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A Framework for Traffic Planning and Forecasting using Micro-Simulation Calibrations

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***Abstract*—This paper presents the application of micro-simulation for traffic planning and forecasting, and proposes a new framework to model complex traffic conditions by calibrating and adjusting traffic parameters of a micro-simulation model. By using an open source micro-simulator package, TRANSIMS, in this study, animated and numerical results were produced and analysed. The framework of traffic model calibration was evaluated for its usefulness and practicality. Finally, we discuss future applications such as providing end users with real time traffic information through Intelligent Transport System (ITS) integration.**

Keywords—traffic congestion; traffic planning; traffic modeling; micro-simulations;TRANSIMS

I. INTRODUCTION

The rapid movement of people and goods is essential to economic growth [1], and yet traffic congestion increases travel times, traveler stress, and accident rates; reduces mobility, accessibility, and system reliability; and results in loss of productivity and environmental degradation [2]. This is especially evident in Russia, the focus of this study.

In Russia, the road system in the vast country is mostly underdeveloped. Many regions are still isolated from an established road network and have no access to federal highways. Despite being the capital of a country with vast territorial resources, Moscow roads occupy only 8.7% of urban space. The levels of motorization in major Russian cities, range from around 250 to 400 cars per thousand inhabitants. The levels are modest in comparison to the world's megacities [3]. However, the severity of persistent traffic jams in these Russian cities is way more serious. There is a significant gross imbalance between road capacity and the real level of motorization in Russia.

Russia loses close to 3% of its annual gross domestic product (GDP) because of poor roads alone. Meanwhile, there is also the issue of road safety. The casualty statistics for Russia is high, fluctuating around 100 deaths per 100,000 vehicles as compared to Organization for Economic Co-operation and Development (OECD) member countries, where the figures are as low as 9-18 deaths per 100 thousand vehicles [3].

Russia Federation's main concern is to pioneer road development over their national territory, eventually ensuring the country's global and local land communications. To achieve their goals, the Russian authorities have renewed their efforts in recent years to improve their traffic networks. Russian Federation had unveiled their transportation plans and policy in place for up to the year 2030 to combat the traffic and to meet their goals of providing safe, efficient and reliable transport. The initial motivation came about as part of the country's preparation to host a number of major events such as the 24th Asia Pacific Economic Cooperation (APEC) summit in 2012, the Winter Olympic Games in 2013, and the Paralympics Games in 2014. The APEC summit was held on Russky Island, near the port of Vladivostok in the far east of the country. To facilitate the movement to the island, a $1 billion-plus USD world longest cable stayed suspension bridge was built to link Vladivostok and Russky Island over the Strait of Bosporus. It was part of a $6 billion project which includes other facilities such as a conference centre and luxury hotels. Another major traffic improvement project is the construction of the new toll link between the two largest Russian cities, Moscow and St Petersburg [3].

Traffic experts are not optimistic in the outlook of the government's development strategy, which essentially follows the old Russian Empire’s cart-road structure with all major roads converging to Moscow. This will result in a lack of quality roads linking neighboring regions in the vast country. Roads are still built based on mathematical models and numerical calculations. Traffic flows are estimated based on road geometry with reference to the Highway Capacity Manual [4, 5]. Another traditional modelling approach is the four step model [6]. The four steps are: trip generation, trip distribution, modal split, and network assignment. Even though the four step approach suffices in providing moderate success in the aggregate [6], it cannot capture traffic details. These traffic models are not able to account for traffic condition changes as a result of dynamic factors in traffic demand and supply. This paper introduces a model calibration framework in adjusting model parameters to better reflect real traffic conditions. The results are evaluated to determine their potential use in future traffic predictions and forecasting.

Simulation refers to the movement of people and/or vehicles on the network and is used to estimate the state of the system (link travel times, turn penalties, link flows) when pure mathematical and analytical models are inadequate to do so [7]. Traffic systems can be modeled differently and there are a wide variety of traffic models in which the traffic systems can be classified under. There are four ways to classify traffic models: physical interpretation, level of detail, discrete versus continuous, and deterministic versus stochastic [8].

