Sensitivity of Equilibrium Flows to Changes in Key Transportation Network Parameters

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1 Introduction

In transportation systems, the interaction of supply and demand results in equilibrium flows and traffic assignment models are used to find those equilibrium flows. Wardrop (1952) distinguished between system equilibrium and user equilibrium in two different approaches. In the first approach, traffic is routed over the network to minimise the total travel time. In the second approach, the users choose their path in order to minimize their own travel time.

Using traffic assignment models, one can estimate traffic volumes in all parts of the transportation system. Moreover, using traffic assignment models enables analysts to evaluate the performance of the current traffic system and to evaluate the effects of any change in the transportation system. One of the most important factors in the performance of traffic assignment models is the level of detail used in the representation of transportation system. In order to save time and money, the level of detail of the input data should be proportionate to the accuracy of the model calibration. This is because collecting unnecessary data does not necessarily lead to more accurate results and it just increases the cost. The objective of this study is to enhance understanding of the sensitivity of traffic assignment results to variations in the parameters used to represent the transport system including: travel-time functions, volume-delay functions at intersections and the number of traffic zones. The study investigates the sensitivity to changes in those parameters, using EMME/2 traffic assignment software (Ashtiani et.al, 1999).

In this paper, the previous studies on sensitivity analysis of the equilibrium flows respect to different travel-time functions and traffic zoning methods are reviewed in section 2. A brief summary of the supply and demand information of Shiraz city is presented in section 3. The general procedure of this study and the obtained results are explained in section 4 and finally the main outcomes of this study are concluded in the last section.

2 Literature review

In urban transportation planning, achieving the equilibrium flows requires information on both supply (e.g. street network, public transportation network) and demand. The accuracy of the data directly affects the accuracy of the obtained equilibrium flows. Reviewing the literature, different data and models have been used. However, few investigations have examined on the sensitivity of equilibrium flows respect to key input data. In this section, we review some research which has focused on the sensitivity analysis of equilibrium flows with respect to the cost functions and traffic zoning methods.

Among all different travel-time functions suggested by different studies, BPR and Davidson's functions have more importance since other travel-time functions similar to one of these two functions. Lee et al. (1998) concluded that when traffic volume is close to capacity, the Davidson's function is more efficient in estimating travel times near to the observed travel times. To apply the Davidson's function, it is recommended to estimate the free flows travel time and capacity directly. Since, it is very difficult to find the capacity directly, using the BPR function is more reliable and acceptable (Spiess, 1990). However, in Davidson's function, the traffic volume in each link should be less than the traffic capacity (Akcelik, 1991). This constraint decreases the speed of the traffic assignment algorithms without a considerable change being observed in the accuracy of the results (Akcelik, 1991).

Openshaw (1977) concluded that the traffic zones configuration has a considerable effect on the results of traffic assignment models. In traffic assignment models, only the travels between zones (between zone travels) are considered in the assignment procedure and the travels occurring within zones (within zone travels) are neglected. This results in underestimation of network traffic volumes which has implications for the design of transportation system.

Crevo (1991) investigated the effect of reconfiguration of traffic zones on estimation of the future trip demand. He studied the effects of increasing the number of traffic zones on trip demand estimation. He concluded that increasing the number of traffic zones and therefore decreasing the within zone travels did not have a considerable effect on travel demand prediction. This may be due to the fact that, despite increasing the number of traffic zones and increasing the level of demand detail, the accuracy of supply information did not change proportionally. Crevo applied some methods to determine the dividable traffic zones which Martin (2002) precisely explained the important methods, including the applied methods by Crevo, to select dividable traffic zones.

Ding (1998) considered the effects of different aggregation levels of socio-economic characteristics on the equilibrium flows. He concluded that once the number of traffic zones reaches a threshold, increasing the number of zones produced negligible changes in the equilibrium flows. However, when the number of traffic zones reduces to a specific lower bound, decreasing the number of traffic zones will cause changes in the equilibrium flows.

3 Case Study Network: Shiraz transportation system

To study the sensitivity of the equilibrium flows respect to network specifications, a real transportation system for Shiraz city in Iran was used as it is required to contain the information of a real transportation system. After each modification, the obtained equilibrium flows are compared with the equilibrium flows of the base network.

