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CHARACTERIZATION OF TRAFFIC PATTERNS IN URBAN AREAS -KUWAIT MODEL AS A CASE STUDY

Waleed Al Haidar[1] , Ahmed Al Hakim[2] and Hozayen Hozayen[3]
[1]Head of Engraining Traffic Division Kuwait
[2] Traffic Eng. & Transportation Planning, Al Azhar University
[3] Highway Eng., Cairo University

ملخص

يهدف هذا البحث إلى إعداد طريقة منهجية قابلة للتطبيق العملي تتضمن دمج نماذج التخصيص ونماذج التأخيرات المتولدة عند التقاطعات في نموذج عملي واحد. لتحقيق هذا الغرض تم دمج النماذج الرياضية المتاحة بدليل سعة الطرق الأمريكية HCM 2010 مع برنامج VISUM المستخدم في تخصيص الرحلات على شبكات الطرق ، وذلك لإمكانية أخذ التأخيرات عند التقاطعات في الاعتبار. ولاختبار مدى فاعلية المنهجية المقترحة فقد تم تطبيقها عن طريق تخصيص مصفوفة رحلات حالية (سنة الأساس) على جزء من شبكة طرق بمدينة الكويت. وتم افتراض أربع تصورات مختلفة لحجم الطلب على النقل فى المستقبل لحالات متنوعة. وقد أظهرت النتائج أنه عند استخدام المنهجية المقترحة تختلف النتائج عن مثيلاتها في نماذج التخصيص التقليدية بدون إدماج أزمنة التأخيرات، بنسب تصل إلى 4%، 6%، 9%، 13% للتصور الأول، الثاني، الثالث والرابع على الترتيب. وفى النهاية يوصى الباحث بضرورة تطبيق المنهجية المقترحة على عدد أكبر من الشبكات ذات الخصائص والأحجام المختلفة، وذلك من أجل الوصول إلى مقاييس يمكن تعميمها لمساعدة مخططي النقل في الحصول على نتائج أكثر دقة في عملية التخصيص ومن ثم زيادة دقة عملية تخطيط النقل بصفة عامة.

ABSTRACT

Combining traffic assignment models and intersection delay functions into a single modeling framework could provide reliable representation of the travel times and route choices and accordingly improve the overall transportation planning process. This paper examines a proposed methodology for combining the traffic assignment models with intersection delay functions on realistic network in interaction with varying levels of congestion. For this aim the well-known HCM 2010 Formulas are used in order to calculate the delays for each turn movements. In addition, a commercial computer-aided transport planning called "VISUM" established at the PTV System Software and Constructing Gmbh Karlsruhe-Germany is used. To facilitate the calculations, an interactive computer program is developed. The proposed methodology is applied on the entire road network of Kuwait City Cente which is part of the city of Kuwait. As a consequence of the applied method, the accuracy of the List area model was raised significantly. The proposed methodology which includes the intersection delay models showed improvements of about 4%, 6%, 9% and 13% in comparison with the traditional traffic assignment methods. Further efforts should be directed toward implementing the modeling framework presented in this paper on larger and more realistic networks.

Key Words : Traffic, Signal, Model, Model Split, Delay, Transport Demand, Actuated Traffic Signals, Traffic Assignment, Reliability.

1. INTRODUCTION

Traditionally, traffic assignment procedures consider that link delay functions are the essential elements when traffic assignment on network at a macroscopic level is carried out. By using these functions, the travel time on each link can be estimated and therefore the shortest path could be selected. The delays at intersections are always treated as constant turn penalties for each movement and are used usually in order to calibrate and validate the model. However, in most urban areas where intersections cause different delays in response to traffic volume variations from node to node, their impacts can change the travel time and the route choice.

For the application of urban transportation planning, in the base year scenario, the traffic planner depends on perceiving whether the assuming values penalties at intersections cause assignment of appropriate volumes or not. However, these adjusted values of turn penalties may not have any meaning for the assignment in the forecast situation, and as a result may not provide a real representation of the travel times and traffic volumes in the future scenarios. Consequently, the future development and management of the transportation systems, which mainly depend on the analysis of the output data from the traffic assignment models, may not guide the transportation system toward a desired direction.