Depending on the level of detail of the traffic stream being modelled, simulation models are generally classified as macroscopic, microscopic, and mesoscopic models. Macroscopic models simulate traffic flow using aggregate stream characteristics such as speed, flow, and density, and their relationships. Microscopic models simulate individual vehicles, their characteristics and interactions on a second or sub-second basis [9]. These models require large amount of traffic data and analysis resources. The required data is significantly more extensive and complex than other modeling approaches. Mesoscopic models, on one hand simulate individual vehicles, on the other hand describe their activities and interactions based on aggregate relationships. In a recent review paper, a number of traffic simulation softwares were compared [10]. TRANSIMS stood out from the rest of the simulator packages through its free use and documentation alone. Together with the GUI simulation and visualization capabilities, TRANSIMS was chosen for this study.

II. MICRO-SIMULATION USING TRANSIMS

This project aims to study the use of micro-simulation models in modeling complex traffic situations including inclement weather, congestion pricing, highway/freeway changes, incidents, construction and work zone activities. A main focus of this work is to determine what parameters can be calibrated to better simulate dynamic traffic conditions. The final simulation results is then evaluated to determine its performance and the possibility of integrating into modern Intelligent Transport Systems (ITS).

Fig. 1. Network view of Alexandria in QuantumGIS.

This study works on the network and census information for Alexandria, Virginia. This is a sample dataset provided with TRANSIMS simulator package. The data was distributed by the U.S. Census Bureau for the Year 2000 Census. The Public Use Micro data Sample (PUMS) provides complete household records for a five percent sample of households within Public Use Micro data Areas (PUMAs) that contain approximately 100,000 people. The dataset provides tables of various household attributes summarized at several levels of geography. Block Groups are geographic subdivisions that contain approximately 1,000 persons. The Alexandria_4.0.06 test case data uses a “real-world” network with 3,600 links and roughly 420,000 trips. The Alexandria test case data illustrates the typical use of TRANSIMS model implementation using actual real-world data to represent the amount of travel demand utilizing the region’s transportation system [11]. The model study included all potential areas that might be impacted by the proposed changes, Fig. 1. The morning (from 7 am to 10 am) and evening (from 5 pm to 8 pm) peak hour periods have been selected as the temporal boundaries for the analysis. Simulated traffic data at hourly averages and 15 minutes intervals will be collected.

TRANSIMS is a widely known agent-based model for traffic simulation, combining demand modeling and flow behavior. TRANSIMS requires large amounts of detailed data and computing resources as it models the large scale dynamics of a system. TRANSIMS is an open source micro simulation package which includes an integrated set of tools as binaries executables. In version 4.0.8, there is a total of 71 executables, which will be referred to as programs or modules interchangeably. The goal of the TRANSIMS micro-simulation is to load traffic onto the network and iterate towards the state of Nash Equilibrium where no travelers will improve their travelling time by changing travelling routes. Sub-modules include population synthesizer, activity generator, route planner and micro simulator. An iterative feedback process draws the output from the sub-modules and fed in as input to the next stage. This process iterates and converges to equilibrium. At equilibrium, travelers are modeled with a transportation mode to travel on a path that is best for the overall population [12].

III. BASE MODEL DEVELOPMENT

The base model was developed using TRANSIMS Studio 0.9.9, which provides an integrated development environment (IDE) for TRANSIMS. The IDE supports the development of Python 2.6 user scripts, driven by the TRANSIMS Run Time Environment (RTE). The RTE is a Python module that automates much of the complex interaction among the TRANSIMS modules. TRANSIMS utilizes control files in which parameters can be modified. There are five main python scripts (ConvertNet.py, ConvertTrips.py, RouterRuns.py, MicrosimulationRuns.py, and Visualize.py) facilitating the interaction of program modules and control files.

