Traffic Policy Evaluations Using Micro Traffic Simulation
A Case Study Of Thailand

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ABSTRACT

As the travel demands of society are increased, road networks are also expected to supply better service by many ways including proper transportation planning and traffic policies. This paper proposed a solution for evaluating traffic policies to reduce traffic congestion in urban road network in Sukhumvit area - Bangkok - Thailand. The probability distribution of link traffic flows were constructed and then, random variables were generated to reflect the fluctuation of volumes. The Least Squared Error Model was employed to estimate Origin Destination demands consistent with the link volumes available. The traffic simulation NETSIM (NETwork SIMulation) was applied to simulate the actual traffic condition in Sukhumvit area. The improvement of traffic condition after changing traffic policies was shown by the improvement of total vehicle-kilometer and average travel time for the whole network. Three scenarios were proposed in the paper: changing one-way roads to two-way roads, constructing new roads and changing one-way roads to two-way roads accompanied by constructing new roads.

Keywords: Traffic Simulation, Traffic Control System, Infrastructure Development.

INTRODUCTION

At present, Bangkok has been suffering from a severe congestion problem and has an international legend of being the worst traffic jam. It is not unusual to be stuck in traffic jams for a long time to reach a destination that only seems a few minutes. The possible reasons are increasing number of vehicles over the infrastructure developments, inconvenient and unattractive public transportation, and lacking of effective transportation planning and traffic policies in Bangkok. Located on the busiest area in Bangkok, carrying large number of vehicles, Sukhumvit road network, bounded by Phetchaburi Rd. from North, Rama IV from South, Ratchadamri Rd. from West and Ekamai from East, is the most heavily traveled urban network (FIGURE 1). It has been attracting high traffic volumes as the major road system for Central Business District and as the primary roads for through traffic. Moreover, continuously increasing traffic demand has made this road system beyond its original design capacity. It has caused into recurring congestion at all business hours. Non-recurring congestion is also common for both private vehicles and commercial automobiles. The objective of this research is to evaluate traffic policies and infrastructure developments in order to improve traffic condition in the area. Due to a large number of applications of conventional methods for estimating, Origin Destination (OD) demands become too costly, time and manpower consuming, this paper also proposed the applicability of a method, Least Squared Error Model, in obtaining OD traffic demands directly based on most common traffic information, link flows.

METHODOLOGY

Traffic policy analysis based on traffic simulation software is not the new topic. Up to now, there are many of studies have been conducted traffic simulation to evaluate traffic conditions by changing some traffic policies and infrastructure development. Romeo at al (1) used NETSIM package to assess traffic impact of port development projects of Manila by constructing some different road infrastructure scenarios. This paper emphasized the importance of traffic simulation in estimating the vehicle-miles, delay time, travel time, etc. to assess the advantages and disadvantages of each scenario. Similarity, Maze at al (2) developed some models, which were different traffic policies, to reduce congestion and delay time of the US 61 corridor in Burlington, Iowa, United States. However, in most studies, the accuracy of the results applied in real situation is not as high as expected since traffic volumes were considered as constant as not really exists. This paper proposes a method using micro traffic simulation to evaluate traffic impacts with different traffic policies and infrastructure developments in which, traffic flows are considered as variables. In order to describe the vary of these values, after getting data from surveying and secondary data, the probability distributions of link traffic flows are constructed, then generated random variables. The travel time data is used to estimate route choice probability. Based on Least Squared Error theory, OD demand matrixes are built for each value achieved from generating random variables. NETSIM simulation software is used to evaluate traffic policies.

Three scenarios are proposed in the paper. Scenario 0 describes the existing condition that is, the present traffic volumes on the existing road network system. The first scenario depicts the traffic condition after Phloen Chit Rd., Chitlom Rd., Wireless Rd., Phetchaburi Rd., Nana Rd., Asoke Rd., Ratchadamri Rd. and Kluaynamthai Rd. change from one-way to two-way. The second scenario describes the traffic impact after two new roads connecting Sukhumvit Rd. to Phetchaburi Rd. are built. The third scenario shows the traffic condition after changing

Phloen Chit Rd. from one-way road to two-way road as long as constructing one new road connecting Sukhumvit Rd. to Phetchaburi Rd. The study network is shown on the FIGURE 1.

The network is abstracted into a series of directed links and nodes. Links are defined as the road segments connected between two nodes. Nodes are shown on FIGURE 1 and separate into internal nodes and external nodes described as bellow

- External node: Intersection among the road segments inside and outside network, including trip generations and trip attractions, and called as origin-destination;
- Internal node: Intersection linked road segments inside network only.

A summary of the number of links and nodes required to present the network is provided in TABLE 1.

External nodes, 2,10,14, represent the on ramp and off ramp of Second State Expressway. IN order to improve the accuracy of simplified network, nodes 6, 7, 8 describe the complex small road (soi) system and are shown as FIGURE 1. These nodes also include trip generations and trip attractions and known as external nodes.

Data Collection

The evaluations start at the data collection in order to develop a base model. The model simulates traffic condition throughout the facilities under current traffic operations in the network. The collected field traffic data is significant to compare to base model output to make sure the model representing the existing condition of the simulated traffic facility. The required data in the study are classified into three categories: supply, demand and control. Supply data primarily consists of geometric and traffic characteristics. Demand data includes traffic flow and travel time data. The control data comprises signal-timing specifications at intersections of the network. All data are collected from surveying and secondary data. The conducted time is a peak hour afternoon from 5 pm to 6 pm. At that time, the traffic condition is the most congested.