In this study, the Shiraz city is identified as a region with the radius of 80 kilometres from its centre. The Shiraz region is divided into 189 traffic zones including 156 internal city zones and 33 external city zones (Ashtiani et.al, 1999). It should be noted that to achieve the demand information and the trip rate between traffic zones, different origin-destination surveys for Shiraz city were performed in 1999 and the 189×189 origin-destination demand matrices were obtained for different vehicle types and time intervals (Ashtiani et.al, 1999).

The supply infrastructure in Shiraz transportation network consists of two separate sections: street network and public transport system. In 1999, the street network of Shiraz included 1078 nodes and 1611 links (either one or two directional). These links can be categorized into 4 main categories: access, collector/distributor and ramps, arterial roads type 2, arterial roads type 1 and freeways. In addition to the information about nodes and links, the information of forbidden turns at intersections, signal phasing at signalized intersections and the borders of 189 traffic zones and borders of the CBD was identified (Ashtiani et.al, 1999). Shiraz public transport system included 382 buses and 74 bus lines (Ashtiani et.al, 1999). In this study, the equilibrium flows in the base network is obtained from the assignment results of the observed demand of a morning peak hour in 1999 and the street and bus network of 1999.

4 Sensitivity analysis

In this section, the general approach and underlying assumptions used to investigate the sensitivity of the equilibrium flows respect to modifying the input data are presented. To show the effects of each modification, the equilibrium flows in the base network, in the modified networks and the observed traffic flows are compared.

4.1 Number of traffic zones

An important issue in transportation studies is the number of traffic zones. In practice, reducing the number of traffic zones results in reduction of the dimensions of the problem and ignoring within zone travels. Meanwhile, increasing the number of traffic zones results in more accurate results and increase in the cost of data collection and analysis. Therefore, determining the appropriate number of traffic zones which is proportional to the required accuracy is essential.

4.1.1 Aggregation of Traffic Zones

In this section, the number of traffic zones was reduced and the assignment results were compared with the results of the base network. The number of internal zones in Shiraz was decreased from 156 to 55, which is approximately one-third of the initial number of internal zones in base network. The traffic zones were aggregated based on the important criteria in zoning configuration. Some of these criteria are summarized below:

- The aggregated zones should have similar socio-economic characteristics,
- The area of the aggregated zones should be limited to ensure homogeneity,
- The aggregated zones should have a convex shape, so that the centroid is an appropriate point to represent the zone,
- The aggregated zones should not contain a natural or artificial barrier which would prevent any problem,
- The average of trip production and trip attraction should be similar in order to ensure there are no “unbalanced” zone,
- The boundaries of the initial zone should be protected therefore a traffic zone could not be divided into some new aggregated zones.

The number of external zones was remained constant at 33 zones. Therefore, the total number of traffic zones in Shiraz was reduced from 189 to 88. Having determined the shapes of the new traffic zones, the new traffic zones’ centroids and connecting the new centroids to the transportation network, the demand matrices for the network with aggregated zones were calculated. The trip demand of each new traffic zone was the summation of the trip demand of the initial traffic zones (the zoning systems in the base network and the aggregated network are shown in Figures 1(a) and 1(b)).

Evaluating the results of the traffic assignment model after aggregation of traffic zones showed that the total traversed distance and the total travel time in the network decreased by around 15% and 16% respectively. The average speed in the whole network increased by more than 3% compared to the base network. These effects are expected since of changing some of the between zone travels to within zone travels, reduces the number of trips to be loaded onto the network. The correlation between the observed passenger car equivalent flows and the predicted flows decreased from R^2=0.779 in the base network to R^2=0.657 here. Finally, the linear correlation between predicted traffic flows in aggregated network and the base network was R^2=0.899 for the whole network, 0.478 for access roads, collectors/distributors and ramps, 0.635 for arterials type 2, 0.852 for arterials type 1 and

0.867 for freeways. The most observable changes in the equilibrium traffic flows were for access roads, collectors/distributors and ramps and also arterial roads type 2. This is due to the fact that, the new zone centroids were mainly connected to Arterial types 1 while in the base network, most of the zone centroids were connected to access roads, collectors/distributors and arterial roads type 2.

a) Base Network

b) Aggregated Network

c) Disaggregated Network

d) Aggregation of Traffic Zones Out of the CBD

Figure 1: Different configurations in the zoning system of transportation network of Shiraz.