A. Link-Node Diagram

The link-node diagram, that can be created directly in TRANSIMS or through other computer-aided design (CAD) softwares, identifies the streets and highways modelled in the simulation. Each node represents the x-y coordinates of the intersection of two or more links. The node coordinates can be obtained from maps, aerial photographs, or other means. Links represent the one-directional segments of streets or freeways, with shape points to represent link curvatures. The link-node diagram provides the framework of the model. In addition, the following parameters are required: number of lanes, lane width, link length, type, and curvature. The link-node diagram is stored as TRANSIMS flat files (text-based). They can be converted to shape files which are viewable by GIS tools such as ArcGIS and QuantumGIS.

The formation of the diagram can be done through a series of execution of TRANSIMS programs. Without the use of TRANSMS Studio, this was achieved through writing a batch shell script. The script file automates the entire simulation process, handling all the input and output files locations in the project folder and specification of the simulation programs parameters. Alternatively, with TRANSIMS Studio running the Alexandria dataset, the scripting could be done in Python in the Integrated Developer Environment (IDE).This approach is way more efficient than the manual batch scripting process. The link node diagram is generated by running the modules *ArcNet* and *TransimsNet* in the python script *ConvertNet.py*.

B. Traffic Control at Intersections and Junctions

TRANSIMS implements the following traffic controls at intersections and junctions: no control, yield signs, stop signs, and signals (pre-timed and actuated). Intersection details are added to the network by the module *IntControl* in the *ConvertNet.py*. Running this module will generate the following signal files for future use in micro-simulation runs: Signalized Node, Unsignalized Node, Timing Plan, Phasing Plan, Detector, and Signal Coordinator Files.

C. Traffic Demand Data

As TRANSIMS is a demand based modeling simulator, trips are generated based on travelers demand which can be derived from the O-D table, and other demand data such as vehicle characteristics data. There are two approaches to generating travelers demand. One is trip based, where O-D trip tables are used to synthesis the travelling population and their travel plans. The alternative approach is tour-based, where census survey data on the network is used for activity generation. Since census data are not readily available, the trip based approach was used to generate the traffic demand data.

The first step in this approach is to convert the O-D trip table and trip times to other demand files such as travelling population, vehicles and trip plans etc. These traffic demand files are essential for the later stages in the simulation process. They will be generated by executing the program module *ConvertTrips* with the O-D trip table as the main input. The script, *ConvertTrips.py* is responsible for the traffic demand data generation.

D. Driver Behavior Data

Driver behavior data in TRANSIMS represents the driver's aggressiveness (give-way, lane changing) and response to the traffic conditions.

TABLE I. DEFAULT DRIVER BEHAVIOR DATA

Micro-Simulator Variables	**Values**
Look Ahead Distance	260 meters
Look Ahead Lane Factor	4.0
Look Ahead Time Factor	1.0
Permission Probability	55.0 percent
Plan Following Distance	525
Driver Reaction Time	0.7, 0.8, 0.9, 1
Slow down Percentage	10, 20
Slow Down Probability	10, 15 , 20

Table 1 shows the default values of the driver behavior parameters in the micro-simulator. It should be noted that these values can be calibrated to match observed field data provided that the field data is available. The driver behavior values can be changed and calibrated to simulate more complex situations.

E. Simulation Run Control Data

Before running simulations in TRANSIMS, setting up the run control parameters in the control files are required. These parameters include: simulation duration, outputs (e.g., reports, animation files, or both), and resolutions of simulation results (e.g., temporal and special resolution). In addition, control keys and other parameters can be customised.

IV. MODELING CALIBRATION FOR COMPLEX SCENARIOS

By using TRANSIMS Studio, a base working model with error-checking was developed. However, complex situations due to external factors cannot be directly represented in the base model. This limitation is mainly constrained by the micro-simulator capabilities and available options. For example, TRANSIMS does not have the parameters that explicitly represents inclement weather conditions. To overcome the limitation, we propose to use calibrations to cover conditions that cannot be directly simulated by the software. By calibrating the base model parameters, external factors in various scenarios can be more realistically modeled and simulated, and consequently, more accurate predictions can be achieved [13]. A framework incorporating existing calibration techniques to capture the influencing factors is introduced. For each complex scenario, a certain set of parameters need to be adjusted. Ideally observed field data to reflect local conditions should be collected for calibration. In this study, the set of adjustable parameters will be determined without observed field data.

