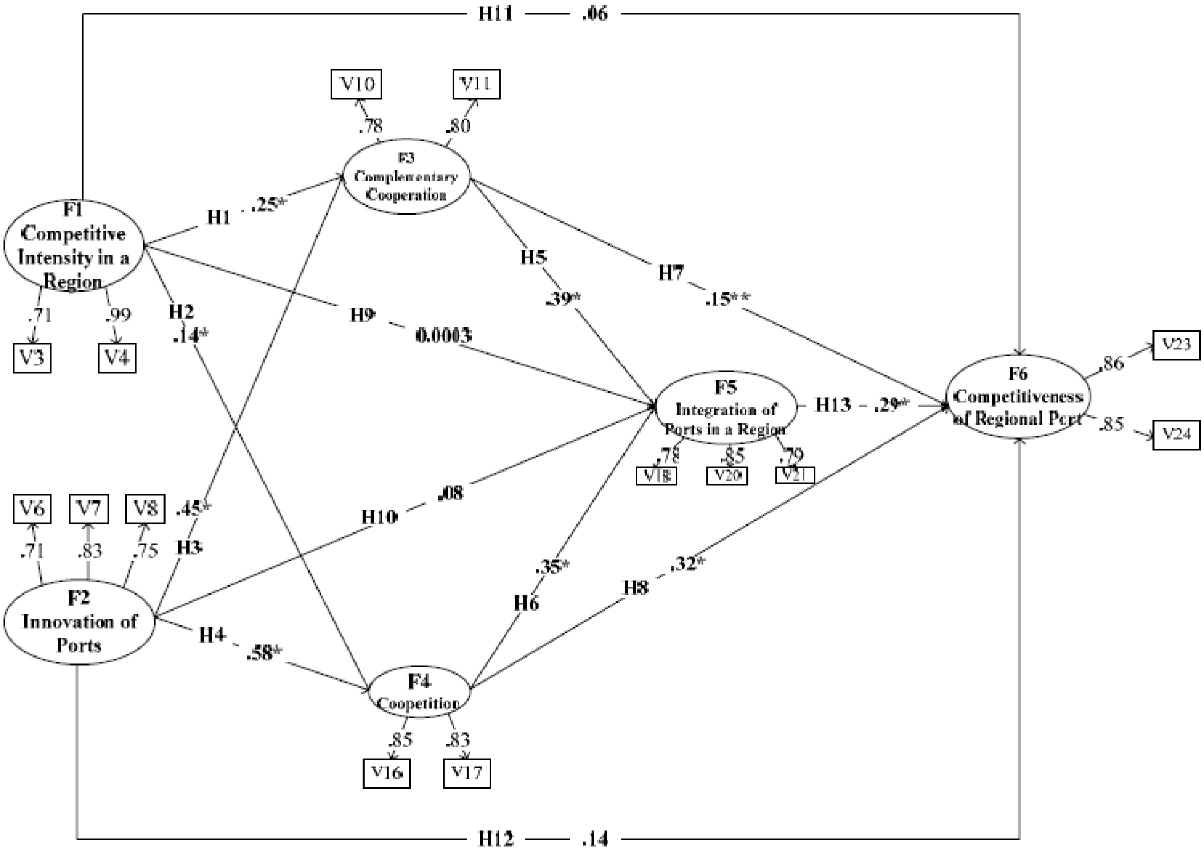

Figure 2. Results of hypothetical model testing

Note: * indicates statistical significance at the 5% level; ** indicates statistical significance at the 10% level

Table 5. Results of hypothesis testing

Hypothesis	Path Loading	t value	Result
H1	0.245	3.585*	Support
H2	0.141	2.297*	Support
H3	0.445	5.633*	Support
H4	0.583	7.623*	Support
H5	0.385	4.437*	Support
H6	0.348	3.915*	Support
H7	0.151	1.787*	Support
H8	0.322	3.615*	Support
H9	0.0003	0.005	Not Support
H10	0.083	0.859	Not Support
H11	0.062	1.082	Not Support
H12	0.137	1.551	Not Support
H13	0.286	3.378*	Support

4.2.2 Effect Analysis

Final testing of H14 and H15 was to analyze the mediating effect of complementary cooperation, coopetition and integration in the model.An indirect effect assesses the impact of one variable on another as that variable's influence works through one or more intervening variables. Furthermore, it is better to measure the mediation and indirect effect in the model, by testing the influence of mediated model.

There are three models to compare with the hypothetical model. Model 1 excludes the complementary cooperation and coopetition in the hypothetical model; Model 2 excludes the integration of ports in the hypothetical model; Model 3 excludes all mediated variables between competitive intensity and innovation of ports and overall competitiveness of regional ports. The structure and testing results of model 1, 2 and 3 are fit good to the data. Model 1 is supported by RMSR =0.02, GFI=0.98, NNFI=0.99, NFI = 0.98, and CFI =0.99. Model 2 is supported by RMSR =0.03, GFI=0.96, NNFI=0.98, NFI = 0.95, and CFI =0.99. Model 3 is supported by RMSR =0.02, GFI=0.98, NNFI=0.99, NFI = 0.98, and CFI =0.99.

In Table 6, the hypothetical model indicates that the indirect effect of competitive intensity toward the competitiveness of regional ports through complementary cooperation and integration of ports in a region (0.027) is greater than through coopetition and integration of ports in a region (0.014). It implies that the effect of competitive intensity toward the competitiveness of regional ports through complementary cooperation and integration is better than through coopetition and integration. But that of innovation of ports is better through coopetition and integration of ports in a region than complementary cooperation and integration of ports in a region.

The result of Model 3 reveals that competitive intensity and innovation of ports toward the competitiveness of regional ports is significant, but is not significant in the hypothetical model. It shows that competitive intensity or innovation of ports toward competitiveness of regional ports should through both cooperation and integration indirectly when these two mediators exist in the hypothetical model. Thus, the mediating role of port cooperation and integration is complete mediation when cooperation and integration exist in the model. The mediating effects test of cooperation or integration in Model 1 and 2 indicates that innovation of ports toward the competitiveness of regional ports in Model 1 and 2 are significant, but the coefficient values in Model 1 (0.294) and Model 2 (0.159) are lower than without a mediating variable in Model 3 (0.494). It implies that either cooperation or integration is a partial mediation between the innovation of ports and competitiveness of regional ports. As to competitive intensity toward the competitiveness of regional port, integration of ports is a partial mediation variable between two factors in Model 1, but cooperation (i.e., complementary cooperation and coopetition) is complete mediation between competitive intensity and the competitiveness of regional port.

Table 6. Effects of mediating variables

Path \ Model	Hypothetical Model	Model 1 (not include cooperation)	Model 2 (not include integration)	Model 3 (not include cooperation and integration)
F1→F6	0.062	0.097**	0.063	0.184*
F1→F5→F6	--	0.066	NA	NA
F1→F3→F6	--	NA	0.066	NA
F1→F4→F6	--	NA	0.058	NA
F1→F3→F5→F6	0.027	NA	NA	NA
F1→F4→F5→F6	0.014	NA	NA	NA
F2→F6	0.137	0.294*	0.159**	0.494*
F2→F5→F6	--	0.204	NA	NA
F2→F3→F6	--	NA	0.120	NA
F2→F4→F6	--	NA	0.242	NA
F2→F3→F5→F6	0.049	NA	NA	NA
F2→F4→F5→F6	0.058	NA	NA	NA

Note: * indicates statistical significance at the 5% level; ** indicates statistical significance at the 10% level; --means path insignificant

Table 6 also reveals that the effects of competitive intensity toward competitiveness of regional ports through complementary cooperation or integration are similar. It implies that port authorities can choice either complementary cooperation or integration to enhance the overall competitiveness of ports in a region. As far as innovation of ports toward the competitiveness of regional ports is concerned, through coopetition is better than through complementary cooperation or integration of ports in a region.

Furthermore, Table 7 shows that innovation of ports has more influence on competitiveness of regional ports than competitive intensity does.

Table 7. Effect analysis of hypothetical model

Path	Direct Effect	Indirect Effect	Total Effect
F1→F3→F5→F6	NA	0.027	NA
F1→F4→F5→F6	NA	0.014	NA
F1→F6	0.062	NA	0.103
F2→F3→F5→F6	NA	0.049	NA
F2→F4→F5→F6	NA	0.058	NA
F2→F6	0.137	NA	0.244

Note: Total effect = Direct Effect + Indirect Effect

5. CONCLUSIONS

1) While different types of cooperation and integration between private firms have been the common practices in many industries, rare cases can be found in port industry before 2000.However, more and more practical cases of port cooperation and integration have appeared since early 2000, as was cited in the literature review section of this paper, The trend seems getting emerged recently due to the increase in level of port competition worldwide.

2) The findings of this study indicate that complementary cooperation, coopetition and integration of ports are positively influence the overall competitiveness of regional ports. Moreover, competitive intensity and innovation of ports are associated with cooperation and integration of ports in a region. The competitive intensity toward the competitiveness of regional ports through complementary cooperation and integration is better than coopetition and integration in a region. But that of innovation of ports is better through coopetition and integration of ports in a region than complementary cooperation and integration of ports in a region.
3) Unless cooperation and integration exist in the model simultaneously, either cooperation or integration is a partially mediated role between the innovation of ports and competitiveness of regional ports. Therefore, innovation of ports can influence the overall competitiveness of regional ports directly. It implies that innovation would play an important role to enhance competitiveness of region. Port authorities should continuously spend efforts on all aspects of port innovations.
4) The effects of competitive intensity toward competitiveness of regional ports through complementary cooperation or integration are similar. It also implies that port authorities can choice either complementary cooperation or integration to enhance the overall competitiveness of ports in a region. As far as innovation of ports toward the competitiveness of regional ports is concerned, through coopetition is better than through complementary cooperation or integration of ports in a region. Therefore, port authorities can choice either complementary cooperation or integration to enhance the overall competitiveness of ports in a region, depending on the influential factors to the competitiveness of regional ports.
5) Cooperation and integration are ways to develop synergies between ports in same region. New behaviors of port authorities and the government are required, if they want to be a positive contributor to enhance the overall port competitiveness of the region

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AN EXACT SOLVING APPROACH TO THE AUTO-CARRIER LOADING PROBLEM

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Abstract: This article presents an algorithm leading to an exact solution of the auto-carrier loading problem (ACLP). The ACLP is defined as assigning vehicles to slots on a trailer for their delivery to the sequenced dealerships on an auto-carrier route while the need for vehicle reloading is minimized. In this paper, we formulated the ACLP as a quadratic assignment model and solved the problem with exact solutions. Sixty test problems in four problem sets were solved by our solution algorithms. The computational results showed that our approach found the optimal and exact solutions of the ACLP problems.