4.1.2 Disaggregating the Traffic Zones

In this component of the study, the number of traffic zones was increased. Since more details in the central traffic zones leads to more accurate results, 96 zones in the regions 1 to 7 was increased to 182 new traffic zones (approximately twice). The traffic zones were disaggregated based on the following criteria:

- The area of the initial zones should be divided into two almost equal subdivisions,

- The initial traffic zones which had a small area or the belonged to a specific socio-economic characteristics, or the initial traffic zones in which the trip production and trip attraction was through a specific road were not changed,
- The traffic zones should be divided based on the socio-economic characteristics.

In addition, the number of traffic zones related to regions 8 to 15 and 33 external city zones was remained constant. Therefore, the total number of traffic zones in Shiraz city was increased from 189 to 275. Having determined the shapes of the new traffic zones, the new traffic zones' centroids and connecting the new centroids to the transportation network, the demand matrixes for the transportation network with disaggregated zones were calculated. To determine the new demand matrices, it was assumed that the trip demand in the initial zone was divided into two equal subdivisions (the disaggregated network is shown in Figure 1 (c)).

Comparing the results obtained from traffic assignment model in this section and in the base network, the total traversed distance increased by 1%. This is mainly due to the fact that a most of the traffic zones were divided into two traffic zones and therefore the within zone travels in the base network was changed to between zone travels after disaggregation. Disaggregating the number of traffic zones caused a reduction of almost 0.5% in average speed, and an increase of about 2% in total travelled time in the whole network with respect to the base network for the same reason. The correlation between the observed and predicted traffic yielded an R^2 value of 0.773 which is slightly less than R^2 value of 0.779 from the base network. Generally, it is assumed that increasing the number of traffic zones, increases the accuracy of the results and the observed and predicted traffic flows will become closer to each other. However, the results from this section did not show this trend. One reason can be the small number of observation points for collector/distributor and arterial type 2 roads. The linear correlation between predicted traffic flows in disaggregated network and the base network was R^2=0.991 for the whole network, R^2=0.930 for access, collector/distributor and ramps, R^2=0.956 for arterial roads type 2, R^2=0.989 for arterial roads type 1 and R^2=0.991 for freeways.

4.1.3 Aggregation of Traffic Zones Outside of the CBD

The main goal of this section was studying one particular region of the transportation network in which more details were provided, while less information was applied to the rest of network. This section investigated the changes in the equilibrium flows when traffic zones reflected detailed network information in one specific region, while other traffic zones were aggregated with less network information. The Shiraz CBD was selected for the focus of this section since the results of the traffic equilibrium showed that Shiraz CBD has a large proportion of trips productions and trip attractions. The number of traffic zones in the CBD remained constant (30 traffic zones). Going farther from the CBD, the traffic zones were aggregated, and the level of aggregation was proportional to the distance from the CBD. Therefore, the number of traffic zones located out of the CBD was decreased from 126 to 37, and similar to the previous section, 33 external traffic zones remained constant. The total number of traffic zones was decreased from 189, in the base network, to 100 in the new network (this network is shown in Figure 1 (d)).

The results obtained from the traffic assignment in this network showed that the total traversed distance and the total travel time in the CBD reduced considerably, while the average speed increased. The linear correlation between the equilibrium flows obtained from this network and the base network for all types of links within the CBD showed yielded an R^2 of 0.977. This correlation implies an acceptable accuracy in predicting the traffic flows with respect to the level of aggregation of the zones located out of the CBD. Finally, the linear correlation between predicted traffic flows in CBD in this case and the base network yielded an R^2 of 0.963 for access roads, collectors/distributors and ramps, R^2=0.885 for arterials type 2 and R^2=0.991 for arterials type 1.