Supply Data

Number of lanes, lane widths, lane channelizations, lane configurations, length of turning pockets, gradient of each approach and the distances between intersections fall into this category. In the research, the distances between intersections are measured from the digital map. Other traffic characteristics are conducted from surveying.

Demand Data

The traffic flows are obtained from surveying by using master station method and from secondary data (3). After counting manually and using a video recording method in short time periods, the traffic volume data is extended to long time periods in case that traffic characteristics at counting locations are similar to master stations. The traffic flows are found with mixed vehicle types. Trucks and buses are larger than passenger cars, thus occupy more road space. The number of large and medium vehicles is converted as equivalent number of passenger cars in order to achieve common unit. The impact of buses and trucks are treated through the using of passenger car equivalents (PCE). The TABLE 2 is shown PCE values currently used in Thailand, which is adopted from Mathetharan (4). Then, traffic flow of each link is computed approximately to average of two approaches of that link.

Another data taken into this category is link travel time. In order to estimate this data, the traditional floating car study is carried out to collect data describing trip duration along each link. In case of some links have more than one lane, the test car is driven in the mid-lane or inner lane. The travel time presents the total time required for a vehicle to pass the link. The time includes time spent in travel and lost time. Thus, the effect of congestion is reflected by the time spent in queues. The link travel time data is used to estimate link use probability later.

Control Data

Due to carrying very heavy traffic, most of intersections in the network have been controlled by signal control systems. The control data is obtained from field observation. Information needed for signalized controls includes signal type (pre-time, semi-actuated, fully actuated), phase patterns, locations and others. Five cycle times per intersection are observed to determine the stability of the count. The recorded cycle time of the intersections varies from 80 seconds to 180 seconds. The allocated green time per phase varies from 30 seconds to 120 seconds. The observed amber time is 3 seconds. All-red time varies from 0 to 2 seconds.

Link Flow Distribution

For traffic flows in urban network are fluctuating and the traffic flow data taken from observation and secondary data is only few samples of population, it is necessary to construct the probability distribution of traffic flow at each link. Then, random variables are generated to evaluate level of variety of traffic condition. The triangular density function is applied for each link (FIGURE 2). The maximum value is the link capacity. The mean is the value taken from surveying and secondary data. The minimum value is based on condition of each link and at the time considered. Assuming that each value of link traffic flow is independent to others. Then, ten cases for generating random variables following triangular distribution at each link are obtained to estimate different OD demands.

Link Capacity

Pignataro (5) provided a widely used formula for obtaining freeway link capacities by multiplying the level of service E volume (2000 passenger car per hour per lane) by appropriate adjustment factor. Pignataro's equation for obtaining freeway link capacities is

$$C = 2000NWT_c \tag{1}$$

where C : Capacity (mix vehicle per hour, total for one direction);
N : Number of lanes (in one direction);
W: Adjustment for lane width and lateral clearance;
T_c : Truck factor at capacity.

However, in Urban Road Network, link capacity is affected strongly by intersections. Vehicles still waiting for service or decelerating at intersection will reduce the number of vehicles passing this link. To express this reduction, the R_s factor less than 1, which is the proportion of the effective green time at that approach to the cycle time of the intersection, is added into this equation.

$$C = 2000NWT_cR_s \tag{2}$$

The value of T_c depends on the percentage of truck in traffic volume and less than 1. The number of lanes is obtained from surveying.

Triangular Distribution and Generating Random Variables

Assuming that traffic flows are independent each other, random variables are generated with triangular distribution in order to run the simulation model. Law et al (6) had generated random variables of triangular as follow:

Firstly, if X ~ triang(0,1, (c-a)/(b-a)) then X' = a + (b-a)X ~ triang(a,b,c), so it can be restricted attention to triang(0,1,c) random variables, where $0 < c < 1$. The distribution function is easily inverted to obtain, for $0 \le u \le 1$,

$$F^{-1}(u) = \begin{cases} (cu)^{1/2} & \text{if } 0 \le u \le c \\ 1- \ [(1-c)(1-u)]^{1/2} & \text{if } c < u \le 1 \end{cases} \tag{3}$$

Therefore, it can be stated the following inverse-transform algorithm for generating
X ~ triang(0,1,c):

1. Generating U ~ U(0,1);
2. If $U \le c$, set $X = (cU)^{1/2}$ and return. Otherwise, set $X = 1 - [(1-c)(1-U)]^{1/2}$ and return.

Origin-Destination Traffic Demand Estimates from Link Traffic Flow

Least Squared OD Estimation Model

The need of dynamic demand estimation can be established when OD demand exhibit significant temporal and spatial variations (7). At that situation, the assumptions, which are made in the estimation of static demand, are increasingly violated as the time is more disaggregated. However, the estimated dynamic demands also need more required data, which is costly and time consuming. In this study, the data is observed in one hour. Considering the timing and budget required, the static OD demand estimation is conducted. Hellinga in 1994 (7) proposed a method, called Least Squared OD Estimation Model, which minimizes the squared link flow differences between estimated and observed link flow and is one of the simplest methods for OD demand estimation, is derived as follow:

$$E = \sum_a (V_a - V_a')^2 \tag{4}$$

such as

$$V_a = \sum_{ij} T_{ij} P_{ij}^a \tag{5}$$

where V'_a : Observed flow on link a (Vph);
V_a : Estimated flow on link a (Vph);
i : Origin zone number;

j : Destination zone number;
a : Link number;
P_{ij}^{a} : Probability that demand between i and j will use link a;
T_{ij} : Demand departing from origin i to destination j.