Combining traffic assignment models and intersection delay functions (CTAID) into a single modeling framework could provide reliable representation of the travel times and route choices under different alternative scenarios in the future and accordingly improve the overall transportation planning process.

2. COMBINING TRAFFIC ASSIGNMENT MODELS AND INTERSECTION DELAY FUNCTIONS

Research in the area of CTAID was firstly pointed out by Allsop (1974) [1] who maintained that the traffic planners must take into consideration the impact of the signal settings on the traffic assignment.

In numerous papers, Smith provided some mathematical fundamentals in the area of CTAID. Smith (1979) [2] discussed conditions which guarantee the interaction between signal control polices and the users' route choice decisions. Simith (1981) [3] developed a new signal setting policy, named Po, which aims at maximising the travel capacity of a network and need only to information about link flow in order to determine the signal timings. He tested this policy against two standard polices (Webster’s Method and delay minimisation method) on four networks using the assignment model Saturn and concluded that this strategy will only be useful for the application of congested networks.

Allsop and Charlesworth (1977) [4] developed a new method that can solve the problem of CTAID through an iterative procedure in which the signal optimization sub-problem is solved using the well known TRANSYT software. They carried out numerical tests on a simple network.

Sheffi and Powell (1983) [5] reviewed the shortcomings of the iterative procedures which set signal timings at each intersection to minimize delay and suggested a new solution algorithm for overcoming these shortcomings. This algorithm can only be used for small networks and used to quantify the errors in the simpler approach. Gartner and Al-Malik (2008) [6] presented a procedure for combining traffic assignment with Webster's and HCM delay models in which they considered a network with two-phases pre-timed signal control at all intersections with two approaches. Menguzzer (2011) [7] defined a methodological framework for the evaluation of the performance of various traffic-responsive signal control strategies in interaction with different levels of user information. She carried out several computational experiments on a small, contrived network and used realistic intersection delay functions, in order to test the behavior of the model under a wide range of conditions. Nielsen et al. (1998) [8] described a model where turn delays have been included in the solution algorithm of Stochastic User Equilibrium (SUE) traffic assignment. His model is a probit-model where the cost-functions of the links are traffic dependent. Hereby, overlapping routes are handled in a consistent way. The main conclusion of this review is that, most studies over the last three decades investigated and developed mathematical formulations and algorithms for solving the CTAID problem from the theoretical point of view and on non-realistic networks. In addition, the aim of most studies was the optimization of networks performance in the short term rather than enhancing assignment models for the aim of improving the future development. It seems that there is significant lack of the applications on real world networks that are needed in order to promote the predictive power and policy relevance of urban traffic assignment models in the long term.

3. MODEL DEVELOPMENT

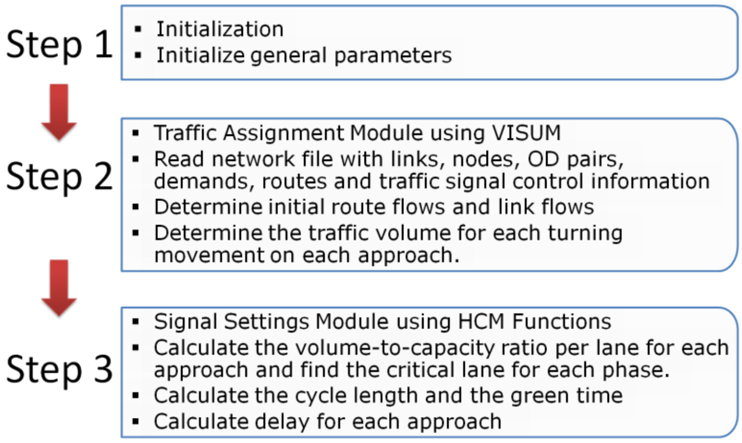
The traditional traffic assignment models depend mainly on the link-based delay functions which ignore intersection settings. One approach is to use the traditional algorithm and to expand simple nodes to represent all intersections in which each possible turning movement is coded as a dummy link, thus allowing different delays to be associated with different maneuvers. Good software provides efficient ways of automatically expanding junction representations and banning or penalizing movements; alternatively, this must be done by hand in the network-building stage itself [9]. In either case, it is likely that the traffic planners adjust turn penalties for each movement only in the calibration and validation phases. However, since the main objective of the traffic assignment models is to develop information data about traffic behavior in the future situations, these turn penalties may not at all provide a good representation for the traffic behavior in the forecast situations.