Key Words: Auto-carrier; loading problem; quadratic assignment programming

1. INTRODUCTION

Auto manufacturers usually rely on the services of a special transportation company (TC) to efficiently deliver vehicles, including cars, vans and trucks, from their storage lots to auto dealerships. The TC uses a special type of delivery truck called "auto-carrier"to ship vehicles. The auto-carrier is a combination truck with a tractor and a trailer, as shown in Figure 1, to load and deliver the vehicles to their destinations, or auto dealerships. The request from an auto dealership is usually less than the capacity of a trailer, and therefore an auto-carrier is usually loaded with vehicles to be delivered to several dealerships on a delivery route. The capacity of a trailer is defined by the number of slots on the trailer. For example, the trailer shown in Figure 1 has a nine-slot capacity.

The TC needs to route auto-carriers on a daily basis and the routing decisions are similar to the typical vehicle routing problems. There are certain loading constraints between a trailer and vehicles. For example, a trailer can only use a specific gate to load and unload vehicles; some vehicles cannot be loaded onto a specific slot on a trailer because the height of the slot is restricted, etc. A reloading activity is required to move the vehicles on a trailer in order to provide a free path for other vehicles during the vehicle unloading process. Reloading vehicles will not only increase the auto-carrier driver's workload but also increase the risk of damaging vehicles in the process. Therefore, the TC wants to assign vehicles to slots not only to ensure each vehicle can be successfully loaded onto a trailer, but also to minimize the reloading activities on a delivery trip.

Figure 1. An auto-carrier

In theory, the TC should load all vehicles in the "right"slots on a trailer before an auto-carrier is sent out so that no reloading is reuired. However, in practice, it is a difficult task to effectively load every single vehicle in the right slots during the auto-carrier route planning process. In real world applications, loading operators would usually divide the task into four steps, as described below.

Step 1: Segregate destination dealerships into clusters. The dealerships in each cluster would receive vehicles from the same trailer.

Step 2: Make a routing decision for a trailer to serve each cluster of dealerships.

Step 3: For each trailer with an assigned routing decision, allocate vehicles to the slots of the trailer based on the sequence of the dealerships to be visited.

Step 4: Based on the assignment results in step 3, some vehicles may not be feasibly loaded onto any slots on a trailer due to capacity or loading constraints. To ensure that all vehicles can be loaded onto their appropriate slots for delivery, the TC may decide to use multiple auto-carriers to deliver vehicles to the dealerships in the same cluster or adjust the assignment results in step 3, such as exchanging assigned slots (or trailers) of vehicles.

From the steps above, the operators may be able to load all vehicles onto a trailer but they may use more auto-carriers than necessary; or the assignment results may require extra reloading activities during the shipping process. If a TC can always find an optimal vehicle loading plan that minimizes the required auto-carrier trips and reloading activities, the TC may reduce operation cost and improve its competitiveness. Therefore, it becomes an important business issue for the TC to optimally assign vehicles to appropriate trailer slots to minimize the reloading activities in the shipping process. This article is focused on the autocarrier loading problem (ACLP), which is defined as assigning vehicles to slots on a trailer for their delivery to the sequenced dealerships on an auto-carrier route while the need for vehicle reloading is minimized.

The ACLP has been addressed by Agbegha *et al*. (1998) who developed a heuristic algorithm to solve the ACLP. Four problem sets with sixty test problems were solved by their heuristic algorithm. The computational results showed that there were still some infeasible solutions and suboptimal solutions in the sixty test problems. However, since practically there are usually no more than twelve available slots on a typical trailer, the ACLP is not a large scale problem. Besides, the number of slots on a trailer is constant and loading two vehicles onto two different slots may cause differences in the number of reloading, so this type of ACLP is similar to the quadratic assignment problem (QAP). In this article, ACLP problem was formulated as a quadratic assignment model. To address this topic in detail, this paper is organized as follows: section 2 reviewed related previous work; section 3 illustrated the reloading work; section 4 illustrated the mathematical formulation of the ACLP; section 5 presented some test problems; section 6 demonstrated computational results on the test problems; and conclusions were summarized in section 7.

2. LITERTURE REVIEW

In the assumptions of Agbegha *et al*. (1998), if a vehicle is unloaded from a trailer slot and needs to be reloaded back to the trailer at a dealership, the unloaded vehicle has to be loaded back to its original slot on the trailer regardless if the trailer still has other empty slots. In practice, however, the vehicle may be loaded in any feasible empty slot. Tadei *et al*. (2002) tried to solve the loading and routing problem of auto-carriers simultaneously to maximize the TC profit. To simplify the auto-carrier loading computation, each auto-carrier is assumed to have only a single equivalent loading plane on which vehicles are loaded horizontally. The auto-carriers are classified by length of the equivalent loading plane, which equals the sum of the lengths of real auto-carrier loading planes and a nonnegative constant, which takes into account the special loading techniques available for those auto-carriers. The authors further discussed the auto-carrier transportation problem but their method only came up with an approximate solution to the ACLP.

The QAP is a combinatorial optimization problem, as stated for the first time by Koopmans and Beckmann (1957). The problem is defined as: Given a set of *n* possible locations, *n* facilities are to be located on these locations with only one facility at a location, find a minimum cost allocation of *n* facilities into *n* locations.

By using the definition, Loiola *et al*. (2007) presented some of the most important QAP formulations and classified them according to their mathematical sources. Loiola et al. also presented a discussion on the theoretical resources used to define lower bounds for exact and heuristic algorithms. Detailed discussions on the progress made in both the exact and the heuristic solution methods, including those formulated according to metaheuristic strategies, were also presented. It also analyzed the contributions brought about by the study of different approaches. There were some other literatures discussing the QAP after Loiola *et al*. (2007), including Erdogan *et al*. (2007)'s branch-and-cut algorithm; Drezner (2008)'s hybrid genetic algorithm with other tabu searches, and James *et al*. (2009)'s cooperative parallel tabu search algorithm (CPTS). Some additional literatures using other algorithms to solve the QAP can be found in Ramkumar *et al*. (2008), Drezner (2005), and Demirel and Toksarı(2006).

3. RELOADINGWORK

As described in section 2, there are two vehicle reloading methods: reloading the unloaded vehicle to its original slot; or reloading the vehicle to any feasible empty slot. In this section, we will explain the difference between the two reloading methods. For illustration purpose, we converted a trailer into a tree loading network as shown in Figure 2. In the tree loading network, each node represents a slot and each directional arc from node *i* to node *j* indicates that the vehicle on node *i* must be unloaded before the vehicle on node *j* can be unloaded through node *i* . Node 1 represents the gate of the auto-carrier. In addition, an auto-carrier must sequentially visit the dealerships from destination 1 (dealership 1) to destination 4 (dealership 4) on a route. The destinations of vehicles are shown in Table 1. The example listed in the table shows seven vehicles, numbered from 1 to 7, of three different types (Type 1, 2, and 3), to be delivered to four destinations. There are two loading constraints:

1. Type 1 vehicles cannot be assigned to slot 1, 3, or 5.
2. Type 2 vehicles cannot be assigned to slot 1.

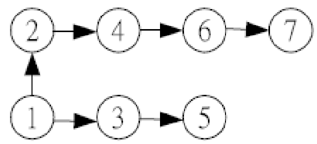

Figure 2. A tree loading network (seven slots)

Table 1. The example data

Vehicle	Vehicle number						
	1	2	3	4	5	6	7
Type	2	2	1	1	1	3	3
Dest.	1	1	2	2	3	3	4

Dest.=Destination

In this example, vehicle 1 is assigned to slot 3, vehicle 2 is assigned to slot 5, and vehicle 7 is assigned to slot 1 in the vehicle storage lot. When the auto-carrier arrives at destination 1, vehicle 7 must be unloaded first before unloading vehicle 1 and vehicle 2. After vehicles 1 and 2 are unloaded, vehicle 7 must be reloaded back onto the trailer before leaving for destination 2. If vehicle 7 (to be shipped to destination 4) is reloaded onto the original slot (slot 1) then it will have to be unloaded and reloaded again at destination 2. Therefore, as the auto-carrier arrives at destination 2 there will be two unnecessary unloading and reloading activities. If at destination 1 vehicle 7 is reloaded onto slot 3 (an empty slot after vehicle 1 was unloaded), there will be no reloading of vehicle 7 at destination 2. With the explanation of this example, if a vehicle is allowed to be reloaded onto an empty trailer slot at a destination, it is possible to avoid some unnecessary reloading at other downstream destinations. In this paper, all vehicles are assumed to be loaded back to any feasible empty slot when reloading activities are required at any destination.

4. FORMULATION OF THE AUTO-CARRIER LOADING PROBLEM

Agbegha *et al*. (1998) converted a trailer slots into a tree loading network as depicted in Figure 2 and a general loading network shown in Figure 3. In this section, we also use the tree loading network and the general loading network for constructing the ACLP model. In section 4.1, we will demonstrate the model in a tree loading network. In section 4.2, we will show the model in a general loading network. Dummy vehicles will be introduced in formulating the model when the number of vehicles is less than the number of slots. The definition and use of dummy vehicles are described in section 4.3.

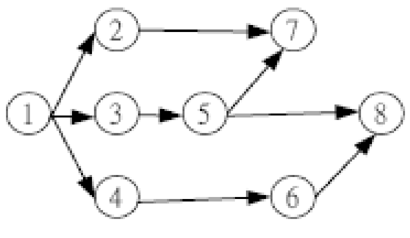

Figure 3. A general loading network

4.1 Formulation of ACLP as a Tree Loading Network

The formulation of ACLP as a tree loading network is as follows.

1. Notations

i, k : index of vehicles(i =1,2,…,m; k =1,2,…,m)

j, l : index of slots (j =1,2,…,m; l =1,2,…,m)

$d(i)$: destination of vehicle i .

$PRED(j)$: the set of predecessor slots of slot j .