A. Calibration for Capacity

The capacity calibration step adjusts the global and link-specific capacity-related parameters in the simulation model to best replicate expected local field measurements for capacity. This is an important step as capacity has a significant effect on predicted system performance (delay and queues) [13]. In the beginning, global calibration is performed to identify the values for the capacity adjustment parameters that help best reproduce the observed traffic capacities in the field [14]. HCM would be used as an alternative source of capacity target values as actual field measurements are not attainable. Link-specific capacity parameters are then adjusted to fine-tune the model so that it matches the field-measured capacities at each bottleneck more accurately. One approach in capacity calibration is to perform search optimisation on model estimates. As field measurements of capacity were not available in this study, the HCM methodology will be used to estimate capacity. The HCM methods should not be considered a default technique since the estimates are not as accurate as direct field measurements.

B. Obtaining Model Estimates of Capacity

In TRANSIMS, the outputs generated are vehicle volumes for network links. The input traffic demand, that is, O-D trip tables have to be manipulated to create a queue upstream of the target section to be calibrated so that the model will report the maximum possible flow rate through the bottleneck. If the model does not initially show congestion at the same bottleneck locations as exist in the field, then the traffic demands coded in the model are temporarily increased to force the creation of congestion at those bottlenecks. These temporary increases must be removed after the capacity calibration has been completed, but before the route choice calibration step. If the model initially shows congested bottlenecks at locations that do not exist in the field, it will be necessary to temporarily increase the capacity at those false bottlenecks (using temporary link-specific headway adjustments). These temporary adjustments are then removed during the fine tuning phase. The model runs should be repeated several times and the maximum flow rate at each location should be averaged across the runs. The minimum required number of runs to obtain a value of capacity within a desired confidence interval can be calculated.

C. Calibration Parameters Selection

Only the model parameters that directly affect capacity are calibrated at this time. Each micro-simulation software program has its own set of parameters that affect capacity, depending on the specific car-following and lane-changing logic implemented in the software. In TRANSIMS, the parameters affecting capacity directly can be found in the input link file. For each link connecting node A to B, the parameters are as follows:

- Length: length in meters
- Lanes_AB: number of lanes from A to B
- Speed_AB: maximum speed allowed from A to B
- Lanes_BA: number of lanes from B to A
- Speed_BA: maximum speed allowed from B to A

The program module *TransimsNet* will automatically provide an estimated value of the link capacity according to the number of lanes and the length of the link. This estimated capacity will be used in the *Router* module, but not the *Microsimulator* module. Nevertheless, the capacity can be modified in the link network files for calibration purposes. For the base model, the default parameter values are assumed to be the most optimal. For the complex situations, parameter values are adjusted to HCM values and determined to be optimal.

D. Link-Specific Fine-Tuning

Once the optimal global capacity calibration parameter values are identified and completed, there will still be some locations where model performance deviates a great deal from the field conditions. Therefore, the next phase is to fine-tune the predicted capacity to match the location-specific measurements of capacity as closely as possible. Link-specific adjustments to cost or speed are made during this fine-tuning phase. Link-specific capacity adjustments account for roadside factors that affect capacity, but are not typically coded in the micro-simulation network input data. Most simulation software programs have link-specific capacity adjustment factors that apply only to the subject link. In TRANSIMS, these roadside links are known as 'pocket' subjected to the facility type. Following are a few examples of facility types in TRANSIMS: 1 = freeway; 2 = expressway; 12=bikeway; 14=light rail, and so on. Pocket lengths parameters are specified in TRANSIMS net control files.