Using models which combined the traffic assignment and intersection delay functions into a single modeling framework may provide reliable representation of the travel times and route choices under different alternative scenarios in the future and accordingly improve the overall transportation planning process. For this aim the well-known HCM 2000 Formulas [10] are used in order to calculate the optimal cycle length and green time splits for each intersection during each time interval as well as to calculate the delays for each turn movements.

For the aim of modeling the traffic on the network, a computer-aided transport planning, called VISUM [11], is used. VISUM is developed by the PTV System Software and Constructing Gmbh Karlsruhe-Germany. VISUM is a PC-based program using MS Windows and offers data and image exchange in the Windows environment via clipboard or interfaces to industry standard formats. VISUM is a comprehensive, flexible software system for transportation planning, travel demand modeling and network data management. Designed for multimodal analysis, VISUM integrates all relevant modes of transportation into one consistent network model.

VISUM provides assignment procedures and 4-stage modeling routines to meet the requirements of all the different modes. VISUM can build conventional four-step models, as well as provide many specialized methods for the advanced user. In addition, VISUM has an open object-oriented concept that enables users to program their own applications using Visual Basic or the programming language of their choice. It supports planners to analyze and to evaluate network modifications.

The proposed methodology is based on running an assignment problem with ignore signal settings, obtaining a set of link flows and then calculate the signal settings for these new flows. This process should be repeated with the signal settings, obtaining in turn new flows, with the hope that these iterations will converge to a stable and self-consistent solution. For this aim, the following algorithm shown in Figure 1 is used.



Step 1
- Initialization
- Initialize general parameters

Step 2
- Traffic Assignment Module using VISUM
- Read network file with links, nodes, OD pairs, demands, routes and traffic signal control information
- Determine initial route flows and link flows
- Determine the traffic volume for each turning movement on each approach.

Step 3
- Signal Settings Module using HCM Functions
- Calculate the volume-to-capacity ratio per lane for each approach and find the critical lane for each phase.
- Calculate the cycle length and the green time
- Calculate delay for each approach

Fig. 1: Proposed Algorithm

In the framework of this research a script system is developed to estimate the delays at each intersection according to the output of the assignment model. The script file is written and impeded in VISUM software. The main advantage of this system that it is simple to run and can be applied to any network as long as the input data can be provided.

The script file is defined in the intersection data from the network coded by VISUM (number of arms, capacities, traffic volumes and number of phases), then read the updating Signal Settings by VISUM, after that the output is divided into two stages. The first stage is signal setting calculations (cycle length and green time for each movement) for each intersection according to its input data. The second stage is the delay calculations for each movement at each intersection.

4. CASE STUDY

4.1 Study Area and traffic Survey

Figure 2 shows the location of the study area in the heart of Kuwait city. A comprehensive traffic survey program was undertaken to achieve the aim of this study common quantitative data collected include field measurements for traffic volumes and Signalized Setting. The traffic data consisted of Turning Movement Counts (TMC) at the major intersections. This survey was conducted during the month of April, 2014. Traffic Survey locations are illustrated in Figure 2.