$SUC(j)$: the set of successor slots of slot j .

a_{ijkl} : cost of reloading vehicle i from slot j when vehicle k is in slot l , if $j \in PRED(l)$ and $d(i) > d(k)$ then $1 = a_{ijkl}$, otherwise, $0 = a_{ijkl}$.

m : number of slots in a trailer.

T_{jl} : if $j \in PRED(l)$, the set of slots in $SUC(j)$ with node labels less than l ,

$$T_{jl} = \left\{ t \mid t \in SUC(j), t < l \right\}.$$

L_{ik} : the set of vehicles (not including i) with destinations other than $d(k)$,

$$L_{ik} = \left\{ q \mid d(q) \neq d(k) \right\}.$$

n : number of destinations on a route.

s : index of destinations (s =1, 2, …, n).

m_s : the smallest number of remaining vehicles on the trailer when an auto-carrier arrives at destination s and unloads vehicles whose destinations are s . For example, a route that has three destinations (s =1, 2, 3) and the auto-carrier has to deliver four vehicles (i =1, 2, 3, 4) to the three destinations. The destinations of vehicle 1 and vehicle 2 (i =1, 2) are the first dealership (s =1), the destination of vehicle 3 (i =3) is the second dealership (s =2), and the destination of vehicle 4 (i =4) is the final dealership on the route (s =3). When vehicle 1 and vehicle 2 are unloaded at the first dealership (s =1), vehicle 3 and vehicle 4 should remain staying on the trailer. Based on the definition of m_s , m_1 = 3 because 3 is the smallest index number of vehicles remaining on the trailer. When the auto-carrier arrives at the second dealership (s =2), then m_2 will be equal to 4.

z_{ij}^{s} : if vehicle i is assigned to slot j for destination s at destination s -1, then z_{ij}^{s} =1, otherwise z_{ij}^{s}=0.

p : when a vehicle is unloaded and reloaded to a different slot at any destination, the reloading will incur a penalty cost p , $0< p <1$.

2. Mathematical Model

A QAP was used to construct the ACLP model. There are two components in the objective function as shown in (1). The first component represents the number of reloading of vehicleson completion of delivery when all vehicles are delivered to their appropriate destinations. For the joint assignment (i, j , k,l) at destination s -1 (i.e., vehicle i is assigned to slot j(z^s_{ij}=1) and vehicle k is assigned to slot l (z^s_{kl} =1 , $i \neq k$, $j \neq l$) the assignment cost is defined as $a_{ijkl}\prod_{t\epsilon T_{jl}}\sum_{q\epsilon L_{ik}} z^s_{qt}$ The quantity $\prod_{t\epsilon T_{jl}}\sum_{q\epsilon L_{ik}} z^s_{qt}$ will take a value of 1 if no vehicles going to d (k) is assigned to a slot in the set T_{jl}, otherwise it will be 0. Based on this and the fact that the above assignment cost needs to be considered only if $j \in PERD(l)$ and $d(i) > d(k)$. The second component represents a penalty cost defined as unloading a vehicle from some trailer slot at destination s -1 and reloading it onto a different slot for the next destination s. This penalty cost is denoted as p .$p^* \sum_{j=1}^{m} z_{ij}^{s-1}(\sum_{j'=1,j'\neq j}^{m} z_{ij'}^{s})$can be used to compute the penalty cost when a vehicle is unloaded from a trailer at destination s -1 and reloaded onto a different slot of the same trailer for destination s . If $\sum_{j=1}^{m} z_{ij}^{s-1}(\sum_{j'=1,j'\neq j}^{m} z_{ij'}^{s})$=1 then $p * \sum_{j=1}^{m} z_{ij}^{s-1}(\sum_{j'=1,j'\neq j}^{m} z_{ij'}^{s})$ p, else if $\sum_{j=1}^{m} z_{ij}^{s-1}(\sum_{j'=1,j'\neq j}^{m} z_{ij'}^{s})$=0 then $p^* \sum_{j=1}^{m} z_{ij}^{s-1}(\sum_{j'=1,j'\neq j}^{m} z_{ij'}^{s})$=0. In the same example as shown Figure 2, when vehicle 7 is loaded onto slot 1 of the trailer for destination 1 at the storage lot, then $z^1_{71} = 1$ and $z^1_{72}=\ldots=z^1_{77}$ =0. If vehicle 7 is reloaded onto slot 1 for destination 2 at the destination 1, then z^2_{71} = 1 and $z^2_{72}=\ldots=z^2_{77}$=0. Therefore, according to the reloading manner, the vehicle 7 does not incur any penalty cost at destination 2 because $p^* \sum_{j=1}^{m} z_{ij}^{s-1}(\sum_{j'=1,j'\neq j}^{m} z_{ij'}^{s}) = p^* \; z^1_{71}(z^2_{72} + z^2_{73} + \ldots + z^2_{77}$)=0. Finally, when the auto carrier visited all destinations, the number of reloading of vehicle 7 is 2. Alternatively, if vehicle 7 is reloaded onto slot 3 for destination 2, then $z^2_{73} = 1$ and $z^2_{71}=z^2_{72}=z^2_{74}=\ldots=z^2_{77} = 0$. The penalty cost of vehicle 7 is p at destination 2 because .$p^* \sum_{j=1}^{m} z_{ij}^{s-1}(\sum_{j'=1,j'\neq j}^{m} z_{ij'}^{s}) = p^* \; z^1_{71}(z^2_{72} + z^2_{73} + \ldots + z^2_{77}) = p^* \; z^1_{71} z^2_{73} = p$ Finally, after the auto-carrier visited all of the dealerships, the number of reloading of vehicle 7 will be 1 and the penalty cost is p . Since $0< p <1$, if a vehicle is reloaded onto an empty slot at destination $\tilde{s}$ 1 , we may avoid reloading the same vehicle at the next destination s . Since we can rearrange vehicles to load them onto appropriate empty slots at every destination, the reloading activities can be minimized after the auto-carrier visit all destinations.

$$Min \sum_{s=1}^{n}\sum_{i=1}^{m}\sum_{j=1}^{m}\sum_{k=1}^{m}\sum_{l=1}^{m}\frac{1}{2}a_{ijkl}\, z^s_{ij} z^s_{kl}\prod_{t\in T_{jl}}\left(\sum_{q\in L_{ik}} z^s_{qt}\right)+\sum_{s=2}^{n}\sum_{i=m_s}^{m} p*\sum_{j=1}^{m} z^{s-1}_{ij}(\sum_{\substack{j'=1\\ j'\neq j}}^{m} z^s_{ij'}) \qquad (1)$$

The constraints of the ACLP model were formulated as follows.

(a)The loading constraints between vehicles and slots: Not all vehicles can be assigned to all trailer slots due to various physical dimensions of the vehicles and the slots. The loading constraints are formulated to prohibit incompatible vehicle-slot assignments. Let S_i be the set of slots that vehicle i can be assigned to and S_j be the set of vehicles that can be assigned to slot j. Equation (2) represents that each vehicle is assigned to exactly one slot, and equation (3) represents that each slot is loaded with only one vehicle.

$$\sum_{j\in S_i} z^s_{ij} = 1 \qquad \forall i, \forall s \qquad (2)$$

$$\sum_{i\in S_j} z^s_{ij} = 1 \qquad \forall j, \forall s \qquad (3)$$

(b) A single over-sized vehicle may be assigned to occupy two adjacent slots if its length exceeds that of a slot. Equation (4) was formulated to address the over-sized vehicles in the model:

$$z_{ij}^{s} \le z_{kl}^{s} \qquad \forall i \in B,\ \forall (j,l) \in C,\ \forall k \in V \qquad (4)$$

where

B : the set of over-sized vehicles. For example, all vehicles are numbered from 1 to 7; among these, vehicles 1, 3, and 5 are over-sized vehicles, then $B = \{1, 3, 5\}$.

C : the set of adjacent slot pairs. For example, if an over-sized vehicle i is assigned to occupy both slot 3 and slot 5, then the $(3, 5) \in C$.

V : the set of dummy vehicles.

To better formulate the model constraints, dummy vehicle variables are used to construct constraint (4). The following is an illustration example to help explain the use of the dummy vehicle variables in the constraints. Assuming we have to deliver 6 vehicles numbered from 1 to 6 to three destinations by an auto-carrier with 7 trailer slots. Let's assume vehicle 7 is a dummy vehicle and vehicle 1 is an over-sized vehicle. Since vehicle 1 may be assigned to occupy both slots 3 and 5, then constraint $z_{13}^{1} \le z_{75}^{1}$ must be satisfied for destination 1. This implies that z_{75}^{1} must be 1 when $z_{13}^{1} = 1$, meaning when vehicle 1 is assigned to slot 3 then the dummy vehicle (vehicle 7) must be assigned to slot 5. Since a dummy vehicle is used as a "place holder", which will be explained in more detail in Section 4.3, the solution result simply represents that vehicle 1 assigned to slot 3 also occupies slot 5.

(c) The loading constraints between vehicles. It could happen that when a vehicle is assigned to a slot, certain other vehicles cannot be assigned to some specific slots. Equation (5) is formulated to address this situation:

$$z_{ij}^{s} z_{kl}^{s} = 0 \qquad \forall (i,j,k,l) \in R, \forall s \qquad (5)$$

where

R : the set of exclusive vehicle-slot assignments. If vehicle i is loaded onto slot j then vehicle k cannot be loaded onto slot l. This exclusive assignment is denoted as $(i, j, k, l) \in R$. The following is an example to explain the use of the set R. If vehicle 1 is assigned to slot 3 then vehicle 3 cannot be assigned to slot 6; similarly, if vehicle 1 is assigned to slot 6 then vehicle 3 cannot be assigned to slot 3. In this situation, both $(1, 3, 3, 6) \in R$ and $(1, 6, 3, 3) \in R$.

In the same example, $z_{13}^{s} z_{36}^{s} = 0$ for the $(1, 3, 3, 6) \in R$ which means if vehicle 1 is assigned to slot 3 for destination s ($z_{13}^{s} = 1$), then vehicle 3 cannot be assigned to slot 6 for destination s ($z_{36}^{s} = 0$). Also, if vehicle 3 is assigned to slot 6 for destination s ($z_{36}^{s} = 1$), then vehicle 1 cannot be assigned to slot 3 for destination s ($z_{13}^{s} = 0$); or if both vehicle 1 and vehicle 3 are not assigned to slot 3 and slot 6 then($z_{13}^{s} = 0$ and $z_{36}^{s} = 0$). Similar constraints need to be addressed on $z_{16}^{s} z_{33}^{s} = 0$ for the $(1, 6, 3, 3) \in R$.

