STUDY ON THE CHARACTERISTICS OF CONGESTION PRICING

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Abstract: Congestion pricing is one of the most popular strategies to tackle the congestion problem in recent TDM practices. Because of its special inherent performance to combat the congestion problem at specific time and period, transport professionals are become interested to introduce to their cities. For the fact that, study on the characteristics of congestion pricing is ever more demanding and playing an important role in entire process. Taking this into consideration, this paper analyzes and explores the characteristics of time based, distance based and area wide congestion pricing schemes by tiss-NET microscopic simulator. The hypothesis based algorithms were developed to conduct the simulation, and the function value of time from the developed algorithms has been estimated from route choice behavior model. State preference data has achieved to estimate the value of time for motorists. The simulation results show the effectiveness, impacts, and their characteristics on the congested imaginary road network.

Key Words: congestion pricing, modeling route choice behavior, simulation

1. INTRODUCTION

Traffic congestion in most cities around the world is serious and impacting the many facets of urban life. It is also worsening the global environment and degrades the quality of urban life by making travel unreliable. Supplying the better roads to relief the congestion problem could not always be the best option because building the better roads may induce more traffic. Thus, the demands should be restricted to match the supply. Since a few decades ago, congestion pricing schemes has been introduced in some congested cities and it has been widely suggested like an appropriate policy tool for reducing traffic congestion problem by transport economists and planners. The analysis on the characteristics of congestion pricing is becoming a key factor for transport planner and for the city itself because congestion pricing is widely impact to the city. Relate to the fact that, Hong Kong has adopted ERP experiment in the period 1983 to 1985 and Stockholm trail congestion pricing was planned in year 2005-
Clearly it highlighted the characteristics of congestion pricing should study before its implementation. Gomez-Ibanez and Small (1994) determined the seven basis forms of congestion pricing; point pricing, cordon pricing, zone pricing, parking charges, charge for distance traveled, charge for time spent in the area, and charge for both time spent and distance traveled in the area. All those schemes have their unique characteristics and impact to the city in different ways. Knowing all possible route choice behaviors under congestion pricing is important, because the impact of congestion pricing originates from the route choice behavior of motorists. Figure 1 covered all route choice behaviors as much under congestion pricing. However in this study, only the route choice behaviors from commuting motorists were emphasized to analyze. Benita M. Beamon (1999) analyzed the effects of two transportation control strategies on congestion and automobile emissions from two types of road pricing schemes which are; Cordon Scheme and a Per-Mile Area Link Charging Scheme by developing a simulation-based methodology. Georgina Santos and Laurent Rojey (2002) also studied the distributional impacts and regressive effects of cordon toll by using simulation method. In this paper, the characteristics and the sensitivity of fare on reduction of traffic and collecting revenue from three types of congestion pricing schemes were studied.

Figure 1 Individual choice travel pattern under congestion pricing
2. HYPOTHEIS

The hypothesis of this study is that the effect of congestion pricing to the city will based on motorist's route choice behavior. Then the route choice behavior of motorist under congestion pricing in turn, will depend on their generalize cost of the trip. In other word, route choice behavior under congestion pricing can be expressed by following equation;

\[ GC = CPFare + VOT \times TT \]  \hspace{1cm} (1)

where, \( GC = \text{Generalize Cost}, \) \( CPFare = \text{Congestion Pricing Fair}, \)
\( VOT = \text{motorist Value of Time}, \) \( TT = \text{Travel Time} \)

In this study, time based scheme (TBS) - (charge is based on the driving time in congestion pricing zone (CPZ)), distance based scheme (DBS) - (charge is based on the driving distance in CPZ) and area wide scheme (AWS) - (one time charge for one day use within CPZ) were emphasized to study their characteristics. Therefore, three hypotheses can be defined; - **Hypothesis 1;** when time based congestion pricing scheme 'TBS' is introduced, motorists will try to reduce their generalize cost by reducing the travel time. - **Hypothesis 2;** when distance based congestion pricing scheme 'DBS' is introduced, motorists will try to reduce their generalize cost by reducing the travel distance. - **Hypothesis 3;** when area wide congestion pricing scheme 'AWS' is introduced, motorists will try to reduce their general cost by changing to charge free route.