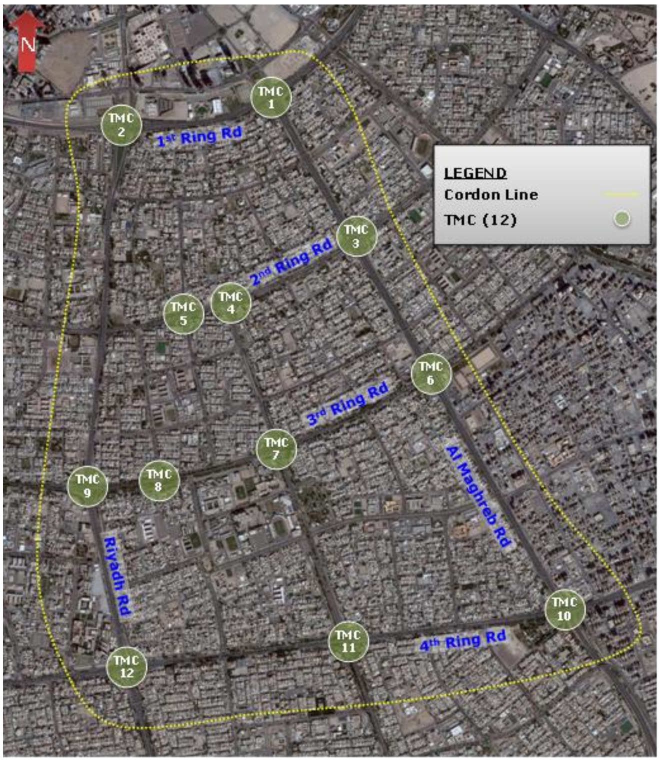


Figure 2: Study Area and Traffic Survey Locations

4.2 Results of Traffic Surevy

Figure 3 illustrates the daily traffic volume for all sites. Wednesday record the highest traffic volume while the lowest traffic volume occurred in Friday. **Figure 4** illustrates the 24-hour traffic volumes for a typical working day for all TMCs locations. The figure shows that the 24-hour traffic pattern has a typical traffic pattern for urban areas with two significant peak periods. These two peak periods are:

- Morning Peak (from 07:00 to 08:00)
- Evening Peak (from 19:30 to 20:30)

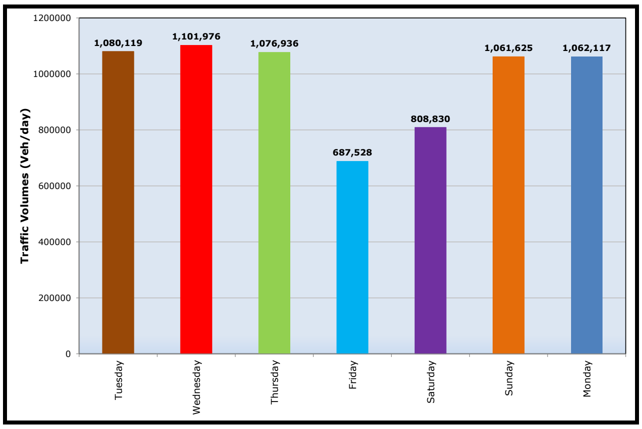


Figure 3: Weekdays Traffic Volumes

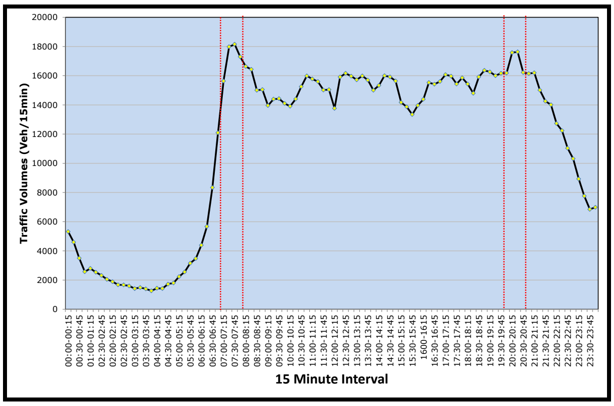


Figure 4: Typical Working Day Traffic Pattern

Normally, the level of Service (LOS) for signalized junctions is defined in terms of delay, which is a measure of driver discomfort and frustration, fuel consumption and increased travel time. **Figure 5** shows the location of study intersections. The analysis of the twelve junctions (J1, J2, J3, J4, J5, J6, J7, J8, J9, J10, J11, J12), have been performed using Synchro software to examine the delays and the operational level of service during the peak hours in base year.

Figure 5: Location of Study intersections

Table 1 below shows the results of analyzing intersections for all TMCs locations. It can be seen that J4, J6, J7, J9, J10 and J11 are operated at unacceptable LOSs “F” during the AM and PM peak hours with high delay values. J1, J2, J3, J5, J8 and J12 are operated at acceptable LOSs “C” or “D” during the AM and PM peak hours.