4.2 Formulation of ACLP as a General Loading Network

As shown in Figure 3, there are multiple directed paths from the gate (node 1) to a particular slot (node 7 or node 8). If we formulate the general loading network as a tree loading network, the number of reloading of vehicles will include the number of reloading of every path that are from the gate to the particular slots. For example, in Figure 3, if vehicle 1 to be delivered to destination 1 is placed on node 7 (slot 7), vehicle 2, vehicle 3 and vehicle 4 to be delivered to destination 2 are placed on node 2 (slot 2), node 3 (slot 3) and node 5 (slot 5) respectively. If we use the tree loading network to model the problem, the number of reloading is at least three at destination 1 because the number of reloading includes the reloading of vehicle2 through path 1->2, and the reloading of vehicle 3 and vehicle 4 through path 1->3->5. In fact, vehicle 1 is unloaded from node 7 through one of the path 7-

>2->1 and path 7->5->3->1, so the number of reloading is one or two to unload vehicle 1. To deal with the general loading network more effectively, we transformed the general loading network into a tree loading network. The process is to transform node7 to node7'and node9', and transform node 8 to node8'and node10'as illustrated in Figure 4. In figure 4, the loading network has ten nodes (slots) to accommodate 8 vehicles; we will use two dummy vehicles to construct constraints (6) and (7):

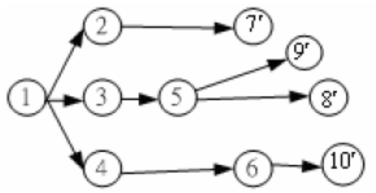

Figure 4. Transforming general network into tree network

$$\begin{cases} z^s_{i7'} \le z^s_{k9'} \\ z^s_{i9'} \le z^s_{k7'} \\ z^s_{k7'} + z^s_{k9'} = 1 \end{cases} \quad \forall i \in A,\ \forall k \in V,\ \forall s \qquad (6)$$

$$\begin{cases} z^s_{i8'} \le z^s_{k10'} \\ z^s_{i10'} \le z^s_{k8'} \\ z^s_{k8'} + z^s_{k10'} = 1 \end{cases} \quad \forall i \in A,\ \forall k \in V,\ \forall s \qquad (7)$$

where
A : the set of vehicles that can be assigned to slot 7 or slot 8.
V : the set of dummy vehicles.

For example, if vehicle 1 may be assigned to slot 7'and vehicle 9 is a dummy vehicle, then $z^s_{17'} \le z^s_{99'}$, $z^s_{19'} \le z^s_{97'}$, and $z^s_{97'} + z^s_{99'}$ =1 for destination s . The results will show $z^s_{17'}$=1 and $z^s_{99'}$=1, or $z^s_{19'}$=1 and $z^s_{97'}$1, or $z^s_{19'}$0 and $z^s_{17'}$=0 which represent vehicle 1 is assigned to slots 7'and a dummy vehicle is also assigned to slots 9', or vehicle 1 is assigned to slots 9'and a dummy vehicle is also assigned to slots 7', or vehicle is not assigned slot 7'or 9'. Because the dummy vehicle is a place holder, when a real vehicle is assigned to slot 7' (or slot 9') it will also occupy slot 9' (or slot 7'). Therefore, the above constraints can make a vehicle that belongs to set A assigned to slot 7 or slot 8. The exact amount of reloading of vehicles after the auto-carrier visit all dealerships can also be calculated.

4.3 Dummy Vehicles

If the number of vehicles (n) is less than the number of slots (m), we will be hard to model the problem and easy to solve the model. For example, when the number of vehicles (n) is less than the number of slots (m) and we do not have any dummy vehicles, the equation (3) is hard to construct or the equations can be constructed but they are more complex. Moreover, dummy vehicles are used to construct the model but they can not affect the computational results of model. Thus, dummy vehicles may be introduced to increase the vehicle number from n up to m to help formulate the constraints in this paper. Besides, a dummy vehicle is the one with no loading restrictions and is assigned with a destination index of zero. Because a dummy vehicle has not any loading restrictions, it can be assigned to any slot of a trailer and no affect assignment of any real vehicles into trailer. Besides, a dummy vehicle is assigned with a destination index of zero, it will not be unloaded at any destination and not be counted the number of reloading. Because, according to the definition of a_{ijkl}, if $j \in PRED(l)$ and $d(i) > d(k)$ then a_{ijkl} =1, otherwise, a_{ijkl} =0. Since the dummy vehicle i with a destination index of zero and the d(*dummy vehicle i*) always less than or equal to $d(k)$, the associated a_{ijkl} =0 which leads to $a_{ijkl} z^s_{ij} z^s_{kl} \prod_{t \in T_{jl}} (\sum_{q \in L_{ik}} z_{qt})$ so equals to zero. Therefore, the dummy vehicles will not affect the computational results and the number of reloading that is computed from objective function is correct.

5. TEST PROBLEMS

To evaluate the ACLP models, test problems used by Agbegha *et al*. (1998) and Agbegha (1992) were also used for validation the ACLP model and for solution test. The test problems included four problem sets which were designed based on four trailer types (trailer type 1 to trailer type 4). The loading network of trailer type 1 is shown in Figure 2 and the loading network of trailer type 4 is shown in Figure 3. The loading networks of trailer type 2 and trailer type 3 are shown in Figure 5. The problem statements of these four problem sets are described below.

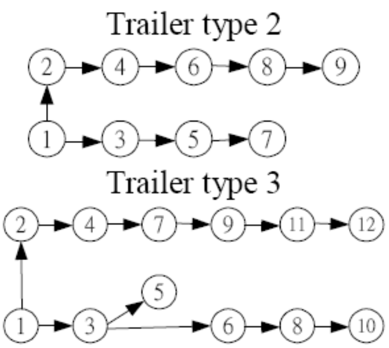

Figure 5. Loading networks of trailer type 2 and type 3

1. Problem set #1

As shown in Figure 2, four types of vehicles are to be delivered and each vehicle's type and destination are listed in Table 2. The problem considers the following loading constraints:

(a) Vehicle types 2 and 3 cannot be assigned to slot 1. Vehicle type 3 cannot be assigned to slot 7. Vehicle type 4 cannot be assigned to any slot.

(b) If a vehicle of type 2 or type 3 is assigned to slot 3 (or slot 4), then vehicles of type 3 cannot be assigned to slot 4 (or slot3).

(c) If a vehicle of type 2 or type 3 is assigned to slot 5 (or slot 6), then vehicles of type 3 cannot be assigned to slot 6 (or slot5).

Table 2. Data for problem set # 1

No.		Cars						
		1	2	3	4	5	6	7
1	Type	2	3	1	1	1	1	3
	Dest.	1	1	2	3	4	5	6
2	Type	3	1	3	1	3	1	2
	Dest.	1	1	1	2	2	2	2
3	Type	2	1	3	3	1	3	2
	Dest.	1	2	2	3	3	4	4
4	Type	1	1	2	1	2	2	3
	Dest.	1	2	3	4	5	6	7
5	Type	1	1	1	1	2	1	1
	Dest.	1	1	2	2	2	3	3
6	Type	1	1	2	3	2	3	2
	Dest.	1	2	3	4	4	5	6
7	Type	2	1	1	3	3	1	1
	Dest.	1	2	3	4	5	6	7
8	Type	3	1	1	3	2	1	3
	Dest.	1	1	2	2	3	3	3
9	Type	1	1	2	2	2	1	2
	Dest.	1	2	3	3	4	4	5
10	Type	3	3	3	1	1	1	2
	Dest.	1	1	1	1	2	2	2
11	Type	1	1	2	1	1	3	2
	Dest.	1	2	2	2	3	4	4
12	Type	1	1	1	1	3	2	1
	Dest.	1	2	3	3	4	4	5
13	Type	1	1	2	2	3	3	2
	Dest.	1	2	3	4	5	6	7
14	Type	2	2	3	3	2	1	1
	Dest.	1	1	2	3	4	5	5
15	Type	2	3	2	1	1	1	3
	Dest.	1	1	2	3	3	3	4

2. Problem set #2

This problem set uses Trailer type 2 shown in Figure 5. Four types of vehicles are to be shipped and each vehicle's type and destination are shown in Table 3. The problem considers the following loading constraints:

(a) Vehicle type 2 cannot be assigned to slots 7 or 9. Vehicle type 3 cannot be assigned to slots 3, 5, 7, or 9. Vehicle type 4 cannot be assigned to slots 3, 5, 7, 8, or 9.

(b) If any vehicle of type 2 is assigned to slot 3 (or slot 5), it will also occupy slot 5 (or slot 3).

(c) If any vehicle of type 2, 3, or 4 is assigned to slot 4 (or slot 6), it will also occupy slot 6 (or slot 4).

(d) If a vehicle of type 2, 3, or 4 is assigned to slot 1 (or slot 2), then vehicles of these types cannot be assigned to slot 2 (or slot 1).

(e) If a vehicle of type 4 is assigned to slot 4 or 6 (or slot 2), then vehicles of type 2, 3, or 4 cannot be assigned to slot 2 (or slots 4 and 6).