4.2 Travel-time functions

Travel-time functions are an important input for traffic assignment models. To develop these functions, extensive data collection and model calibration are required (Rose and Raymond, 1992). In this section, the sensitivity of the equilibrium flows respect to reducing the diversity of these travel-time functions is considered.

The general type of the travel-time function utilized in the Shiraz traffic assignment model (Ashtiani et.al, 1999) to predict the travel time of passenger cars is shown in Equation (1).

$$t(v) = t_{\circ}\left[1 + 0.15\left(\frac{v}{Q}\right)^{4}\right] \tag{1}$$

Where:
$t(v)$ = Mean travel time for one kilometre length of the road (minutes),
t_0 = Mean free travel time for one kilometre length of the road (minutes),
v = Traffic volume in one meter width of the road (PC/hour),
Q = Practical capacity for one meter width of the road (PC/hour).

In the base network, 15 different travel-time functions are defined for all types of links in Shiraz network. Different travel-time functions with their relevant parameters are presented in Table 1. In this component of the study, the number of travel-time functions was reduced in two stages. First, for those links that have similar or equal performances, a similar travel-time function was considered. Therefore, the most prevalent link type in each performance category was considered as the representative of all links in that category and its travel-time function was selected for that category. In the first stage, five travel-time functions were defined.

Table (1): Parameters of travel-time functions for links of Shiraz city

<table>
<tr><th rowspan="2">Link Type</th><th colspan="2">Base Network</th><th colspan="2">5 Travel-time Functions</th><th colspan="2">2 Travel-time Functions</th></tr>
<tr><th>Free travel time (t_o) (min/km)</th><th>Practical capacity (Q) (PC/hr/m)</th><th>Free travel time (t_o) (min/km)</th><th>Practical capacity (Q) (PC/hr/m)</th><th>Free travel time (t_o) (min/km)</th><th>Practical capacity (Q) (PC/hr/m)</th></tr>
<tr><td>Accessibility</td><td>1.50</td><td>100</td><td rowspan="3">1.33</td><td rowspan="3">165</td><td rowspan="3">1.33</td><td rowspan="3">165</td></tr>
<tr><td>Collector/Distributor</td><td>1.33</td><td>165</td></tr>
<tr><td>Ramp</td><td>1.50</td><td>150</td></tr>
<tr><td>Arterial type 2 (2 way commercial)</td><td>1.20</td><td>180</td><td rowspan="3">1.20</td><td rowspan="3">190.00</td><td rowspan="12">1.00</td><td rowspan="12">250</td></tr>
<tr><td>Arterial type 2 (non- commercial)</td><td>1.20</td><td>190</td></tr>
<tr><td>Arterial type 2 (2 way commercial with parking space)</td><td>1.10</td><td>210</td></tr>
<tr><td>Arterial type 1 (low width)</td><td>1.00</td><td>210</td><td rowspan="3">1.00</td><td rowspan="3">250</td></tr>
<tr><td>Arterial type 1 (high width)</td><td>1.00</td><td>250</td></tr>
<tr><td>Arterial type 1 (without access)</td><td>1.00</td><td>260</td></tr>
<tr><td>Urban freeway with the length less than 1000 meters</td><td>1.00</td><td>250</td><td rowspan="3">0.75</td><td rowspan="3">300</td></tr>
<tr><td>Urban freeway with the length more than 1000 meters</td><td>0.75</td><td>300</td></tr>
<tr><td>Rural freeway</td><td>0.75</td><td>300</td></tr>
<tr><td>Rural minor road</td><td>1.00</td><td>150</td><td rowspan="3">0.86</td><td rowspan="3">200</td></tr>
<tr><td>Rural major road (2 lanes)</td><td>0.86</td><td>200</td></tr>
<tr><td>Rural major road (4 lanes)</td><td>1.00</td><td>250</td></tr>
</table>

Based on traffic assignment results in the base network, the maximum traversed distance in the network was related to arterials type 1 which solely had the highest traversed distance in all link types. Therefore, in the second stage, arterial type 1 was selected to be representative of all different arterials, freeways and rural roads. Since other road types including access roads, collectors/distributors and ramps are considerably different from the previously mentioned group, these road types were incorporated in another separate group.