The solution is based on iterative process and modified Jacobi method. By using a relaxation technique (8), after an iteration is completed, these computed values are modified by factor (1-α) prior to use them in the next iteration. For the general OD estimation case, the modified demand T_{ij} estimation for the current is provided as follow:

$$T_{ij}^{l+1} = T_{ij}^{l} - \frac{\alpha}{n_{ij}}(C_{ij}) \tag{6}$$

and

$$T_{ij}^{l+1} \geq 0 \tag{7}$$

where

$$n_{ij} = \sum_{a}(P_{ij}^{a})^{2} \tag{8}$$

$$C_{ij} = \sum_{a}(V_{a} - V_{a}')P_{ij}^{a} \tag{9}$$

T_{ij}^{l} : The modified demand from origin i to destination j at iterative l;
V_a' : Observed flow on link a (Vph);
V_a : Estimated flow on link a (Vph);
P_{ij}^{a} : Probability that demand between i and j will use link a;
α : Relaxation factor ($0 < \alpha < 1$);
l : Iterative number.

Identifying Link Use Probability

In order to identify link choice probabilities, Irwin et al (9) suggested the following inverse-proportion function of travel time to calculate the percentage of trips between i and j using route r and this model is called Multi-path Assignment

$$P_{ij}^{r} = \frac{(t_{ij}^{r})^{-1}}{\sum_{x}(t_{ij}^{x})^{-1}} \tag{10}$$

The probability that demand between i and j will use link a is equal to sum of all probabilities of trips between i and j using route r which includes link a:

$$P_{ij}^{a} = \sum_{x} P_{ij}^{x} \tag{11}$$

where P_{ij}^{r} : Probability that demand between i and j will use route r;
P_{ij}^{a} : Probability that demand between i and j will use link a;
t_{ij}^{r} : The travel time of route r from origin i to destination j;
x : The number of routes from i to j.

Simulation Using NETSIM

NETSIM, the model was integrated with TRAF simulation system in 1980 is one component model in TRAF designed to represent traffic on an Urban street networks and at microscopic level. Microscopic simulation models represent the traffic flow in term of the individual vehicular movement. The concept is based on route choice behavior and car-following theory. The advantage of those models is that the trip users have full data in the system network over time and space.

The TRAF-NETSIM also includes a traffic assignment, which is designed to expand the applicability of traffic simulation modeling to transportation planning. The algorithm that is used is all-or-nothing traffic assignment. Shortest path tree is constructed for each specified origin node to all other network nodes by using label-correcting algorithm. Traffic assignment models can use for two purposes: to convert OD matrix into actual network and to evaluate demand responses when changing policies. Thus, it is the key to evaluate the traffic policies in this research.

Calibrating TRAF-NETSIM

Many parameters are important to generate the simulation data and to present the real field effectively. The traffic parameters shown bellow using the real traffic data, which is obtained by surveying, are adjusted to calibrate the model.

• Saturation flow rate	1800vph
• Departure headway	2 sec.
• Start-up lost time	3.5 sec.
• Free flow speed	40mph = 64.372kph
• Vehicle’s characteristics change only passenger car‘s length, the other as default.	
• Amber time	3 sec/phase
• All-red time	varied 0 - 2 sec.

Validation of Results

To validate the results of the simulation, the actual traffic flow at each link is compared with the simulated flow. FIGURE 3 shows the correlation between observed and estimated link flows accordingly.

The errors happen due to (i) inaccurate observation of travel time at each link, which affected to probability of demand from origin to destination by using a specified link, (ii) improper traffic parameters and (iii) Least Squared Error Model, error from over-estimation of traffic flow at links with low traffic.

TRAFFIC POLICY EVALUATION USING SIMULATION

By using simulation, three scenarios for improving traffic condition are introduced: changing one-way roads to two-way roads, constructing new roads and changing one-way roads to two-way roads accompanied by constructing new roads. In each scenario, ten cases of different OD demands are constructed. Total vehicle-kilometer and average travel times between before and after change policies are compared to evaluate the policies and infrastructure development.

Change Roads from One-way to Two-way

FIGURE 4a and 4b illustrate the difference between before and after changing Phloen Chit Rd., Chitlom Rd., Withayu Rd., Phetchaburi Rd., Nana (soi 3), Asoke (soi 21), Ratchadamri Rd. and Kluaynamthai from one-way to two-way in total vehicle-kilometer and average travel time.

From FIGURE 4a, after change from one-way to two-way, the total vehicle-kilometer decreases (12.16% in average). The total vehicle-kilometer represents the product of total number of vehicles and total kilometer traveled in the network. This unit, thus, is the total kilometer traveled by all vehicles. The reason is that route users can reduce the travel distance between their origins and destinations. Travelers can choose alternative route since they can use two directions instead of one direction as before. However, the average travel time increases (average 1.65%) as FIGURE 4b. It can be explained that in one-way roads, the conflict points at intersections are less than those of two-way roads. Converting relatively one-way roads to two-way roads can greatly complexity the intersection operation and signal phasing. In the network, the converting of roads told above will make problems of intersection conflicts and delays significantly, especially at intersections Phloen Chit – Ratchadamri, Phloen Chit – Chitlom, Phloen Chit – Wireless, Phloen Chit – Nana.