Table 3. Data for problem set # 2

No.		Cars								
		1	2	3	4	5	6	7	8	9
1	Type	2	1	1	4	1	1	1	1	
	Dest.	1	2	3	3	4	4	4	5	
2	Type	4	1	2	2	1	1	1	4	
	Dest.	1	1	2	3	3	4	5	5	
3	Type	4	2	4	1	3	2	1	1	
	Dest.	1	2	2	2	3	3	4	4	
4	Type	4	1	2	2	1	2	1	1	
	Dest.	1	1	1	2	3	3	4	5	
5	Type	1	1	1	1	1	2	1	1	2
	Dest.	1	2	3	4	5	6	7	8	9
6	Type	2	1	4	2	3	2	1		
	Dest.	1	2	3	4	5	6	7		
7	Type	4	1	2	3	3	1	1		
	Dest.	1	2	3	4	4	5	6		
8	Type	3	1	2	2	1	2	1		
	Dest.	1	2	2	2	3	3	3		
9	Type	4	1	2	2	1	1	3		
	Dest.	1	2	3	4	5	6	7		
10	Type	3	2	2	3	1	1	1		
	Dest.	1	2	2	3	4	4	4		
11	Type	1	2	2	2	1	3	1		
	Dest.	1	2	2	2	3	3	3		
12	Type	1	1	2	4	1	2	1		
	Dest.	1	1	1	2	3	4	5		
13	Type	4	1	2	4	1	2	1		
	Dest.	1	1	1	1	2	2	2		
14	Type	4	1	1	3	1	2	1		
	Dest.	1	1	2	2	3	4	5		
15	Type	4	1	2	4	1	2	1		
	Dest.	1	1	2	2	2	3	4		

3. Problem set #3

This problem set uses Trailer type 3 shown in Figure 5. Four types of vehicles are to be shipped and each vehicle's type and destination are shown in Table 4. The problem considers the following loading constraints:

(a) Vehicle type 2 cannot be assigned to slots 10 or 12. Vehicle types 3 and 4 cannot be assigned to slots 6, 8, 10, or 12.

(b) If any vehicle of type 2, 3, or 4 is assigned to slot 3 (or slot 5), it will also occupy slot 5 (or slot 3).

(c) If any vehicle of type 2, 3, or 4 is assigned to slot 4 (or slot 7), it will also occupy slot 7 (or slot 4).

(d) If any vehicle of type 2 is assigned to slot 6 (or slot 8), it will also occupy slot 8 (or slot 6). If any vehicle of type 4 is assigned to slot 9 (or slot 11), it will also occupy slot 11 (or slot 9).

(e) If a vehicle of type 2, 3, 4 is assigned to slot 1 (or slot 2), then vehicles of type 2, 3, or 4 cannot be assigned to slot 2 (or slot 1).

(f) If a vehicle of type 4 is assigned to slot 4 or 7 (or slot 2), then vehicles of types 2, 3, or 4 cannot be assigned to slot 2 (or slots 4 and 7).

Table 4. Data for problem set # 3

No.		Cars											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Type	3	3	2	2	2	3	1	1				
	Dest.	1	2	2	3	3	3	4	5				
2	Type	2	2	1	4	1	2	4	1				
	Dest.	1	1	1	2	3	3	4	4				
3	Type	1	1	4	4	1	4	2	1	3			
	Dest.	1	1	2	3	4	5	6	7	8			
4	Type	4	1	4	1	3	3	3	1	1			
	Dest.	1	2	3	4	5	6	7	8	9			
5	Type	1	1	1	3	4	1	1	2	2	1	1	
	Dest.	1	1	1	2	2	2	3	3	4	4	4	
6	Type	1	1	2	1	1	1	3	1	2	1	1	1
	Dest.	1	1	2	3	3	4	5	6	7	8	9	10
7	Type	2	4	2	3	1	1	1	2	2			
	Dest.	1	1	1	1	2	2	3	3	3			
8	Type	3	4	1	2	1	2	2	1	1	1		
	Dest.	1	1	1	1	2	2	2	2	2	2		
9	Type	3	2	2	1	4	1	4	4				
	Dest.	1	1	2	2	3	3	4	4				
10	Type	4	2	4	2	1	1	4	1				
	Dest.	1	1	1	2	2	3	4	4				
11	Type	3	1	1	4	2	1	2	1	3	1		
	Dest.	1	1	1	1	1	2	2	2	2	2		
12	Type	4	2	4	1	1	1	2	1	1	1	1	
	Dest.	1	1	2	2	2	3	4	5	5	5	6	
13	Type	3	2	2	3	3	3	1	1	1			
	Dest.	1	1	2	3	4	5	6	7	8			
14	Type	3	2	1	1	3	1	3	2	3			
	Dest.	1	1	1	2	2	2	3	3	3			
15	Type	2	4	4	2	4	2	1	1				
	Dest.	1	1	1	2	2	3	4	5				

4. Problem set #4

This problem set uses Trailer type 4 shown in Figure 3. Four types of vehicles are to be delivered. Each vehicle's type and destination are shown in Table 5. The problem considers the following loading constraints:

(a) Vehicle type 2 cannot be assigned to slots 1 or 5. Vehicle type 3 cannot be assigned to slots 2, or 6. Vehicle type 4 cannot be assigned to slots 2, 5, 7, or 8.

(b) If a vehicle of type 2 is assigned to slot 2, then vehicles of type 3 cannot be assigned to slot 7.

(c) If a vehicle of type 4 is assigned to slot 1 (or slot 3), then vehicles of type 2, 3, or 4 cannot be assigned to slot 3 (or slot 1).

(d) If a vehicle of type 4 is assigned to slot 6, then vehicles of type 3 or 4 cannot be assigned to slot 4.

(e) If a vehicle of type 3 is assigned to slot 4, then vehicles of type 4 cannot be assigned to slot 6.

(f) If a vehicle of type 3 is assigned to slot 7, then vehicle of type 2 cannot be assigned to slot 2.

Table 5. Data for problem set # 4

No.		Cars							
		1	2	3	4	5	6	7	8
1	Type	3	2	1	3	1	3	4	1
	Dest.	1	1	1	2	3	4	5	6
2	Type	4	1	1	3	4	2	1	4
	Dest.	1	2	3	4	4	5	5	6
3	Type	4	1	4	1	3	1	2	3
	Dest.	1	2	3	4	4	5	6	7
4	Type	1	3	4	2	1	3	1	2
	Dest.	1	2	2	3	4	5	5	6
5	Type	1	1	1	4	2	3	1	2
	Dest.	1	2	2	3	3	4	4	4
6	Type	2	1	4	1	1	1	3	2
	Dest.	1	1	2	2	3	4	5	5
7	Type	1	4	3	3	1	4	1	2
	Dest.	1	2	2	3	3	4	5	6
8	Type	2	1	1	1	4	2	3	1
	Dest.	1	2	3	4	5	5	6	6
9	Type	2	2	1	3	1	4	1	1
	Dest.	1	2	3	3	4	4	5	5
10	Type	4	1	2	2	2	1	3	1
	Dest.	1	1	2	3	4	4	4	5
11	Type	2	1	1	1	4	2	4	3
	Dest.	1	1	2	2	3	4	4	4
12	Type	1	2	2	1	1	3	4	2
	Dest.	1	2	3	4	4	4	5	6
13	Type	2	4	1	3	4	2	2	1
	Dest.	1	2	2	3	4	5	5	6
14	Type	2	1	2	4	1	1	4	2
	Dest.	1	2	2	2	3	3	4	5
15	Type	1	3	1	4	4	1	2	3
	Dest.	1	2	3	4	4	4	5	6

6. COMPUTATIONAL RESULTS AND DISCUSSION

We solved the test problem sets by using an optimization software package, OPL. The OPL software includes the solution algorithm for constraints programming (CP) that is capable of solving nonlinear programming models. The ACLP model is a non nonlinear programming model. OPL was selected to solve the four test problem sets by applying the ACLP model. The CP was developed for dealing with the constraint satisfaction problem (CSP). A state of the CSP is defined by the assignment of values to some or all of the variables, $\{X_i = v_i\ ,\ X_j= v_j\ ,\ldots\}$. An assignment that does not violate any of the constraints is called a consistent or a legal assignment. A complete assignment is one with all variables in the model assigned with a value. A solution to the CSP is a complete assignment that satisfies all of the constraints (Marriott and Stuckey, 1998, Brailsford *et al.*, 1999).

6.1 Computational Results

The problem sets were formulated by setting p =0.8 and were solved using a PC with a 2.4 GHz processor. The computational results on the problem sets are summarized in Tables 6 through 9. The data reported in each column were organized as: Freq. = the frequency of loading plan; NS = the number of slots on a trailer; R1 = computational results; R2 = the computational results reported in the literature by Agbegha *et al*. (1998); RN = the amount of reloading; Sec. = the solution time (seconds). The number in boldface represents the result of every vehicle that was assigned to a trailer slot from our computational results.

Table 6. Results of problem set #1

No.	Freq.	NS							R1		R2	
		1	2	3	4	5	6	7	RN	Sec.	RN	Sec.
1	1	3	2	6	1	7	4	5	1	0.88	1	0.0
2	1	2	5	3	6	1	4	7	0	0.55	0	0.0
3									NF	0.1	NF	1.1
4	1	1	2	6	3	7	4	5	0	0.44	1	0.2
5	1	2	5	1	4	7	3	6	0	0.61	0	0.0
6	1	1	4	3	5	2	6	7	1	0.11	1	0.4
7	1	2	1	5	3	7	4	6	1	0.72	1	0.0
8	1	2	4	1	6	3	7	5	0	0.11	0	0.0
9	1	1	4	2	6	3	5	7	0	0.5	0	0.0
10	1	4	3	6	2	5	1	7	0	0.0	0	0.0
11	1	1	4	7	3	6	2	5	0	0.55	0	0.0
12	1	1	4	2	6	3	5	7	0	0.94	0	0.0
13	1	1	5	4	3	2	6	7	2	0.22	2	0.7
14	1	7	3	2	1	6	4	5	2	0.11	5	0.2
	2	-	3	7	-	6	4	5				
15	1	6	2	3	1	7	5	4	1	0.27	2	0.0
	2	-	6	3	-	7	5	4				

NF: no feasible solution

Table 7. Results of problem set #2

No.	Freq.	NS									R1		R2	
		1	2	3	4	5	6	7	8	9	RN	Sec.	RN	Sec.
1	1	1	3	2		7	4	8	6	5	0	6.65	0	0.2
2											NF	0.2	NF	3.9
3											NF	0.2	NF	3.7
4											NF	0.2	NF	5.8
5	1	1	6	3	2	4	7	5	9	8	2	47.62	2	1.7
6											NF	0.1	NF	3.6
7	1	1	2			3	5	7	4	6	0	0.22	0	0.1
8	1	1	2			6	4	7	3	5	0	0.55	0	0.2
9	1	1	2			4	3	6	7	5	1	0.33	1	0.4
10	1	1	7			3	2	6	4	5	1	0.28	2	1.5
	2			7				6	4	5				
11	1	1	4			3	2	7	6	5	0	0.88	0	0.7
12	1	2	4		3	5	1	6	6	7	0	0.5	0	0.4
13	1	4	2			6	1	7	3	5	0	0.0	0	0.2
14	1		1		2	6	3	7	4	5	0	0.22	0	0.0
15	1	1	2			6	4	7	3	5	0	0.06	0	0.2