Table 3.1: LOS Results for Signalized Intersections

No.	Type of Control	Peak Period	Delays (Sec/Veh)	LOS
J1	Signalized Intersection	AM	30.2	C
		PM	29.5	C
J2	Signalized Intersection	AM	30.9	C
		PM	18.4	B
J3	Signalized Intersection	AM	49.9	D
		PM	42.7	D
J4	Signalized Intersection	AM	130.8	F
		PM	117.1	F
J5	Signalized Intersection	AM	19.7	B
		PM	37.3	D
J6	Signalized Intersection	AM	167.25	F
		PM	193.6	F
J7	Signalized Intersection	AM	50.3	D
		PM	72.3	E
J8	Signalized Intersection	AM	21.9	D
		PM	17.8	B
J9	Signalized Intersection	AM	104.2	F
		PM	134.3	F
J10	Signalized Intersection	AM	68.9	E
		PM	56.9	E
J11	Signalized Intersection	AM	198.3	F
		PM	178.7	F
J12	Signalized Intersection	AM	39.2	D
		PM	20.65	C

4.3 Sub-Traffic Model Calibration and Validation

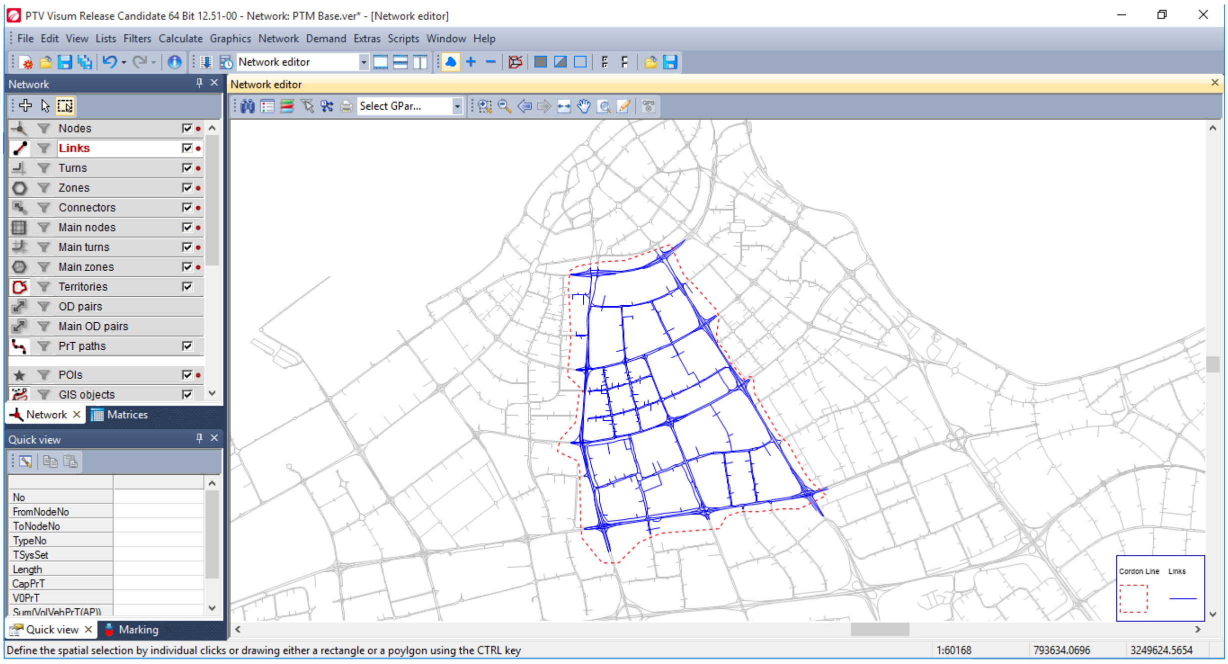
The proposed sub-are model in the base year is developed as shown in **Figure 6** by cordoning this area from the strategic transport model using the sub area generator module in VISUM.

Trip matrices during AM and PM peaks are updated using matrix estimation techniques within “Fuzzy Procedures”, a VISUM software module. This process requires input made up of three elements: a prior matrix, a new set of link traffic count data, and a representation of the area road network. The prior matrix is normally a previously determined and reasonably reliable trip matrix, i.e., formerly validated or containing a high proportion of observed movements.

The set of recent traffic counts are used in order to estimate, by a process consisting of:

- Mention two peak known volumes at count locations in link attributes;
- Estimate OD matrix using the 2014 network which includes traffic counts and 2009 trip matrix;
- Assignment of estimated OD matrix to the 2014 network;
- Comparison of modeled flows to known link flows to know the convergence.