Considering the traffic assignment results from the base network and the modified network with five travel-time functions, it was observed that this change caused a reduction of less than 0.5% in total traversed distance and more than 2% in total travel time of the network respectively. Meanwhile, an increase of 2% in mean speed of the network was observed. The linear correlation between observed passenger car equivalent flows and estimated flows in this network was R^2=0.778, which is close to that of the base network (R^2=0.779). Finally, the linear correlation (R^2) between the equilibrium flows in the modified network and the base network was 0.994 showing a negligible difference between estimated traffic flows in the two networks. In addition, R^2 was 0.962 for access roads, collectors/distributors and ramps, 0.987 for arterials type 2, 0.992 for arterials type 1 and 0.988 for freeways.

The comparison of assignment results from the base network and the network with two travel-time functions showed that selecting two travel-time functions for the entire network resulted in a 1% increase in the total traversed distance, a 4% increase in the average speed of the whole network and a 4% decrease in the total travel time. This is mainly due to the fact that freeways in the Shiraz transportation network have a small proportion of different road types. Therefore, considering the travel time function of arterial roads type 1 for freeways and arterials type 1 and 2 had a major effect on arterial roads type 2 and increased the capacity of this type of road and decreased the travel time in this road type. The linear correlation between the observed passenger car equivalent volume and estimated volume in this case showed better correlation (R^2=0.780) than that of the base network (R^2=0.779). However, the linear correlation between the equilibrium flows after the modification before was R^2=0.974. This shows a considerable difference in the estimated traffic flows of the base network and the network with two travel-time functions. Furthermore, R^2 was 0.911 for access roads, collectors/distributors and ramps, 0.941 for arterials type 2, 0.970 for arterials type 1 and 0.972 for freeways.

4.3 Volume-delay functions

In transportation networks, delay at intersections constitute a major part of travel time. Therefore, accurate estimation of delay at intersections is an important issue in flow modelling. Here we consider the effect of using simpler volume-delay functions in traffic assignment models on the equilibrium flows.

4.3.1 Volume-delay Functions at Signalized Intersections

In Shiraz traffic assignment model (Ashtiani et.al, 1999) the applied model used to estimate the delay at signalized intersections is as follow:

$$d_1(v) = \frac{(c-g)^2}{2c\left(1-\frac{v}{s}\right)} + 43\left(\frac{v}{\left(\frac{g}{c}\right)s}\right)^4 + 5 \qquad (2)$$

Where:

$d_1(v)$ = Average delay to pass the intersection from specific entrance (seconds),

v = Traffic volume in each specific entrance of the intersection for one meter width of the road (PC/hour),

$s =$ Saturation flow rate (passenger car per green hour for one meter width of the road; s=600),
$g =$ The green time for each specific entrance (seconds),
$c =$ The cycle length in the intersection (seconds).

In HCM (2000), the delay function for signalized intersections constitutes three components: uniform delay, stochastic delay and oversaturated delay. Uniform delay refers to occasions when the entrance traffic flow rate is considered to be constant. This delay is defined as follow:

$$d_U = \frac{0.5C\left[1-(\frac{g}{C})\right]^2}{\left[1-(\frac{g}{C})\min(x,1.0)\right]} \tag{3}$$

Where:
$d_U =$ Uniform delay (seconds),
$x =$ Saturation degree (ratio of traffic volume to capacity).

The uniform delay is the first component of Equation (2) which has been applied in the Shiraz traffic assignment model. Since, in the uniform delay model there are no parameters to estimate, it is not necessary to have any traffic volume survey or data collection to develop this function. In this section, utilizing the uniform delay as the delay function at signalized intersections and monitoring its effect on equilibrium traffic flows is considered.

Utilizing the uniform delay as the delay function at signalized intersections, increased the average speed of the network by 3% and decreased the network travel time by 4%. In addition, a very small (less than 0.5%) decrease in the network traversed distance was observed compared to the base network. In this situation, the delay at signalized intersections decreased by more than 19% and this reduction was mainly for the links with traffic flows near the saturation flow rate. It should be mentioned more than 50% of the links which are jointed to signalized intersections are arterial roads type 1. Therefore, the new definition of signalized intersections causes increase in the traffic volume on arterials type1. The linear correlation between the observed traffic flows and the estimated traffic flows, (R^2=0.776) showed relatively small changes in the equilibrium flows compared to the base network (R^2=0.779). Finally, the correlation between the equilibrium flows in this case and the base network was R^2=0.989, implying relatively little difference. This correlation equalled 0.971 for access roads, collectors/distributors and ramps, 0.975 for arterials type 2, 0.973 for arterials type 1 and 0.985 for freeways.