3. THE ALGORITHMS

Due to several challenges and intrinsic difficulties to test the congestion pricing to the city and the lack of appropriate project for this study, simulation method with imaginary congested road network has been used. To conduct the simulation for three congestion pricing schemes, the hypothesis based algorithms were developed. The details of the algorithms are listed in table 1.

<table>
<thead>
<tr>
<th>Schemes</th>
<th>OD FROM Outside &amp; Inside TO Inside and Outside of CPZ</th>
<th>OD FROM Outside TO Outside</th>
<th>OD FROM Inside TO Inside</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBS</td>
<td>( GC = [(Tt ocpz \times VOT) + (Tt icpz \times (VOT + CPfare))] )</td>
<td>( GC = [(Tt ocpz \times VOT)] )</td>
<td>( GC = [(Tt icpz \times (VOT + CPfare)] )</td>
</tr>
<tr>
<td>DBS</td>
<td>( GC = [(Tt ocpz + Tt icpz \times VOT) + (Td icpz \times CPfare)] )</td>
<td>( GC = [(Tt ocpz \times VOT)] )</td>
<td>( GC = [(Tt icpz \times VOT) + (Td icpz \times CPfare)] )</td>
</tr>
<tr>
<td>AWS</td>
<td>( GC = [(Tt ocpz + Tt icpz \times VOT) + CPfare] )</td>
<td>( GC = [(Tt ocpz \times VOT)] )</td>
<td>( GC = [(Tt icpz \times VOT) + CPfare] )</td>
</tr>
</tbody>
</table>

**Note:** 
\( GC = \text{Generalize Cost}, \) \( Tt ocpz = \text{Travel time outside of congestion pricing zone}, \)
\( VOT = \text{Value Of Time}, \) \( Tt icpz = \text{Travel time inside of congestion pricing zone}, \)
\( CPfare = \text{Congestion Pricing fare} \)

From the developed algorithms, we have four functions; travel time, travel distance, congestion pricing fare and value of time to find the generalize cost between origin and destination. Because of using imaginary network, three functions can be determined, except value of time, because the value of time depends on the judgment of users. Therefore, we need to estimate value of time by developing route choice behavior model.
4. MODELING

Totally five route choice behavior models were developed for the origin outside of CPZ to the destination inside and outside of CPZ. Binary logit model was used to estimate the value of time for the motorists. For time based and distance based schemes, two route choice behavior models for destination inside and outside of CPZ were developed. However for area wide scheme, route choice behavior for motorists who have the origin outside of CPZ to destination inside of CPZ cannot be influenced because same charge for all routes. For the fact that, the model for destination inside of CPZ was not developed, only the model for route choice behavior of destination outside of CPZ was developed. The descriptions of models are given in figure 2.

4.1 DATA COLLECTION

To collect the data from respondents, stated preference (SP) questionnaire was designed from hypothetical model. Discrete choice modeling relies on the estimation of a response between the probability of a choice being made and the relative levels of the alternative chosen. Differing attribute levels with alternative is driven the model available to respondents in the choice sets causing and differing probabilities of alternatives being chosen. With multiple attributes and each attribute varying across multiple levels, apparently for a model to be able to separate out the effects on choice of individual attributes, many of choices between alternatives, which incorporate many of different combinations of attribute levels, will need to be observed. To identify completely the relationship, all possible combinations of attribute levels should be presented to respondents. However, the size of the full factorial grows rapidly to the extent that the total number of choice sets required to present them all to respondents soon exceeds the ability of respondents to cope (Bennett 1999). Fractional factorial designs reduce the number of options at the cost of being unable to recover one or more interaction effects. Therefore, fractional factorial design method was used in this research.
Finally, five hypothetical route choice questionnaires were considered on the basis of fractional factorial design method to reduce the bias of repeated measurement in questionnaire. SP choice tasks were given as a tabular form with hypothesis choice pictures to provide respondents with the clear information, which is close to the actual situation in the survey. The SP questionnaires were distributed to Nippon paint Company, which is one of the famous companies in Japan and there is plenty of automobile commuter. SP questionnaires were also distributed in the Saitama University, Japan, to reach the enough level of sample.