Build New Two-way roads

Two new roads are built to connect Sukhumvit Rd. and Phetchaburi Rd. at node 6, 7. The total vehicle–kilometer and average travel time of entire network before vs. after Scenario 2 are shown on FIGURE 5a and 5b.

From FIGURE 5a and 5b, total vehicle-kilometer decreases average 3.94% and average travel time decreases at average 6.54%. The reason is that after second approach is implemented, route users can shift their route to reduce travel distance and travel time.

Build New Two-way Road accompanied by Change One-way to Two-way Roads

A new two-way road is built to connect Sukhumvit Rd. and Phetchaburi Rd. at node 7. The one-way Phloen Chit Rd. is changed to two-way road. After changing policies, total Vehicle-kilometer and average travel time are shifted as FIGURE 6a and 6b.

The total vehicle-kilometer decreases at average 6.68% and the average travel time decreases at average 10.15% in the third scenario.

The Comparison of Three Scenarios

Total vehicle-kilometer and average travel time are conducted to find what is the best solution among three scenarios. From FIGURE 7a, total vehicle–kilometer of the first scenario is the lowest one. It is meant that after changing to all two-way roads, travel distance is reduced. However, the average travel time is highest compared to other scenarios. The reason is that, after changing to two-way roads, conflict points at intersections increase, turning movement is more difficult, and congestions are increased as well. Second scenario has the highest total vehicle-kilometer because some route users use new roads as shortest path for both travel distance and travel time. Besides, some travelers shift their routes to decrease travel time even if that action lets travel distance be increased. The third scenario is the most efficient one among three scenarios. Compared to others, in this scenario, the total vehicle-kilometer is lower than existing condition and average travel time is the lowest.

The confident interval after ten cases conducted for total vehicle-kilometer and average travel time is in FIGURE 8a and 8b.

This figure is shown that the higest average travel time of third approach is lower than that of existing condition. It means that in all cases considered, after traffic policies are changed in third approach, the traffic condition is improved.

CONCLUSION

Traffic simulation using NETSIM can be used to analyze and evaluate traffic impact of changing in traffic policies and infrastructure development. The software calibrated to adopt and reflect actual traffic conditions. By simulating the traffic condition in Sukhumvit road network, the total vehicle-kilometer is 68912 Veh-Km and the total travel time is 4.5 Min/Km. The results imply that the traffic demand is very high and the existing road system is inadequate to handle the present traffic volume.

The results from the simulation of the first scenario in which total vehicle-kilometer reduces 12.16% and average travel time increases 1.65% compared with existing condition, denotes that in the new road network, the total travel distance of travelers reduces and total travel time increases a little due to causing more congestions, especially at critical intersections. The second scenario in which total vehicle-kilometer decreases 3.94% and average travel time also reduces 6.54%, depicts that new road network can handle traffic volume better than existing road network. However, it should be consider the cost of infrastructure development and other impacts. The third scenario in which total vehicle-kilometer reduces 6.68% average and average travel time reduces 10.15%, is the most efficient among three scenarios. The route users can reduce their travel distances as long as travel time. Thus, it is recommended that the traffic condition will be improved if the study road network is changed as the third scenario. The study also indicates that if one-way roads are changed to two-way roads as the third scenario and without infrastructure development, the traffic condition is improved.

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TABLE 1 Number of Nodes and Links in Study Area

Type	Number
Node Origin	16
Node Destination	16
Internal Node	22
Link	97

TABLE 2 Passenger Car Equivalent (PCE) for Medium and Large Vehicles

Vehicle		**PCE**
Motorcycle		0.25
Passenger car		1.00
Taxi	4-wheel	1.00
	Tuk-Tuk	0.75
Bus	Light	1.25
	Medium	1.50
	Heavy	2.00
Truck	4-wheel	1.75
	6-wheel	1.75
	10-wheel	2.00
	Articulated	3.00