NF: no feasible solution

Table 8. Results of problem set #3

NO.	Freq..	NS												R1		R2	
		1	2	3	4	5	6	7	8	9	10	11	12	RN	Sec.	RN	Sec.
1	1		3			1		2	5	6	8	4	7	0	1.42	0	1.5
2	1	3	2			4		6	1		5	7	8	0	1.48	0	4.1
3	1	3	5			4	2	6	1	7	8	9		1	11.65	2	36.8
4	1	1	4			3		5	2	6	9	7	8	0	5.27	0	1.1
5	1	3	5		6	4	2	7	1	8	11	9	10	0	118.14	1	30.2
6	1	2	3	1	5	12	6	4	8	7	11	9	10	0	626.48	1	23.7
7	1	4	6			5		2	8	3	7	1	5	1	1.92	1	55.3
8	1	4	3	10		9		2	7	1	8	6	5	0	0.33	0	2.0
9	1	8				7		5	3	2	4	1	6	4	6.7	4	78.4
10	1	3				7		1	6	2	8	4	5	0	0.11	0	2.3
11	1	5	3	2		10		4	7	1	8	9	6	0	2.3	0	4.5
12	1	3	6	5		11	4	1	10	2	9	7	8	2	9.39	3	68.8
13	1	2	8			6		1	3	4	7	5	9	3	6.2	3	33.1
14	1	3	2			9		1	8	7	6	5	4	2	42.24	2	15.4
15	1					5		2	6	1	8	4	7	0	0.05	2	70.5

Table 9. Results of problem set #4

NO.	Freq.	NS								R1		R2	
		1	2	3	4	5	6	7	8	RN	Sec.	RN	Sec.
1	1	3	8	2	5	1	7	4	6	0	1.82	0	0.3
2*										NF	1.02	1	12.3
3	1	1	6	4	2	8	3	7	5	0	0.55	0	0.0
4	1	1	8	3	6	2	7	4	5	0	3.08	0	0.1
5	1	1	3	8	5	7	4	2	6	0	3.57	0	0.0
6	1	2	6	5	1	7	3	8	4	0	3.46	1	23.3
7	1	1	7	2	6	3	8	4	5	0	1.21	0	0.2
8	1	2	6	5	1	7	3	8	4	1	10.05	1	0.0
9	1	3	8	6	1	5	2	7	4	2	13.95	3	22.0
10	1	2	8	7	1	6	3	5	4	0	2.47	0	0.0
11	1	2	4	7	1	8	5	3	6	0	1.70	0	0.0
12	1	1	8	3	2	6	7	4	5	0	10.1	4	13.7
13	1	3	7	5	1	8	2	6	4	1	0.72	1	0.0
14	1	4	3	6	1	5	7	2	8	1	2.2	1	0.0
15*	1	1	6	5	3	8	4	2	7	1	2.69	0	0.0

NF: no feasible solution

6.2 Discussion

As shown in Table 6 through Table 9, twelve test problems show that our results are better than those reported in the past research (Tadei *et al.*, 2002). These problems are No. 4, 14, 15 of problem set #1, No.10 of problem set #2, No.3, 5, 6, 12, 15 of problem set #3, and No. 6, 9,12 of problem set #4. In addition, our results of test problems No. 14 and No.15 of problem set #1 and test problem No. 10 of problem set #2 show that the choices of some vehicles' reloading onto different slots at destination 1 may minimize the amount of reloading. In Table 9 (problem set #4), two test problems, No. 2 and No. 15, are shown to require more reloading than those reported in the literatures by Agbegha *et al*. (1998). After examining the results of these two test problems reported in the literatures (Agbegha *et al*., 1998, Agbegha, 1992), we concluded that there might have been reporting errors. The computational results from the previous literatures are shown in Table 10.

Problem No. 2 is an infeasible solution. The boldface numbers represent the vehicles' numbers. Based on the loading constraints (d) of problem set #4, if a vehicle of Type 4 is assigned to slot 6, then vehicles of Type 3 or 4 cannot be assigned to slot 4. As shown in Table 5, one can find that vehicle 5 and vehicle 8 of No. 2 are both Type 4, Table 10 shows that vehicle 8 is assigned to slot 6 and vehicle 5 is also assigned to slot 4, which violates the loading constraints. Similarly, vehicle 4 and vehicle 5 of No. 15 are both Type 4, but they are assigned to slot 4 and slot 6. As a result, the solutions reported in Table 10 violated the loading constraint (d) of problem set #4. This violation was not shown in our results, and our solutions met all of the loading constraints of problem set #4.

In conclusion, our computational results for the fourteen test problems consistently show better solutions than the results reported in the literatures. As shown in Table 11, the average computation time of the four problem sets are in the range of 0.39 seconds to 55.58 seconds, as compared with those in the range of 0.2 seconds to 28.25 seconds in the past literature. Although our average computation time is longer than the average solution time reported in the literatures, our solution time is in the acceptable level in real world applications. One drawback of our ACLP model is that as the size of the problem increases, the required solution time increases exponentially. Fortunately, the maximum capacity of a trailer is only 12 vehicle slots, which sets the upper limit of our computation time in real world applications.

Table 10. The results of No.2 and No.15 of problem set # 4

No.	NS								R2	
	1	2	3	4	5	6	7	8	RN	Sec.
2	**1**	**7**	**2**	**5**	**4**	**8**	**3**	**6**	1	12.3
15	**1**	**3**	**2**	**4**	**6**	**5**	**7**	**8**	0	0.0

Sources: Agbegha (1992).

Table 11. Summary of computation results

No.	Type of network	Number of slots	Solution time (Sec.)				Number of unverified	
			R1		R2		R1	R2
			range	mean	range	mean		
1	Tree	7	0.0-9.4	0.39	0.0-1.1	0.2	0	0
2	Tree	9	0.0-47.62	3.86	0.0-5.8	1.5	0	0
3	Tree	12	1.1-626.48	55.58	1.1-78.4	28.5	0	1*
4	general	8	0.0-13.95	3.91	0.0-23.3	4.8	0	4*

* Number of unverified solutions after one thousandth sub-problem count.

7. CONCLUSIONS

This article discusses the auto-carrier loading problem (ACLP) that was previously formulated and solved by Agbegha *et al.* (1998). We constructed mathematical models that allow vehicles to be reloaded onto any feasible empty slots on a trailer at any dealership as the ACLP model. The results show that exact optimal solutions of the ACLP can be solved. The average solution time on the test problem sets is in the range of 0.39 seconds to 55.58 seconds, which is acceptable in real world operation. A drawback of the ACLP model is that as the size of the problem increases the solution time increases exponentially. In real world applications, however, the maximum capacity of a trailer is 12 vehicle slots, which sets the upper limit of problem size. The ACLP model can still be used to efficiently solve real world problems.

8. ACKNOWLEDGEMENTS

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THAILAND'S INTERREGIONAL FREIGHT FLOW ESTIMATION

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Abstract: The purpose of this study was to develop a model to be used as a forecasting tool for estimating interregional freight flow (IRFF). In this paper, we were concerned only with the interregional input-output (IRIO) and the Chenery-Moses models, due to the strong relationship between freight flow and transaction flow of the input-output table. The trade flow matrix was constructed to estimate the IRIO coefficient. The estimated IRIO was converted to IRFF and then compared with the IRFF published by the Thailand Ministry of Transportation (MOT). The results of this study indicated that the Chenery-Moses model was appropriate to forecast the IRFF. The total percentage of error for IRFF estimation was less than five percent.

Key Words: Interregional freight flow, Interregional input-output, Chenery-Moses model, Trade flow matrix, Freight modeling

1. INTRODUCTION

Current transport statistics are limited by lack of data that is appropriate and reliable. The Ministry of Transportation presents commodity flow by origin and destination at a large geographical scale only down to a regional level. This scale is insufficiently fine to identify flows in specific areas, such as at a province level. There is a broad diversity of freight models to estimate freight flow, such as growth factor method, regression model and gravity model, but they are not easily updated. Moreover, the relationships between economic activities and commodity flows are not concerned about constructing a freight model. In order to link between the economic data and freight transport statistics, freight demand models using the Chenery Moses model are applied to estimate an interregional input-output (IRIO) table that performs the value of commodity flow by origin and destination. This model can estimate interregional freight flow (IRFF) that is converted from IRIO.

Several studies developed the interregional freight flow model using the economic data of the input-output table using many different approaches. Hartwick (1971) described the first group of studies that estimated IRIO from the combined effects of technical coefficients and trade flow coefficients, such as the pure trade coefficient developed by Isard in 1951, and Chenery and Moses developed a model in 1955, also called the column coefficient model, which is similar to the Isard model but requires fewer data. In 1963, Leonteif and Strout developed a model that made use of the gravity theory for estimating trade flow. The last study in this group described by Holguin-Veras et al. (2001) is the row coefficient model developed by

Polenske in 1970.

Moreover, there are numerous researches that applied the IRIO model using trade coefficients to develop the IRFF. Liew and Liew (1980 and 1984) developed the IRFF to evaluate the economic impacts of transportation costs. Harrigan et al. (1981) estimated IRFF using the column coefficient and the Chenery-Moses models, and compared it with various techniques such as the Location Quotient methods, the Commodity Balance Technique, and the Tibout method. The study concluded that the Chenery-Moses model provides better estimates of interregional trade flows than any of the non-survey techniques. Mizokami (1995) improved the IRFF model by combining the trade coefficient model, behavioral analysis and equilibrium theory. Inamura and Srisurapanon (1997) proposed the interregional rectangular input-output (IRRIO) method to estimate the IRFF which requires the Chenery-Moses model for estimating trade flows. Durand (1998) explained and modeled freight flow according to two spatial distribution methods: gravity model and the structural coefficients method. Vilain et al. (1999) estimated the commodity flow to a sub-state region by combining state level commodity flow data and the input-output model. Sivakumar and Bhat (2002) proposed and applied the fractional split-distribution model for estimating statewide commodity flows or IRFF in Taxes resulting in a model that is better than the gravity model. The structure of this model is similar to the column coefficient model, also called the Chenery-Moses model**.**

2. INPUT-OUTPUT MODELS

The input-output table (Miller and Blair, 1985) developed by Professor Wassily Leontief in the late 1930s is a macroeconomic tool of analytical formulations that represents the relationships among economic sectors as a transaction flow. The structure of the input-output table, as shown in Figure 1, comprises of intermediate demand, final demand, value added and total output.