Totally 248 set of questionnaires were distributed to the respondents. Respondent rates are 60% and 153 samples could collect from the respondents. Of 153 samples, 138 samples were remained after removing the unusable (or) uncompleted data.

4.2 ESTIMATION RESULTS

The validity of the model estimation can be assessed using several methodologies. In this research, binary logit was used to estimate the VOT.

VOT can change with decreasing, increasing or constant function with travel time. The formulation of VOT estimation can be expressed by following equations.

$$V_{in} = \alpha + \beta_1 t_{in} + \beta_2 c_{in} \quad \text{------- Binary Logit Equation}$$

Where, $\beta_1$ and $\beta_2$ are the parameters which were estimated from the above mentioned five models. The variables are travel time ($t_{in}$) and travel cost ($c_{in}$). For this study, VOT is calculated by following equation.

$$VOT = \frac{\beta_1}{\beta_2}$$

Table 2 summarizes the results of the models estimation. All coefficient estimates have the expected sign. A negative sign implies a decrease in diversion propensity with a decreasing value of the variables. All attributes have t-statistics greater than 1.96 (95% confidence). The average value of time from model number 1 and 2 were used for time based congestion pricing scheme algorithm, for distance based congestion pricing algorithm, the average VOT from model number 3 and 4 were used whereas the VOT from model number 5 was used for area wide congestion pricing algorithm.

5. SIMULATION PROCESS AND IT’S RESULTS

Consideration of simulation forecasting module was started after the development of algorithms and the estimation of VOT. Analysis with the simulation method has achieved to distinguish the characteristics of congestion pricing schemes. Comparison between two traffic conditions; 1) with congestion pricing scheme and 2) without congestion pricing within the imaginary network showed the unique characteristic of individual congestion pricing scheme.
<table>
<thead>
<tr>
<th>Variable number</th>
<th>Variable name</th>
<th>Coefficient estimate</th>
<th>Standard error</th>
<th>t statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Travel Time (TT)</td>
<td>-0.064944</td>
<td>0.023948</td>
<td>-2.7119</td>
</tr>
<tr>
<td>2</td>
<td>Cost</td>
<td>-0.00323885</td>
<td>0.00129263</td>
<td>-2.5056</td>
</tr>
</tbody>
</table>

**Summary statistics**

- Number of observations: 138
- Schwarz B.I.C.: 91.8391
- Scaled R-squared: 0.084715
- LR (zero slopes): 11.8121 [0.003]
- Number of Choices: 276
- LRI (likelihood ratio index, rho-squared): 0.065365

**PATTERN '2'**

<table>
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<tr>
<th>Variable number</th>
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<th>Standard error</th>
<th>t statistic</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Travel Time (TT)</td>
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<td>0.025553</td>
<td>-3.2450</td>
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<tr>
<td>2</td>
<td>Cost</td>
<td>-0.00723077</td>
<td>0.00181511</td>
<td>-3.9836</td>
</tr>
</tbody>
</table>

**Summary statistics**

- Number of observations: 138
- Schwarz B.I.C.: 91.9518
- Scaled R-squared: 0.157083
- LR (zero slopes): 22.1868 [0.000]
- Number of Choices: 276
- LRI (likelihood ratio index, rho-squared): 0.11597

**PATTERN '3'**

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<td>Total Travel Time (TT)</td>
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<td>-4.0170</td>
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<td>Travel Distance</td>
<td>1.39556</td>
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<td>4.8000</td>
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<tr>
<td>3</td>
<td>Cost</td>
<td>-0.0066320</td>
<td>0.00153223</td>
<td>-4.3617</td>
</tr>
</tbody>
</table>