4.3.2 Volume-delay Functions at Unsignalized Intersections

In the Shiraz traffic assignment model (Ashtiani et.al, 1999) the model used to estimate delay at unsignalized intersections is shown in Equation (4):

$$d_2(v) = d_\circ\left[2.5 + 2(\frac{v}{Q})^2\right] \tag{4}$$

In which, $d_\circ$ (seconds) is the constant coefficient of delay at unsignalized intersections for each entrance.

Considering the fact that collection and analysis of data to develop such functions is difficult, in most of the comprehensive transportation studies, delay at unsignalized intersections is either ignored or assumed constant. In this section, a constant amount was considered as the delay at unsignalized intersections and the consequent effect on equilibrium traffic flows was investigated in two separate stages. In the first stage, the delay at unsignalized intersections was assumed to be zero. In the second stage, a constant amount was considered as the delay at unsignalized intersections.

To find the best amount of delay at unsignalized intersections, a constant amount was considered as the delay at unsignalized intersections. Having obtained the results of traffic assignment model, the total delay at intersections in Shiraz city was compared with the total delay at intersections in the base network. This procedure was repeated several times and a constant amount by which the total delay at intersections was nearest to the total delay at intersections in the base network was selected. The magnitude of this constant amount for the Shiraz transportation network was 5.7 seconds.

The obtained results from traffic assignment model showed that when no delay was considered at unsignalized intersections, the total traversed distance in the network increased by less than 0.2%, the average speed increased by almost 16% and the total travelled time decreased by around 14% compared to the base network. At this stage, the significant changes were observed for access roads, collectors/distributors, ramps and arterials type 2 due to the fact that most of the intersections in these road types were unsignalized intersections. Considering no delay at unsignalized intersections improves the performance of access roads, collectors/distributors, ramps and arterials type 2. Inversely, by imposing a constant delay of 5.7 seconds at unsignalized intersections resulted in the total traversed distance in the network decreased by less than 1%. The average speed of the network decreased by around 1% and the total travelled distance increased by less than 0.6%. Considering 5.7 seconds as the delay at unsignalized intersections, reduces the performance of freeways (in merging and diverging sections) and arterials type 1 since 5.7 seconds is a considerable delay and the vehicles travelling in freeways and arterial types 1 rarely experience this amount of delay at unsignalized intersections. The linear correlation between the observed flow and the estimated flow when delay was zero yielded an R^2 value of 0.751 while was less than that of the base network (R^2=0.779). Considering a delay of 5.7 seconds at unsignalized intersections, the linear correlation between the observed traffic flow and the estimated traffic flows reduced further to R^2=0.718.

Finally, in the case of no delay, the correlation between the estimated traffic flows in this case and the base network was R^2=0.967 for the whole network, 0.855 for access roads, collectors/distributors and ramps, 0.911 for arterials type 2, 0.948 for arterials type 1 and 0.901 for freeways. Considering 5.7 seconds as the delay at unsignalized intersections, the correlation between the estimated traffic flows in this case and the base network was R^2=0.951 for the whole network, 0.851 for access roads, collectors/distributors and ramps, 0.932 for arterials type 2, 0.957 for arterials type 1 and 0.865 for freeways.

5 Summary of Conclusions

In this study the effects of changes in the level of details of some important attributes of the transportation network was investigated and evaluated, using EMME/2 traffic assignment software. Achieving an accurate estimation of traffic flows is important in the evaluation of a transportation system. However, increasing the level of detail required for of input data increases the cost of data gathering. Therefore, the level of detail in transportation system is very important in order to obtain desirable accuracy in the minimum time and with the minimum cost. The effect of each of the changes examined in this study is summarized in Table 2. This table presents the changes in the equilibrium flows in the form of linear correlation between observed and predicted traffic flows and also linear correlation between predicted flows in the base network and modified networks.