Source: Mathetharan, 1997

Note: Tuk-Tuk is three-wheeled taxi

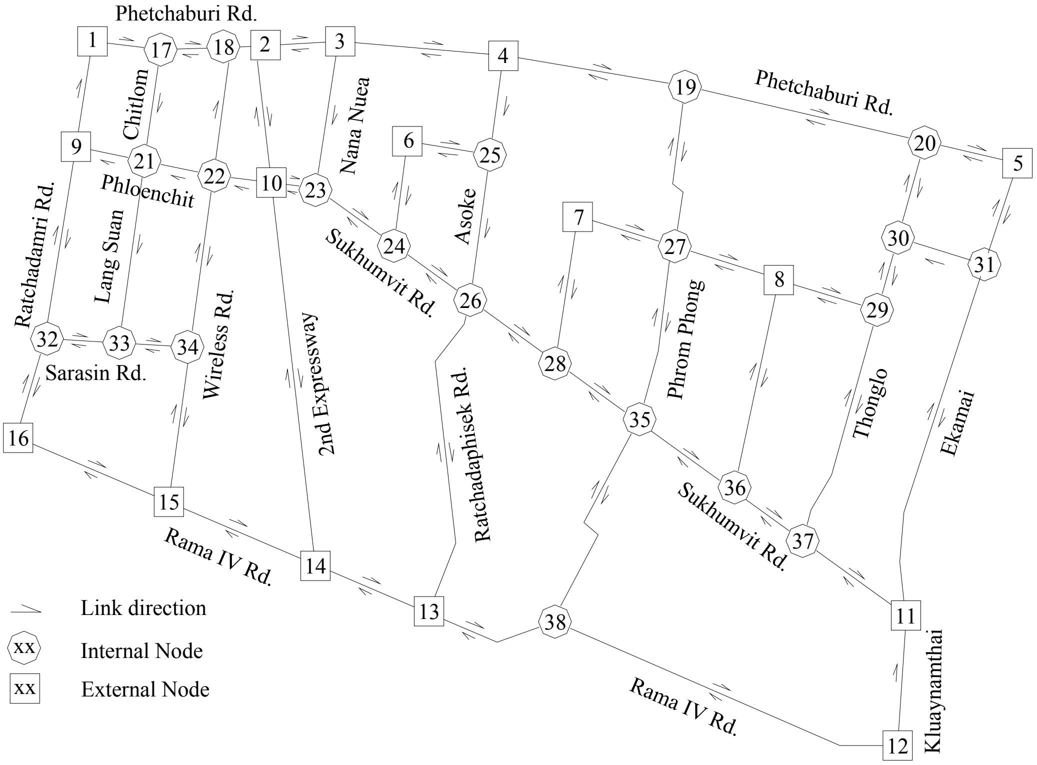

FIGURE 1 The Study Road Network.

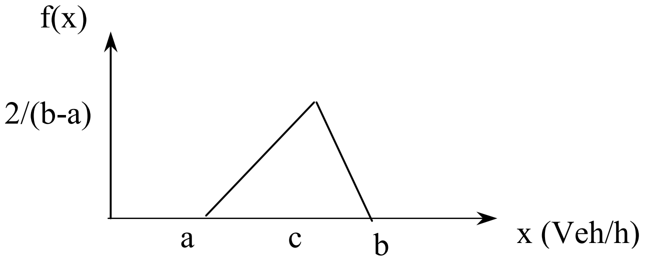

FIGURE 2 Triang(a,b,c) Density Function.

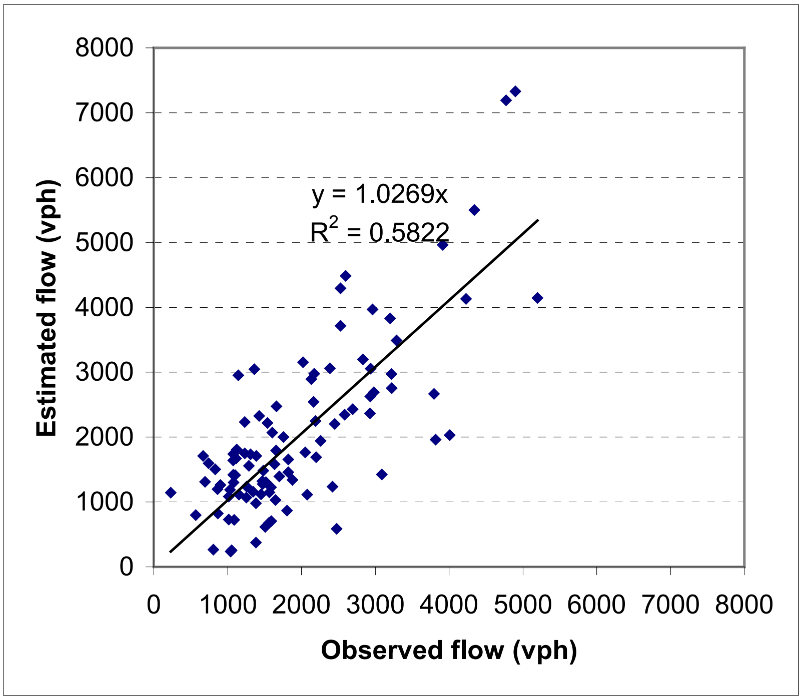

FIGURE 3 Correlation Between Observed And Those Estimated Link Flows.

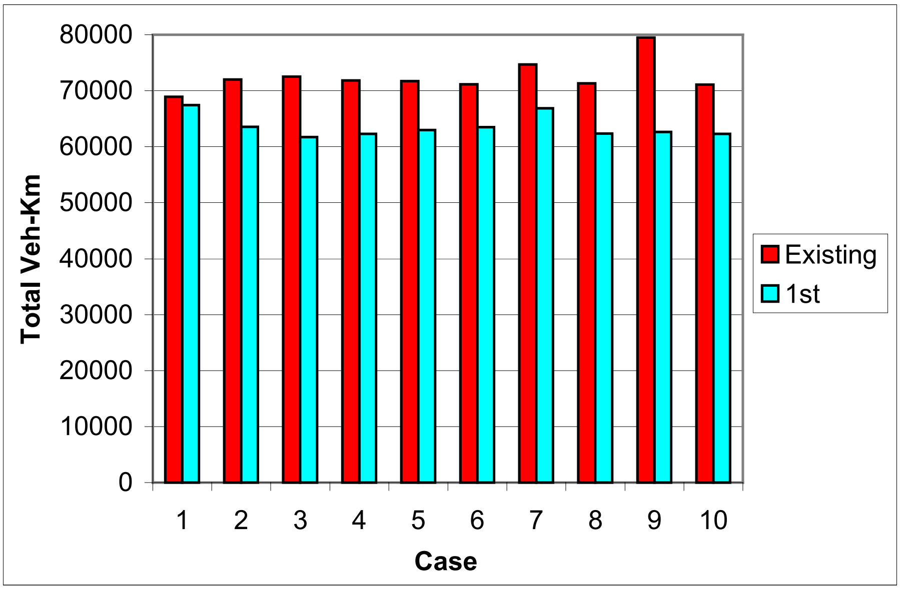

FIGURE 4a Total Vehicle-kilometer Before vs. After Change Policies in Scenario 1.