**Summary statistics**

- Number of observations: 138
- Schwarz B.I.C.: 69.4911
- Scaled R-squared: 0.291710
- LR (zero slopes): 41.1865 [0.000]
- Number of Choices: 276
- LRI (likelihood ratio index, rho-squared): 0.25668

**PATTERN '4'**

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<td>Total Travel Time (TT)</td>
<td>-0.081379</td>
<td>0.022669</td>
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<tr>
<td>2</td>
<td>Travel Distance</td>
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<tr>
<td>3</td>
<td>Cost</td>
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<td>-3.9459</td>
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**Summary statistics**

- Number of observations: 138
- Schwarz B.I.C.: 89.2112
- Scaled R-squared: 0.226400
- LR (zero slopes): 32.3343 [0.000]
- Number of Choices: 276
- LRI (likelihood ratio index, rho-squared): 0.16925

**PATTERN '5'**

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</tr>
</thead>
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</tr>
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<td>2</td>
<td>Cost</td>
<td>-0.00480421</td>
<td>0.00111763</td>
<td>-4.2985</td>
</tr>
</tbody>
</table>

**Summary statistics**

- Number of observations: 138
- Schwarz B.I.C.: 82.5431
- Scaled R-squared: 0.256965
- LR (zero slopes): 36.8090 [0.000]
- Number of Choices: 276
- LRI (likelihood ratio index, rho-squared): 0.19672
5.1 IMAGINARY NETWORK

Since the developed algorithm is not specific to certain road network, the current simulation employed the imaginary road network for simplicity. The imaginary network which had developed for this study has following basic principle;

(i) Cover all travel behaviors for hypothetical model
(ii) The level of distance and travel time was adjusted with the hypothetical model
(iii) Comfortable for tiss-Net simulator and
(iv) Convenience for analyze the result data

The network has four route choices for target destinations, which can be seen in the Figure 2. The targeted origin has exit at the outside of CPZ and destinations are located at outside and inside of CPZ. Setting the others OD value in the network intended to generate the traffic congestion inside the network. There are four different characteristics for the routes inside the imaginary network. It means; route (1) - which has the shortest distance between target OD and it is a toll route. It implies that the whole route is inside the CPZ. While route (2) has longer travel distance between target OD than route 1 and a part of the route is inside the CPZ has the same distance with route 1 but the rest of the part is outside of CPZ. As for route 3 which also has farther travel distance between target OD than route 1 and a part of the route which is inside of CPZ has shorter than route 1. Route (4) - which has the farthest travel distance route between target OD and it is free of congestion pricing charge for destination outside of CPZ and it could be cheapest route for time base and distance base congestion pricing schemes.

![Figure 3 Feature of Imaginary Network](image)

5.2 PROCESS OF SIMULATION

Simulation was conducted for 4800 seconds (1 hour 20 minutes). Nevertheless we don't take the results of first 15 minutes and the last 5 minutes of simulation time to get high accuracy results from the simulation. Due to the facts that using the imaginary network to compare between the two conditions, with, and without scheme, firstly we need to conduct the
simulation with tiss-NET original algorithm to adjust the original traffics condition by using trial-and-error method. After recognizing the original congested traffic condition for the imaginary network, simulation is again taken by using the algorithms which were developed for this study to get the traffic condition under congestion pricing schemes. Traffics condition between with, and without congestion pricing schemes were compared and evaluated to distinguish the characteristics of congestion pricing schemes. Figure 4 describe the process of analysis by simulation method.

![Figure 4 Forecasting module](image)

5.2.1 GOODNESS OF TISS-NET SIMULATOR

- tiss-NET (traffic impact study system for road NETwork) car-by-car microscopic simulator is an event-type Monte Carlo simulation, which traffic flow is simulated the movement of car-by-car, thus it has a power to deal with giving individual characteristics to each vehicle and storing the movement of individual vehicles. tiss-NET represents road networks of district area with nodes, links, and lanes, as dividing the entire street length by compartment with 5 meters length. In order to make vehicles to move, the event schedule for generating vehicles is set by initializing "section network" and "section time". And then, the shortest paths of each Origin-Destination pair are calculated in a way of user-equilibrium, which are updated iteratively in each phase time. In this study, the simulation for congestion pricing schemes has used the developed algorithms and calculation find the cheapest cost route for each Origin-Destination pair. Figure 5 illustrate the step by step process of tiss-NET simulator with original algorithm and new algorithm which was developed for this study.