E. Route Choice Calibration

TRANSIMS micro-simulation model provide alternative routing for travelers according to the route impedance values. Routing is done through the router module in TRANSIMS Studio. As complex situations would impact the route chosen/taken by the travelers, the next step of the calibration approach after capacity calibration is to perform calibration with route choice parameters, Table 2. This is to a achieve a better match to the expected traffic flows. In TRANSIMS, the appropriate parameters should be chosen and the calibration then proceeds through the same process as was used to calibrate capacity.

TABLE II. ROUTE CHOICE PARAMETERS IN ROUTER CONTROL FILE

Router Parameters	Values	
Walk Speed	1.0	meters
Walk Time Value	20.0	impedance/sec
Vehicle Time Value	10.0	impedance/sec
First Wait Value	20.0	impedance/sec
Transfer Wait Value	20.0	impedance/sec
Distance Value	5.0	impedance/cent
Cost Value	1.0	impedance/meter
Transfer Penalty	1200	impedance
Maximum Walk Distance	2000	meters
Minimum Wait Time	60	seconds
Left Turn Penalty	300	impedance
Kiss Ride Stop Type	Stop, Station, External	
Max Kiss Ride Drop-off Walk Distance	100	meters
Parking Hours by Purpose	8.5, 2.5, 1.0, 1.0 hours	

F. System Performance Calibration

Caution should be taken in making changes at this step as it may affect the previous two calibration steps. Fine-tuning adjustments made to the system performance parameters will enable the model to better match the field measurements. As of before, the HCM estimated values are applied. Calibrating parameters for the module *Microsimulator* is important. These parameters, defining the driver behavior, are the key attributes in the complex traffic simulation scenarios. In addition, vehicle characteristics such as acceleration and deceleration are also affected by the local traffic situation. By adjusting these key values, the traveler reaction to various complex situations can be modeled. The default key parameters are listed in Table 3.

G. Weather Conditions

Weather conditions have huge impacts on the efficiency of transportation systems. Inclement weather reduces visibility and traction of the road and affects driver behavior significantly. Not only does experiencing weather conditions affect driver behavior, but knowledge or warning of inclement weather also has been seen to result in more cautious driver behavior [15]. Drivers would normally reduce speeds and increase headways leading to slowed traffic flow. Additionally, driving under inclement weather shows a higher frequency of acceleration and deceleration. The magnitude of vehicles acceleration and deceleration significantly lower than under dry weather. In short, inclement weather conditions would impacts roadway surface conditions and driver behavior, which result in increased delays and crash risks [16].

In this study, the types of inclement weather condition to be analyzed will be light, heavy rainfall and light, heavy snow. According to Highway Capacity Manual [5], the impact of light rain on freeway capacity is minimal with percentage as low as 0% reduction. For heavy rain, capacity reduction is about 15%. For the case of snow and light snow, capacity reduction ranges from 5% and 10% reduction. Heavy snow would reduce capacity by a range between 25% and 30%.

TABLE III. KEY SIMULATION PARAMETERS FOR CALIBRATION

Micro-Simulator Parameters	Values
Look Ahead Distance	260 meters
Look Ahead Lane Factor	4.0
Look Ahead Time Factor	1.0
Permission Probability	55.0 percent
Plan Following Distance	525
Driver Reaction Time	0.7, 0.8, 0.9, 1
Slow down Percentage	10, 20
Slow Down Probability	10, 15 , 20
Maximum Speed	37.5 meters/second
Maximum Acceleration	7.5 meters/second^2
Maximum Deceleration	7.5 meters/second^2

TABLE IV. HCM PERCENTAGE REDUCTION FOR INCLEMENT WEATHER

Variable	Range (in/hr)	Categories from HCM 2000	Capacities (Percentage Reduction)	Avg. Operating Speeds (Percentage reduction)
Rain	0-0.01	Light	0	2-14
	0.01-0.25	Light	0	2-14
	>0.25	Heavy	14-15	5 - 17
Snow	<= 0.05	Light	5-10	8 -10
	0.06-0.1	Light	5-10	8 -10
	0.11-0.5	Light	5-10	8 - 10
	>0.5	Heavy	25-30	30 - 40

In order to achieve the HCM recommended reductions, parameters listed in Table 1 need to be adjusted. Most of the parameters can be found in the control file for the module *Microsimulator.* Refer to Table 7 in Section V for the full list of calibrated values. The last three parameters are vehicle performance values which can be modified in the vehicle input file.