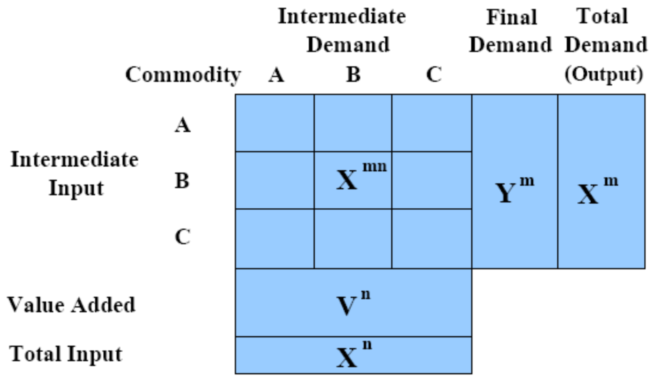

Figure 1. Input-output table

The total output of sector m in the input-output table, X^m, is given by

$$X^m = \sum_n X^{mn} + Y^m \quad (1)$$

where X^{mn} is the intermediate demand that refers to the transaction flows that a given sector m sends to the other economic sectors n.Y^m is the final demand for sector m. The unit flows from sector m to sector n measured with respect to the output of n, referred to as technical coefficients, can be estimated as shown in Equation 2. The technical coefficients are also called direct requirements because they measure the proportion of the inputs that are directly required from other sectors.

$$a^{mn} = \frac{X^{mn}}{X^n} \quad (2)$$

So Equation (1) can be written as:

$$X^m = \sum_n a^{mn} X^n + Y^m \quad (3)$$

In the matrix format, Equation (3) can be re-written as:

$$X = AX+Y \quad (4)$$

and,

$$X = (I-A)^{-1}Y \quad (5)$$

where X is a vector of outputs, Y is a vector of final demand, A is the technical coefficient matrix, and $(I-A)^{-1}$ is the Leontief coefficient that is referred to as the matrix of direct and indirect requirements.

Although able to appropriately model the economy of a nation, the input-output model is not able to represent the regional flows of commodities in monetary terms. To overcome this limitation, the interregional input-output models were constructed to estimate the interregional freight flow from one region to other regions.

3. INTERREGIONAL INPUT-OUTPUT (IRIO) MODELS

Various studies have been done to construct the interregional input-output models. The first interregional input-output model, published in 1951 by Isard, has been manipulated on a small scale because of the problems of data availability, Chenery and Moses developed a model called the column coefficient model, which is similar to the Isard model but requires fewer data. Leonteif and Strout developed a model that uses gravity theory for estimating interregional freight flow.

Although all of the models are similar in the way of merging between the effects of technical coefficients and trade flow coefficients in the IRIO model, the source of trade coefficients and the method for merging together both coefficients are different (Holguin-Veras et al., 2001).

The IRIO represents the relationships of the inter-linkages among economic sectors located in a given geographic region. The structure of the interregional input-output table, as shown in Figure 2, depicts the IRIO that has been divided into two regions (Region I and Region II).

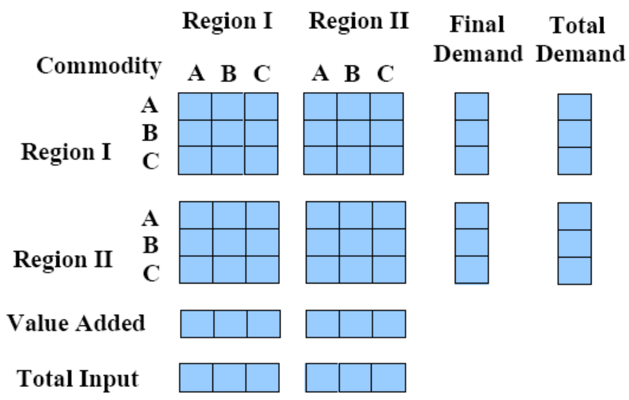

Figure 2. Interregional input-output table

Suppose there are i regions, with m and n sectors in each region. The basic equation in the IRIO model would be:

$$X_{ij}^{m} = C_{ij}^{m} A_{ij}^{mn} X_{ij}^{n} + C_{ij}^{m} Y_{ij}^{m} \quad (6)$$

where C is the trade flow matrix that refers to the fraction of total consumption of commodity m in region i that is imported from region j. In the matrix format, Equation (6) can be re-written as:

$$X = CAX + CY \quad (7)$$

The matrix CAX describes the source of intermediate inputs as well as the distribution of intermediate use for each sector in each region. The matrix CY describes the distribution of final demand for each sector in each region.

4. METHODOLOGY

In this section, we describe the summary process and our methodology for estimating interregional freight flows.

4.1 Model size

Based on the IRFF data published by the Ministry of Transportation and the gross domestic product (GDP) data announced by the

National Economic and Social Development Board (NESDB), the regional division in both data for Thailand is divided into seven regions—Bangkok and Vicinity, Northern, Northeastern, Central, Eastern, Western, and Southern.

4.2 Data acquisition

The required data to calibrate the IRFF model are 1) the 2000 input-output table which is the latest version, 2) the gross regional product or GDP by region from 1995 to 2005 as collected from NESDB, and 3) the origin and destination table by region from 1995 to 2007, which contains the amount of commodity flows from produced region to consumed region, also called the IRFF table, as collected from the Ministry of Transportation. The OD freight data were combined from various sources separated by modes of transportation. Road freight transport data were estimated based on the Land Transport Department 1996 survey data and the yearly commodity production. Rail freight transport data were collected from the State Railway of Thailand. Waterway freight transport data were estimated based on the data from the Marine Department. Air freight transport data were collected from the Thai Airways.

In this paper the base year is set to 2005, therefore the 2000 input-output table was updated to the 2005 input-output table using the gross domestic product (GDP) and the expenditure consumption data from the national income report in 2005. The original input-output table is prepared for technical coefficient calculation processed by grouping the 180 original industry sectors into 2 groups: commodity group and service group. The first group consisted of sector 1 to sector 134. The second group consisted of sector 135 to sector 180.

4.3 Conceptual Framework for IRFF Estimation

The summary process of IRFF estimation, as shown in Fig. 3, comprises of three sub processes. The first process is the interregional input-output coefficient estimation. The second process is the interregional freight flow estimation in monetary terms (Baht). The last process is the amount of the interregional freight flow estimation in terms of volume (Ton).

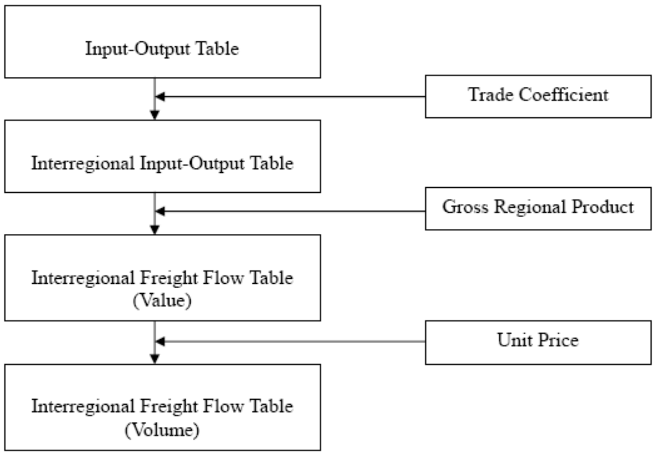

Figure 3. Conceptual framework for IRFF estimation

4.4 Technical coefficient calculation

Technical coefficients A_{ij}^{mn} the amount of input m required to produce output n in region i—are famous parameters in the IRIO models. Due to the lack of technical coefficients at a regional level, so we assumed that the technical coefficients in region i and the national technical coefficients are similar in the proportion value. Thus, from the input-output table, the technical coefficient is defined as shown in Equation (2).

4.5 Trade coefficient calculation

Trade coefficients C_{ij}^{m} , reflecting the scale of attracted commodity which depend on the produced output and transport out of each region in each type of commodity, are very significant parameters in the IRIO models, according to the IRFF by region collected from the Ministry of Transportation. So, trade coefficient is defined as shown in Equation (8).

$$C_{ij}^{m} = \frac{T_{ij}^{m}}{\sum_{j} T_{ij}^{m}} \tag{8}$$

Before we use these coefficients to estimate the IRIO coefficient, we must organize and modify them from normal matrix format to diagonal matrix format, as shown in Fig. 4, so that we can propose an IRFF which is comprised of 2 regions (I and II) and 3 commodities (A, B and C). Thus, from this example, we have 12 cells of freight flow by volume, as shown in the left side of Fig. 4. When trade coefficient is calculated, we have three matrices comprised of trade coefficients for commodities A, B and C respectively, as shown in the middle of Fig. 4, and they are re-organized from a normal matrix format to a diagonal matrix format, as shown in the right side of Figure 4.