The algorithms to conduct the simulation for congestion pricing scheme has included cost functions, VOT (value of time) and CPfare (congestion pricing fare). Cost function VOT was taken from the model estimation result and it is constant. But CPfare needed to adjust the level because, when the level of CPfare is set to very high level in tiss-NET algorithms, then generalize cost for the routes which are inside of CPZ are become very expensive than the routes which are not in the CPZ. In that kind of situation, the routes which are outside of CPZ is become stuck with traffic while simulation is conducting. Also for the result for very low level of CPfare may not apparently different with the result of without congestion pricing. To avoid those kinds of bias, three applicable levels of CPfare were elected for each scheme.
Making “Section Network” And Initializing “Section Time”

Simulation Time = 0 [s]

Is “Simulation Time” “more than Each “Phase Time” ?

Calculating the Shortest Path between OD Pair = calculating the shortest travel time route between OD Pair

Setting the First Event Schedule (Generation) for All the Car

Simulation Time = min [ Event Time ]

Getting CarID of the Minimum Event Time

Moving the Car, Calculating the Next Event Time and Updating the Event Time

Simulation Time ≥ Total Simulation Time

END

Calculating the Shortest Path between OD Pair = calculating the cheapest general cost route between OD Pair

Setting the First Event Schedule (Generation) for All the Car

Simulation Time = min [ Event Time ]

Getting CarID of the Minimum Event Time

Moving the Car, Calculating the Next Event Time and Updating the Event Time

Simulation Time ≥ Total Simulation Time

END

Fig 5 Comparison of tiss-NET simulators
5.3 THE RESULTS

After the simulation result of original traffic condition in the network has been reached to acceptable level, the condition become suitable to test the congestion pricing schemes. It means that the condition of the route 1 is congested but the others routes were not. When simulation is carried out for the congestion pricing scheme, the whole part of route 1 was converted to the CPZ route. So, we may clearly see the route change behaviors under the congestion pricing, because route 1 has been congested. The simulation results for average travel time and distribution of traffics between targeted OD have been shown in Table 2 and 3.

The results shows that the average travel time for route 1 under congestion pricing schemes are always less than the average travel time under congestion pricing. It could be said that after any congestion pricing scheme is introduced the travel time for the route which are inside of CPZ can reduce. Reversely, the average travel time for route 4 under time base and distance base is become increase. This is because the route choice behavior is become influence and the distribution of traffics has been changed based on the generalize cost of the routes. Base on those kinds of situation, we can say that the effectiveness of time based and distance based congestion pricing on decreasing traffic congestion affect to outer CPZ routes.

<table>
<thead>
<tr>
<th>Schemes</th>
<th>Route 1</th>
<th>Route 2</th>
<th>Route 3</th>
<th>Route 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCP</td>
<td>22.29</td>
<td>24.34</td>
<td>29.44</td>
<td>19.04</td>
</tr>
<tr>
<td>TBS5V</td>
<td>16.52</td>
<td>20.07</td>
<td>22.88</td>
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</tr>
<tr>
<td>TBS10V</td>
<td>16.42</td>
<td>19.07</td>
<td>25.87</td>
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</tr>
<tr>
<td>TBS20V</td>
<td>21.84</td>
<td>26.45</td>
<td>28.36</td>
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</tr>
<tr>
<td>DBS50V</td>
<td>17.54</td>
<td>20.15</td>
<td>24.40</td>
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</tr>
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<td>DBS100V</td>
<td>16.23</td>
<td>18.60</td>
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</tr>
<tr>
<td>DBS200V</td>
<td>7.88</td>
<td>9.53</td>
<td>37.31</td>
<td>36.26</td>
</tr>
<tr>
<td>AWS100V</td>
<td>18.23</td>
<td>18.75</td>
<td>20.52</td>
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</tr>
<tr>
<td>AWS300V</td>
<td>10.58</td>
<td>11.72</td>
<td>15.82</td>
<td>15.11</td>
</tr>
<tr>
<td>AWS600V</td>
<td>10.58</td>
<td>11.72</td>
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</tbody>
</table>