Table 2: The effects of different modifications on the estimated flows in terms of (R^2)

Different Networks	Observed Flows & Estimated Flows	Estimated Traffic Flows in the Base Network and Modified Networks				
		Access, Collectors/ Distributors, Ramps	Arterials type 2	Arterials type 1	Freeways	The whole Shiraz Network
Base Network	0.779	-	-	-	-	-
5 Travel Time Functions	0.778	0.962	0.987	0.992	0.988	0.994
2 Travel Time Functions	0.780	0.911	0.941	0.970	0.972	0.974
Uniform Delay at Signalized Intersections	0.776	0.971	0.975	0.973	0.985	0.998
No Delay at Unsignalized Intersections	0.751	0.855	0.911	0.948	0.901	0.967
5.7 sec. Delay at Unsignalized Intersections	0.781	0.851	0.932	0.957	0.865	0.951
Aggregation of Traffic Zones	0.657	0.478	0.635	0.852	0.867	0.899
Disaggregating the Traffic Zones	0.773	0.930	0.956	0.989	0.991	0.991
Aggregation of traffic zones out of the CBD (Links in the CBD)	-	0.963	0.885	0.991	-	0.977

In conclusion, when the transportation studies are concentrated on a specific region, the detailed transportation data are used for that region. However, the aggregated information can be used for the rest of transportation network in order to get acceptable results. To estimate the travel time in network links, it is acceptable to use one travel time function for each main type of the road. To estimate the delay at signalized intersections, using the uniform delay function, simplifies the transportation studies and results in accurate equilibrium flows.

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7 References

Akcelik, R. (1991) Travel Time Functions for Transport Planning Purposes: Davidson's Function, It's Time-Dependant form and An Alternative Travel Time Function *Australian Road Research 21 (3), pp. 49-59.*

Crevo C. C. (1991) Impacts of Zonal Reconfigurations on Travel Demand Forecasts, *Transportation Research Record, 1305, pp.72-80.*

Ding, C. (1998) The GIS-Based Human Interactive TAZ Design Algorithm: Examining The Impacts of Data Aggregation on Transportation Planning Analysis *Environment & Planning B: Planning and design, Vol 25, 601-616.*

Lee, C. H. and J. W. Kim (1998) The Equilibrium Trip Assignment with Variation of Traffic Flow-Travel time Relationship, *Department of Urban Planning & Engineering, Yonsei University, Korea.*

Martin, D. (2002), Developing the Automated Zoning Procedure to Reconcile Incompatible Zoning Systems, *Department of Geography, University of Southampton, UK.*

Spiess, H. (1990) Conical Volume-Delay Functions, *Transportation Science, vol 24, No.2, pp. 122-131.*

Openshaw, S. (1977) Optimal Zoning Systems for Spatial Interaction Models *Environment and Planning A, vol 9, pp. 169-184*.

Rose, G. and Raymond, M. (1992) Simulated Estimation of Davidson's Travel Time Function, *Transportation Planning and Technology*, Vol. 18, No. 2, pp. 89-96.

Traffic assignment model and the performance of the transportation system in Shiraz city (1999), Report no.79-17, *The Institute for Transportation Studies and Research of Sharif University of Technology.*

The region of the transportation studies and the zoning system of Shiraz city (1999) Report no.79-01, *The Institute for Transportation Studies and Research of Sharif University of Technology.*

The public transport system of Shiraz city (1999) Report no.79-11, *The Institute for Transportation Studies and Research of Sharif University of Technology.*

The street network of Shiraz city (1999), Report no.79-06, *The Institute for Transportation Studies and Research of Sharif University of Technology*.

Travel time functions for Shiraz city (1999) Report no.79-07, *The Institute for Transportation Studies and Research of Sharif University of Technology.*

US Transportation research Board (2000) Highway Capacity Manual, *TRB Report 209, Washington D.C.*

Wardrop, J.G. (1952), Some theoretical aspects of road traffic research, *Proceedings of The Institution of Civil Engineers*, Part II, 1, pp. 325-378.