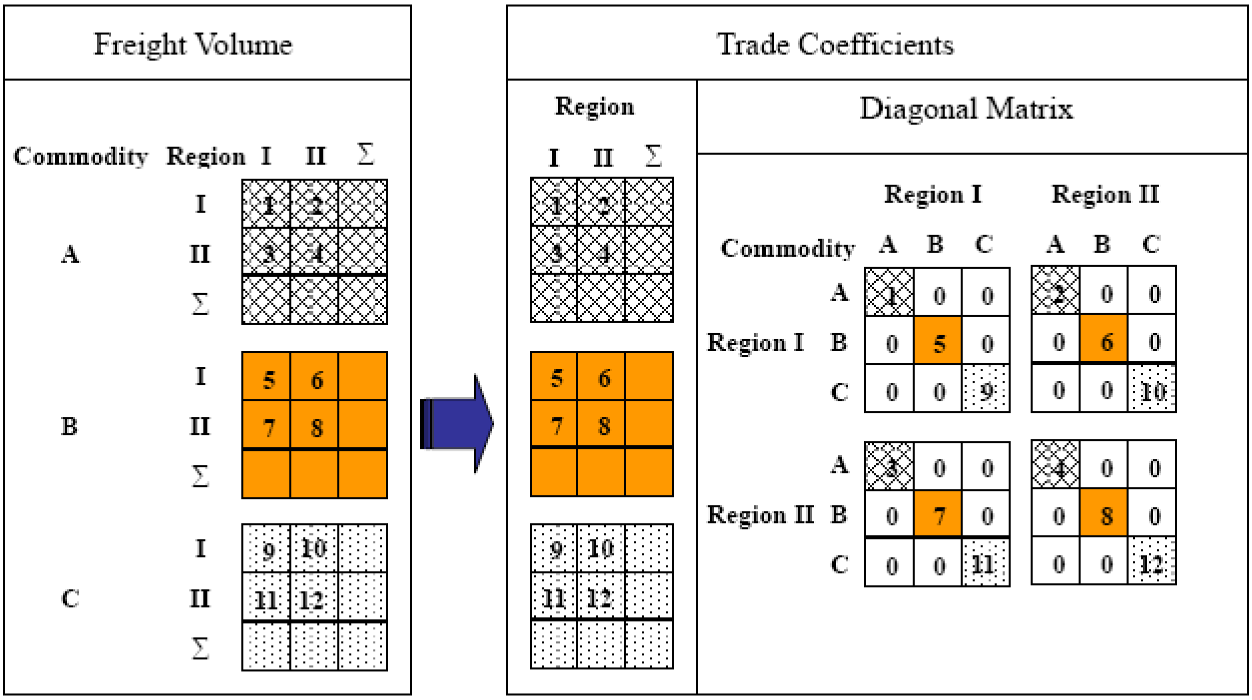

Figure 4. Trade coefficients calculation process

4.6 Interregional Input-Output Coefficient estimation

Technical coefficients and trade coefficients calculated from sections 4 and 5 were important parameters in the IRIO models as shown in Equation (6). Both parameters were multiplied to determine the IRIO coefficients.

4.7 Interregional Freight Flow Estimation

The IRFF in monetary terms (Baht) is calculated by multiplying the IRIO coefficients by the gross output that was estimated from the gross domestic product by region, also called gross regional product (GRP), which was collected from the NESDB. The next process is the estimation of IRFF in terms of volume (Ton), where the price of commodity (P) is used to convert the value of IRFF (Baht) to the volume of IRFF (Ton), as shown in Equation (9).

$$T_{ij}^{m} = \frac{X_{ij}^{m}}{P_{ij}^{m}} \tag{9}$$

The 2005 unit prices were calculated from the value of freight divided by the amount of freight, then used to convert the value of freight to the volume of freight in year 2007.

4.8 Validation

The last step of this study—the validation process—is a critical process where the model is tested with the collected data. The IRFF model was used to estimate the IRFF table in 2007, which depicts commodity flow by region (7x7 regions as described in the model size section). The estimated year of the IRFF model was set to 2007, therefore the 2000 input-output table was updated to the 2007 input-output table using the gross domestic product (GDP) and the expenditure consumption data from the national income report in 2007.

The gross domestic product by region (GRP) data as collected from NESDB is available until 2005. For estimating the 2007 interregional input-output table, the 2007 GRP was estimated by time series method using the GRP data from 1995 to 2005.

In this respect, the comparison between the estimated table and the collected table was computed, and the result was showed in terms of percentage of error for the interregional freight flow estimation in 2007.

5. RESULTS

In this section, the analyses of results for the IRFF model in 2007 are discussed. The first result is the 2007 estimated IRFF, as shown in Table 1, which depicts Thailand's commodity flow by region.

Table 1. Interregional freight flow estimated in 2007 (Million Tons)

Region	BKK and Vic.	Northern	Northeastern	Central	Eastern	Western	Southern	Total
BKK and Vic.	19	22	10	10	23	16	9	**108**
Northern	19	45	1	10	1	2	5	**82**
Northeastern	14	1	22	2	0	6	6	**50**
Central	25	20	1	3	2	4	1	**55**
Eastern	48	3	8	7	34	7	5	**112**
Western	35	1	0	3	7	10	1	**57**
Southern	5	0	0	0	8	7	20	**41**
Total	**165**	**91**	**41**	**35**	**74**	**51**	**48**	**506**

Table 1 illustrates that the share of Bangkok and Vicinity (BKK and Vic.)—the most significant region in terms of consumption and largest share of total freight flow—is 33% of the total IRFF in 2007. Bangkok and Vicinity is not only the most consumed region, but it is also the most produced region. Eastern and Bangkok and Vicinity are the top two produced regions, whose shares are 22% and 21% of the total IRFF in 2007, respectively.

Table 2. Interregional freight flow data collected from MOT in 2007 (Million Tons)

Region	BKK and Vic.	Northern	Northeastern	Central	Eastern	Western	Southern	Total
BKK and Vic.	19	21	9	10	28	16	9	**114**
Northern	19	44	1	10	1	2	5	**81**
Northeastern	13	1	21	2	1	6	6	**49**
Central	25	19	0	3	2	4	1	**54**
Eastern	41	3	8	7	34	6	3	**103**
Western	35	1	0	3	7	10	1	**57**
Southern	6	0	0	0	10	7	20	**44**
Total	**158**	**90**	**40**	**35**	**84**	**50**	**46**	**502**

The base data used to validate the result of the IRFF model is the 2007 commodity flow by region contained in the Ministry of Transportation IRFF table, as shown in Table 2.

Table 3. The percentage of error of interregional freight flow estimation in 2007

Region	BKK and Vic.	Northern	Northeastern	Central	Eastern	Western	Southern	Total
BKK and Vic.	0	1	1	1	-21	0	2	**-5**
Northern	0	1	-1	1	-4	1	1	**1**
Northeastern	1	0	1	0	-12	1	1	**1**
Central	1	1	59	1	3	1	1	**2**
Eastern	17	5	1	1	-1	13	61	**9**
Western	2	-1	-33	1	-7	0	-6	**0**
Southern	-5	-4	-55	-4	-23	1	-1	**-6**
Total	**5**	**1**	**1**	**1**	**-11**	**2**	**4**	**1**

The percentage of error for the comparison between the estimated table and the collected table, as shown in Table 3, is the result of the validation process. There are 9 cells in this table that have a percentage of error that is more than 10%, but they do not represent the scale of error in terms of volume. Thus, we can classify the percentage of error in Table 3 into 3 categories depending on the volume of freight flow in million tons such as 0-0.9, 1.0-9.9, and 10.0-49.9, as shown in Table 4. The 49 (7x7 regions) cells in the IRFF conclude the whole region of the IRFF table.

Table 4. Summary data of validation

Entry Size (Million Tons)	Number of Entry	Volume (Million Tons)	Absolute Error (Million Tons)	Percentage of Absolute Error
0-0.9	5	0.9	0.1	11.54
1.0-9.9	26	104.7	7.1	6.80
10.0-49.9	18	400.0	16.5	4.11
Total	**49**	**505.7**	**23.7**	**4.68**

The data from Table 3 was used to calculate the percentage of absolute error of IRFF estimation in 2007 and to summarize the data in Table 4. The results of this table indicated that the Chenery-Moses model is an effective tool to forecast the IRFF because the total percentage of absolute error for IRFF estimation in 2007 is less than five percent (4.68%). The third category (10.0-49.9 million tons) is the interval which has the most error. The share is 69% (16.5 million tons) but, when computed in terms of percentage of absolute error, it is 4.11 % compared with total volume in the third category.

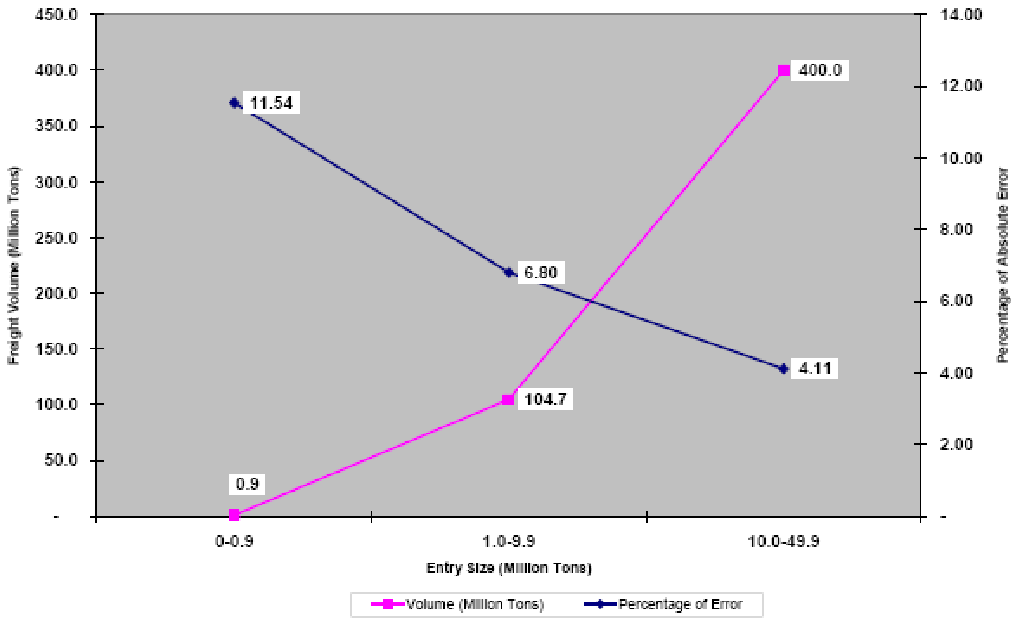

Figure 5. Volume and the percentage of absolute error in each category of IRFF data

The percentage of absolute error decreased from 11.54% to 4.11% according to the scale of freight flow volume. The percentage of absolute error in the category contained in the large volume is less than in the category contained in the small volume, as shown in Figure. 5.

6. CONCLUSION

The results of this study indicated that the Chenery-Moses model is an appropriate model to estimate Thailand's IRFF table because the total percentage of error for IRFF estimation in 2007 was less than five percent (4.68%). Further work is needed to estimate the IRFF using various trade flow predicting techniques and by comparing the results among these models.

Another subject for future research could be to extend and develop the model for estimating IRFF by mode.

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