The results of the basic calibration of TMC counts are shown in **Figures 7 and 8** for AM and PM peak periods respectively. In broad terms, the traffic model appears to perform well with the traffic counts showing regression coefficients at 97% and 98% for AM and PM peak periods respectively. The Root Mean Square Error (RMSE) values were also observed to be well within the acceptable range for all the peak period models. The RMSE percentages for all the calibrated TMC were found to be 11 and 10 for AM and PM respectively peak models.



Define the spatial selection by individual clicks or drawing either a rectangle or a poylgon using the CTRL key

Figure 6: Proposed Sub-Model Coverage Area

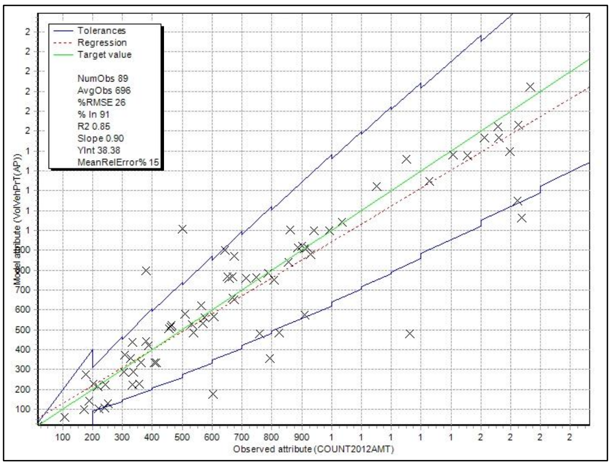


Figure 7: Observed Traffic Counts versus Assigned Turning Volumes for AM Peak Hour (Calibration Results)

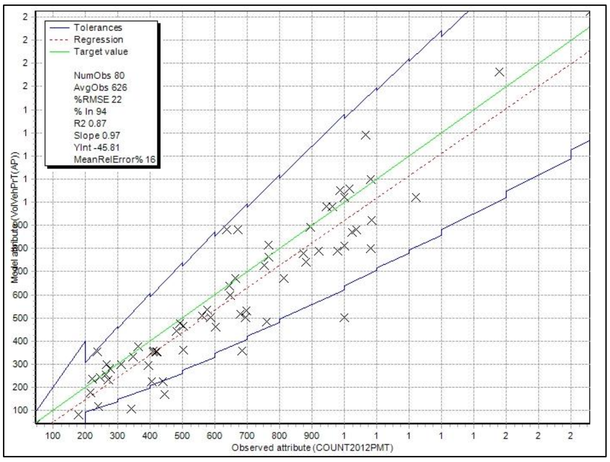
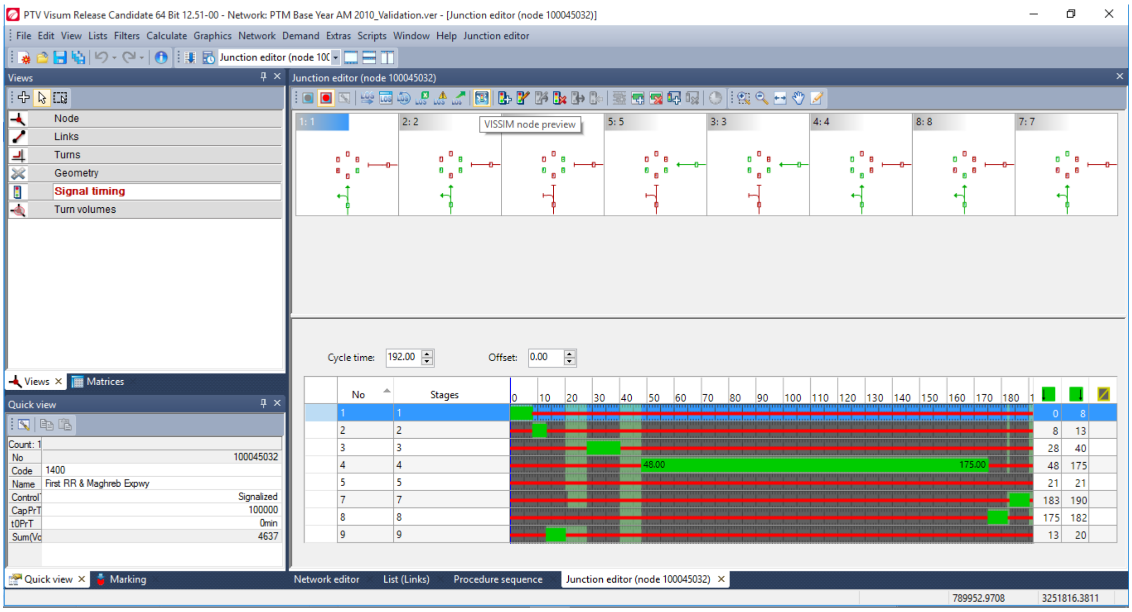