<table>
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<tr>
<th>Schemes</th>
<th>Route 1</th>
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<th>Route 3</th>
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<td>WCP</td>
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<td>35.25</td>
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<tr>
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<table>
<thead>
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<th>Distribution of traffics inside of CPZ</th>
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<tr>
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<td>TBS5V</td>
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<td>TBS10V</td>
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<td>TBS20V</td>
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Under the time based congestion pricing scheme, the travel time for route 2, 3 and 4 has not much different between one another. This is because of the following facts; - distance between the targets OD for those routes is not different enough, - the algorithm adjusted the generalize cost of the routes. We can say from the result that the travel time for the routes which are inside of CPZ can become equilibrium when the scheme is introduced.

For the distance based congestion pricing scheme, the travel time of route 1 is decreased and route 4 is increased belong to increasing the level of charge. This is because the whole part of the route 1 is inside of CPZ and increasing charge rate was directly effected on generalizing cost for the route 1, it is become expensive. Thus, most of the traffic switched to the route 4 which has short travel distance at inside of CPZ and less generalize cost than route 1. Distribution of the traffics from simulation result in Table 4 can also shows that when the charge rate has become highest, no traffic for destination outside of CPZ has used route 1 to reach their destination, all traffics has switched to route 4 and then route 4 got heavy congested with longer travel time. Because of there are no several route choices in tasted imaginary network, almost the traffics from route 1 were switched to route 4 to reduce their generalize cost. So, route 4 becomes heavily congested with traffic. This is clear that the distance based congestion pricing should not introduce if the congested area has no several routes choices.

In the fact of travel time for all the routes under area wide scheme are less than under without congestion pricing scheme can say that the area wide scheme is more effective to relief the congestion problem. Distribution of the traffics under area wide scheme can also shows that; - the traffics for the destination outside of CPZ were switched to charge free route, it is route 4, away from route 1 which has not free of charge and the traffics for the destination inside of CPZ were only used the route 1, its means that route choice behavior was not influenced for the destination inside of CPZ. By checking the number of traffics reached to the destination in
one hour simulation time was also shown that more traffic could use the routes within the simulation time.

5.3.1 SENSITIVITY OF FARE AND ITS REVENUE

In general, payment from the user should at least the same to the benefit which gain by using some kinds of facilities. If user think payment is higher than benefit, users have no willing to use or cannot be satisfied after using those kinds of facilities. Similarly for the congestion pricing facility, users should get benefit such as reducing travel time by paying charge for congestion pricing facility. Taking such kind of hypothesis into consideration, this study analyzed on the relation between total revenue from congestion pricing and total travel time inside of CPZ. tiss-NET simulator has an ability to check the travel time and fare for individual vehicle. Therefore, the total travel time and total revenue for all congestion pricing schemes under every level of congestion pricing fare can be calculated.

Figure 6 shows the relation between total travel time and total revenue for each scheme. Position A represent the scheme has low revenue with low travel time; position B represent the scheme has low revenue with high travel time; position C represent the scheme has high revenue with low travel time and position D represent the scheme has high revenue with high travel time. If the scheme was near position B and C, we could logically conclude that the scheme has usual characteristic, because - low payment or low revenue - with - low benefit or high travel time (position B) and - high payment or high revenue - with high benefit or low travel time (position C). If the scheme was near position D, that kind of scheme should not implement. If the scheme was near position A, that scheme is the best option to relief the congestion problem and public also could accept after implementation. From the analysis of relation between total travel time and total revenue, we found some special feature amongst the tested congestion pricing schemes.