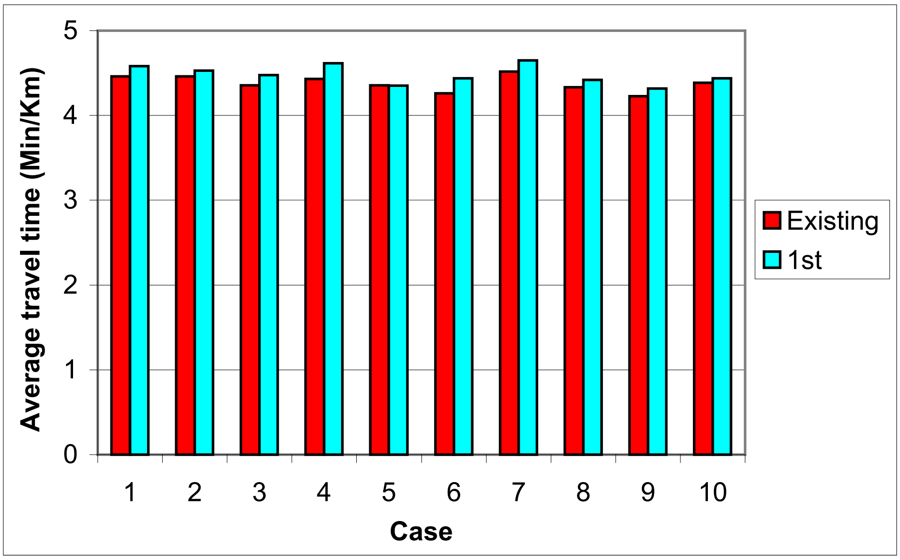

FIGURE 4b Average Travel Time Before vs. After Change Policies in Scenario 1.

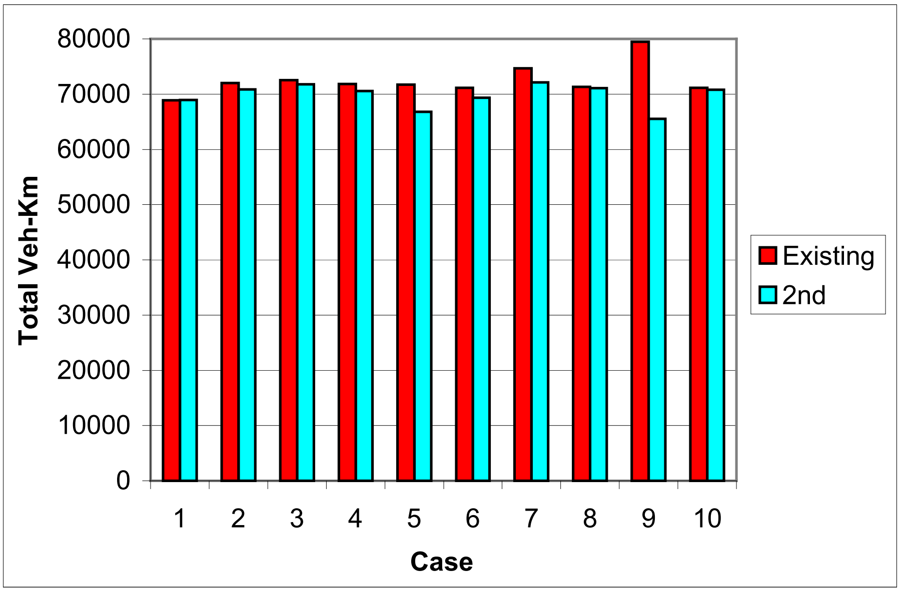

FIGURE 5a Total Vehicle-kilometer Before vs. After Change Policies in Scenario 2.

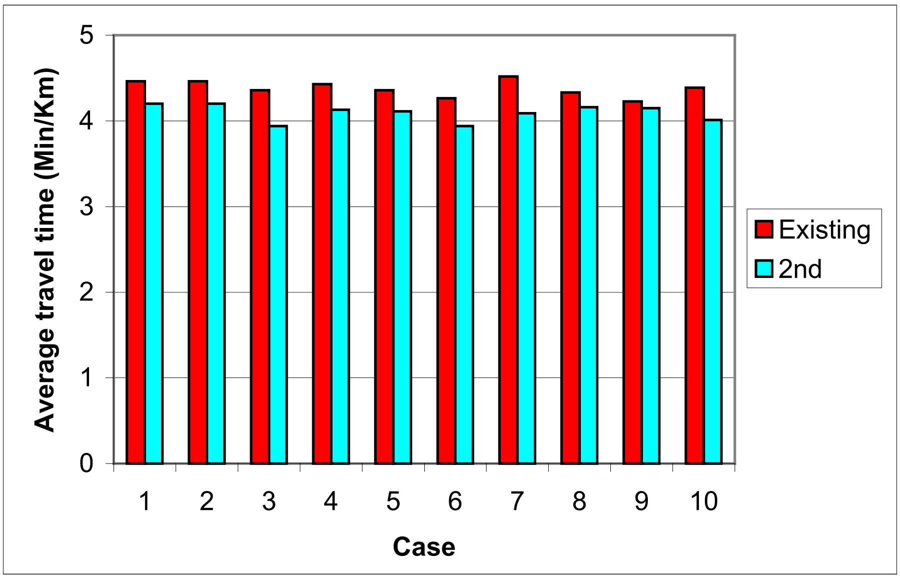

FIGURE 5b Average Travel Time Before vs. After Change Policies in Scenario 2.