Figure 8: Observed Traffic Counts versus Assigned Turning Volumes for PM Peak Hour (Calibration Results)

4.4 Defining Delay Functions for Signalized Intersections in VISUM

Signalized intersections can be modeled in VISUM either using the built-in fixed-time control or an optional external signal state generator. In VISUM every signal controller (SC) is represented by its individual SC number and signal phase. Signal indications are typically updated at the end of each assignment. Signal control and signal groups are to be modeled from Signal Control window as shown in **Figure 9**.



Count: 1

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Code	1400
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Control	Signalized
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No	Stages	🟩	🟩
1	1	0	8
2	2	8	13
3	3	28	40
4	4	48	175
5	5	21	21
7	7	183	190
8	8	175	182
9	9	13	20

Figure 9: Signal Setting in VISUM

4.5 Comparison between with and without intersection delay Cases

For the aim of examining the proposed methodology under different travel demand situations (various OD demands), different levels of congestion are used. The congestion level is defined in this study as the ratio of the number of trips made by vehicles relative to the same number in 2014. Different congestion levels (1.5, 2.0, 2.5 and 3.0) are assumed and used in order to satisfy different forecast situations. The maximum congestion level 3 is found to be suitable since the higher congestion levels produce unrealistic oversaturated traffic conditions.

For the selected network, traffic assignments are performed for all congestion levels under the traditional traffic assignment approach (without intersection delay functions) as well as the proposed methodology (with intersection delay functions). As the overall analysis results were very comprehensive, only the assigned traffic volumes are selected as a criterion for comparison which mainly affects the calculation of the transportation situation in the long term. Estimated traffic volumes using the proposed methodology (with intersection delay functions) are compared against estimated traffic volumes using the traditional method (without intersection delay functions). **Figures 10** and **11** show the coefficient of determination (R2) between the assigned traffic volumes using the two methods for all congestion levels. The results indicate that the proposed methodology resulted in some improvement over the traditional traffic assignment in the traffic volumes for all cases. For the example studied, the proposed methodology showed improvements of about 20% in comparison with the traditional traffic assignment method for the congestion level 3, whereas at congestion level 1.5, 2 and 2.5 the proposed methodology shows improvements of about 9%, 13% and 16% respectively. Thus, the improvement is increased with the increase of the congestion level. This is due the fact that in the case of the traditional method the difference between the assumed turn penalties in the base year (congestion level = 1) and the actual intersection delays grows significantly as the congestion level increase.

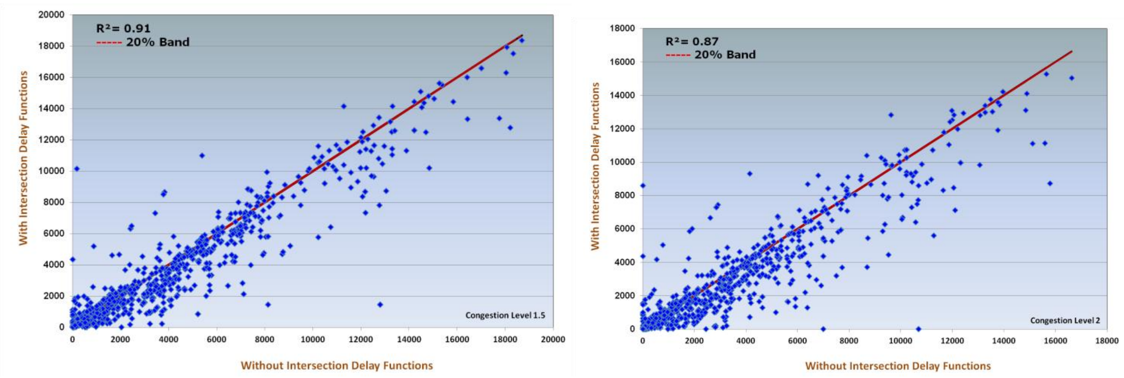

Figure 10: Assigned Traffic Volumes from the Proposed Methodology versus Assigned Traffic Volumes from the Traditional Method – Congestion Levels 1.5&2