- For the time based scheme with charge rate 20 ¥ per minutes, it has high total travel time with high total revenue. That kind of congestion pricing scheme is not the acceptable one from the public and for the government.
- For the area wide scheme with charge rate 600 ¥, it has high total revenue with low total travel time. That kind of congestion pricing scheme is better for the view point of government to making the revenue.
- Area wide scheme with the charge rate 100 ¥ can be evaluated like the most suitable congestion pricing scheme for tested imaginary network. Because it has less total travel time with low total revenue, and that kind of congestion pricing scheme can more acceptable from public.

After evaluation of the relation between the total revenue and total travel time, additionally the relation between total travel time and total revenue has been checked. It is shown in figure 7 and it is providing the evaluation of the schemes, for example; - decreasing total travel time for area wide scheme with charge rate 100 ¥ is not by dropping traffic volume inside of the network, it is because, the scheme shift the traffic which has destination outside of CPZ; - increasing total travel time in time base scheme with charge rate 20 ¥ is not related to increase traffic volume inside the network, it is because, the scheme perform unbalance route choice behavior with charge rate 20¥ per minute.
### 5.3.2 RESULTS SUMMARY

Finally, the characteristics of tested congestion pricing schemes could summarize as follows:

- All congestion pricing schemes which were tested in this study can reduce the traffic congestion in the congestion pricing zone.
The effectiveness of reducing traffic congestion inside of CPZ can be impact to the outer CPZ routes.

Increasing charge rate under all congestion pricing scheme could happen the unsuspected route choice behavior.

Travel time within the CPZ route could become equilibrium when time based scheme is introduced.

Distance based scheme should not implement if the network have no several route choices.

Area wide scheme is the more suitable to tackle the congestion problem.

Base on the feature of the network, the characteristics of congestion pricing maybe different.

Based on the above evaluations of simulation results, we could conclude that area wide scheme is the best congestion pricing scheme for tested imaginary road network. Because area wide scheme has lower total travel time with higher vehicle volume and the scheme could collect the high level of revenue under every level of fare Figure 5 and 6.

6. CONCLUSION AND DISCUSSION

Implementing the congestion pricing scheme to tackle the congestion problem is latest technique and it has high accuracy to combat the congestion problem. Probably, the most important thing to done before the process of implementation is to find the suitable scheme for the area. Regarding to that mentioned fact this research was explored the characteristics and effectiveness of congestion pricing schemes.

Simulation method is the best option to predict and compare the effectiveness of congestion pricing schemes. According to the prediction of congestion pricing schemes by simulation, the hypothetical algorithms were developed and it was achieved to simulate the congestion pricing scheme. Regarding to the algorithms which has developed for this research included cost function (VOT) value of time, route choice behavior model was developed to estimate it.

Route choice behavior models under congestion pricing schemes were extracted from discrete choice analysis. Those models were used to estimate the value of time for respondents who response on congestion pricing facilities. The data for estimation of the models were derived from the Stated Preference (SP) experiment. From those empirical models, the value of time was estimated for the algorithms in tiss-NET simulator.

The forecasting module was developed by tiss-NET simulation-based prediction method. To explore the effectiveness and the characteristics of congestion pricing schemes, the imaginary network with congested traffic carried out by using Geoconcept software and tiss-NET simulator. To generate and evaluate the congestion pricing schemes, simulation for three different congestion pricing was conducted by using related algorithm for individual congestion pricing scheme. Simulation for congestion pricing schemes accomplished to evaluate the effect and impact of congestion pricing schemes on tested imaginary network.

This research contributed the idea of analysis on congestion pricing with simulation method. The further study can use the actual data with real congested road network. Travel behavior under congestion pricing for this research is only concentrated on commuting trip purpose from origin outside of congestion pricing zone to destination inside and outside of congestion.
pricing zone. For the further study can include the behavior for origin inside of congestion pricing zone to destination inside and outside of congestion pricing zone. Respondent on congestion pricing facilities by individual person should take into count for increase the accuracy of the results.

REFERENCES