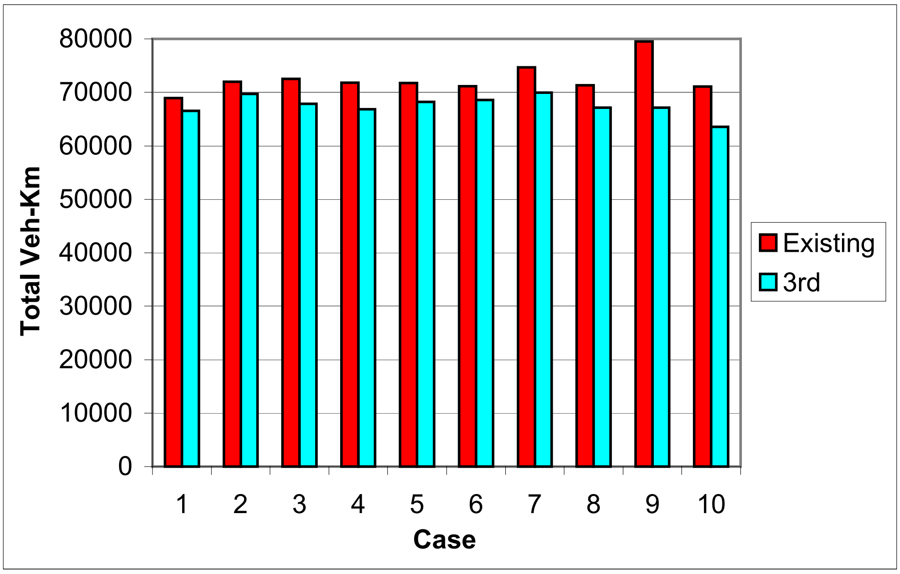

FIGURE 6a Total Vehicle-kilometer Before vs. After Change Policies in Scenario 3.

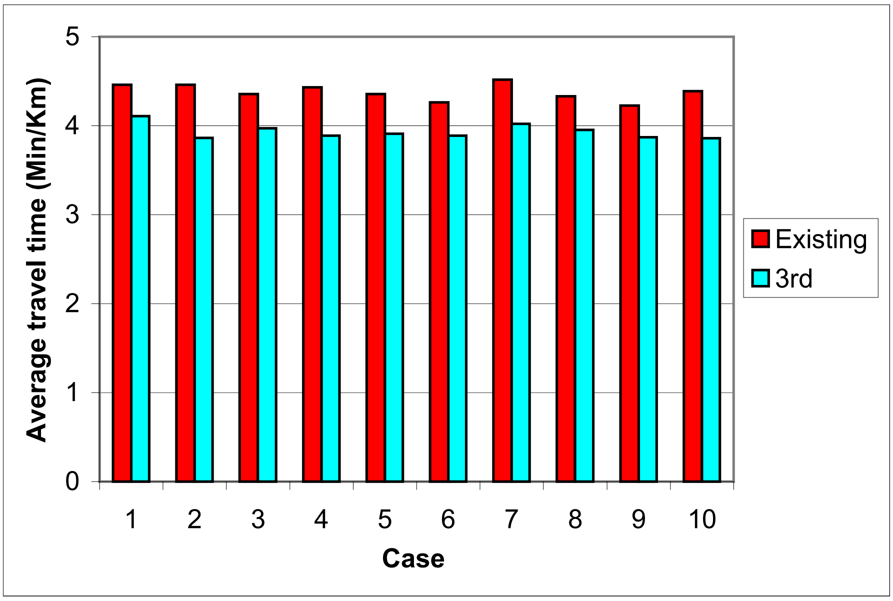

FIGURE 6b Average Travel Time Before vs. After Change Policies in Scenario 3.

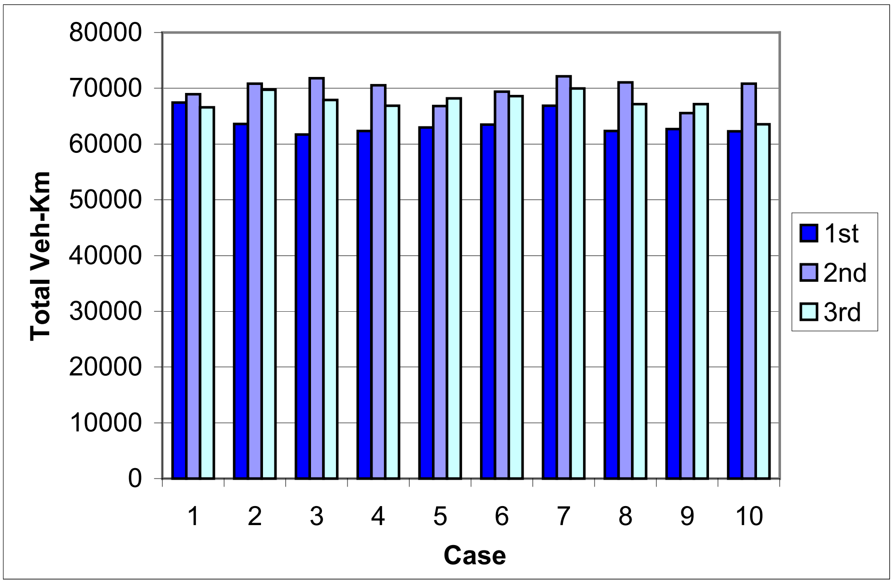

FIGURE 7a Total Vehicle-kilometer Before vs. After Change Policies of Three Scenarios