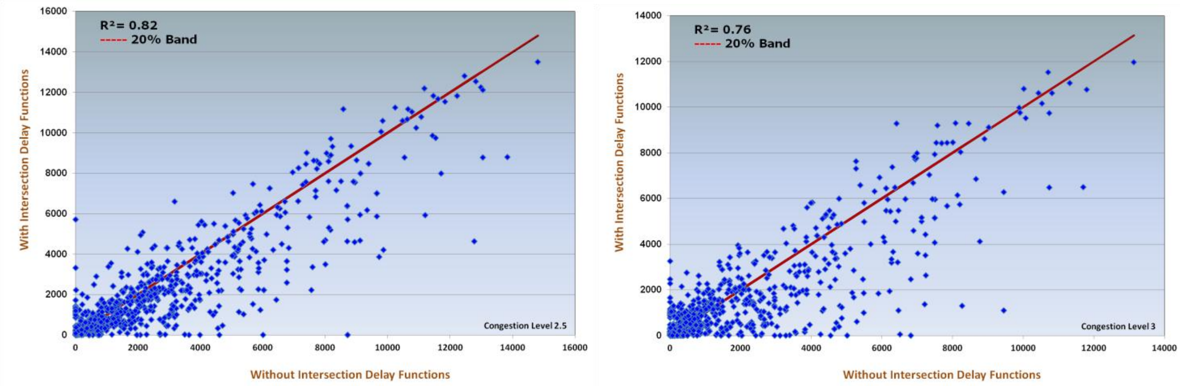

Figure 11: Assigned Traffic Volumes from the Proposed Methodology versus Assigned Traffic Volumes from the Traditional Method – Congestion Levels 2.5&3

By applying intersection delay functions, the average delay was reduced by 13.37%, 8.90%, 5.89% and 4.01% respectively as shown in Figure 12 for different congestion levels (1.5, 2.0, 2.5 and 3.0)

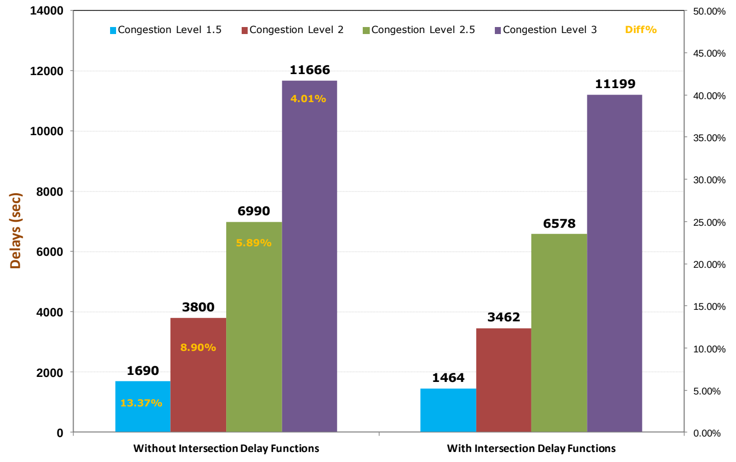

Figure 12: Delays from the Proposed Methodology versus Delays from the Traditional Method

CONCLUSION

This paper has presented a modeling framework suitable for investigating key properties of combined traffic assignment and intersection delay models. Fairly large improvements are possible if intersection delay models are taken into account in the traffic assignment.

As a consequence of the applied method, the accuracy of the study area model was raised significantly. On average, the proposed methodology which includes the intersection delay models showed improvements of about 13.37%, 8.90%, 5.89% and 4.01% in comparison with the traditional traffic assignment methods at congestion levels 1.5, 2, 2.5 and 3 respectively. Further efforts should be directed toward implementing the modeling framework presented in this paper on larger and more realistic networks.

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