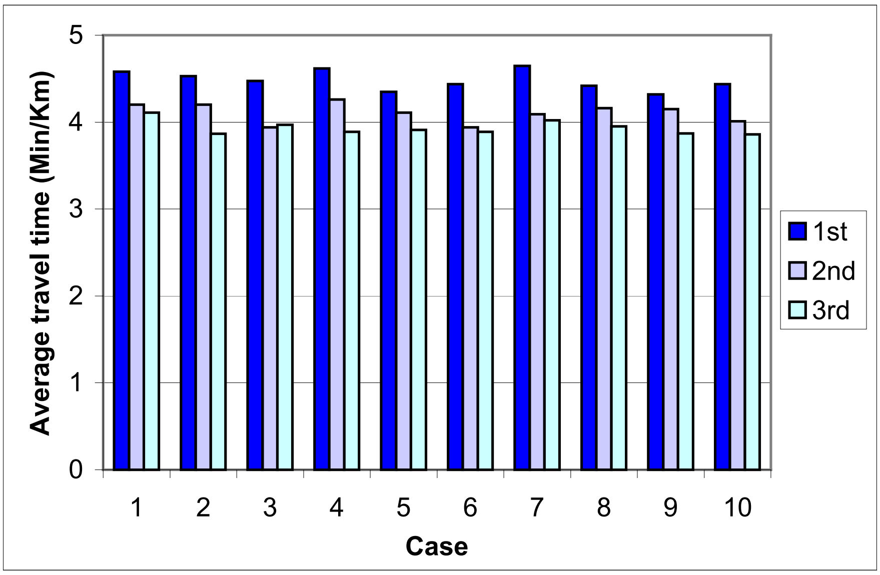

FIGURE 7b Average Travel Time Before vs. After Change Policies of Three Scenarios.

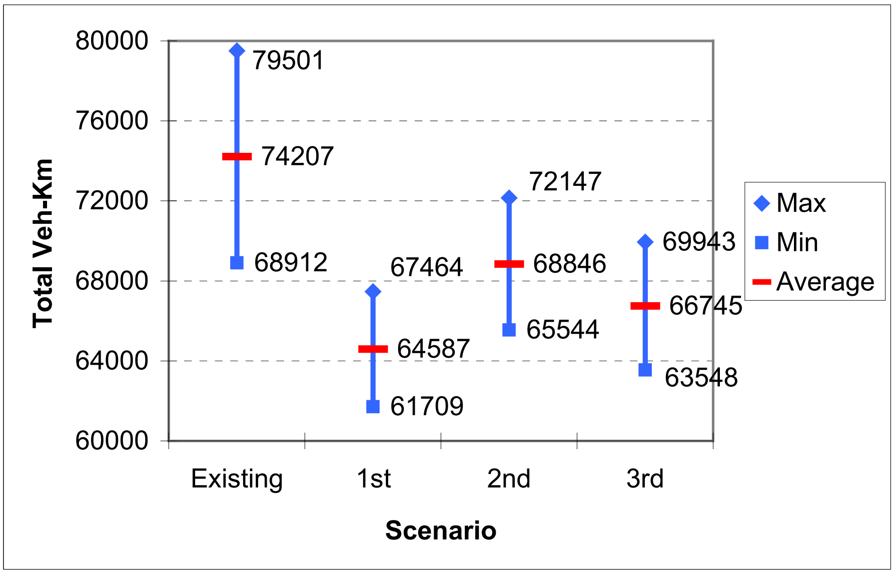

FIGURE 8a Interval of Total Vehicle-kilometer for each scenario.

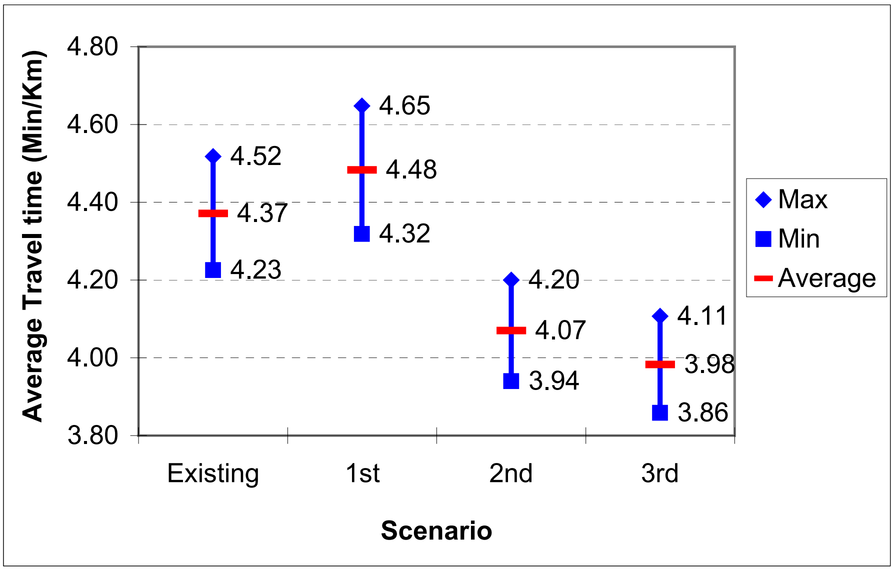

FIGURE 8b Interval of Average Travel Time for each scenario.