H. Congestion Pricing

Toll collections, often occur on freeways, are a unique form of traffic control device. Toll collections usually result in delays. With the mix of electronic toll collections (ETC) and cash payments, vehicles can result in uneven queues that block lanes, and significant weaving, ultimately resulting in safety problems [17]. TRANSIMS has a data file type 'Toll' to model toll payments for travelers utilizing links. Route choice as a result of toll was explicitly represented as an additional cost associated with the particular route path.

As road tolls will affect the travelers choice of route, route choice calibration has to be done. In this case, the router control file is analyzed for the required changes. Through review of TRANSIMS documentation, it was determined that the toll table can be included in the router control file for modeling toll links in the network. Inclusion of the toll table in the *Router* module was implemented to simulate tolls on the target link. Within the router control file, the perceived impedance value by the traveler is represented by the parameter *COST_VALUE*. This parameter can be adjusted to show the elasticity of travel demand related to costs.

TABLE V. TOLL PARAMETERS IN NETWORK FILES

Parameters	Descriptions
Link	Link ID on which the toll is collected
Dir	Node ID or direction code toward which the toll collection is headed.
Start	Start time for the toll collection
End	End time for the toll collection
Use	Vehicles type that must pay toll
Toll	Cost of toll in cents

TABLE VI. PARAMETERS ADJUSTED FOR CONSTRUCTION AND WORK ZONE ACTIVITIES, AND INCIDENTS

Downward Adjustments	Upward Adjustments
Link capacity	Driver reaction time
Link free flow speed	Slow down percentage
Link speed limit	Slow down probability
	Plan following
	Look ahead distance
	Look ahead lane
	Look ahead time

In some other simulation systems, toll collection can be modeled with direct acceleration effects as vehicles slow or stop to the necessary speed. Tolls are also effective in limiting flow of vehicles and relieving crowded streets [18].

I. Construction and Work Zone Activities, and Incidents

The impacts of construction and work zone activities, and incidents are reduction in capacity and the likely congestion as a consequence. To capture the scenario in the simulation, the parameters to adjust include driver behaviors, vehicle performance values and link capacities. The modeling of incidents was deemed similar to situations in construction and work zone activities. In the scenario that a stalled vehicle stops in the middle of the lane, the capacity of the road network link is reduced. Similarly, in a scenario where a lane is heavily used for parking, loading and unloading activities, the affected parameters in TRANSIMS would be capacity parameters. Hence, the related parameters were adjusted to model the scenarios. As an extreme example, a solution would be to remove the lane from the link as that yields the same result for a lane blocked virtually all of the time. In this study, the link with the afflicted lane will have the free flow speed, speed limit and capacity adjusted accordingly. Table 14 summarizes the possible changes to the simulation parameters in modeling these situations.

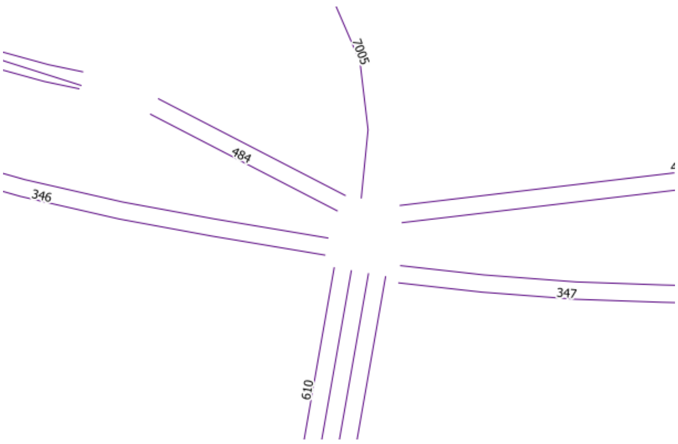
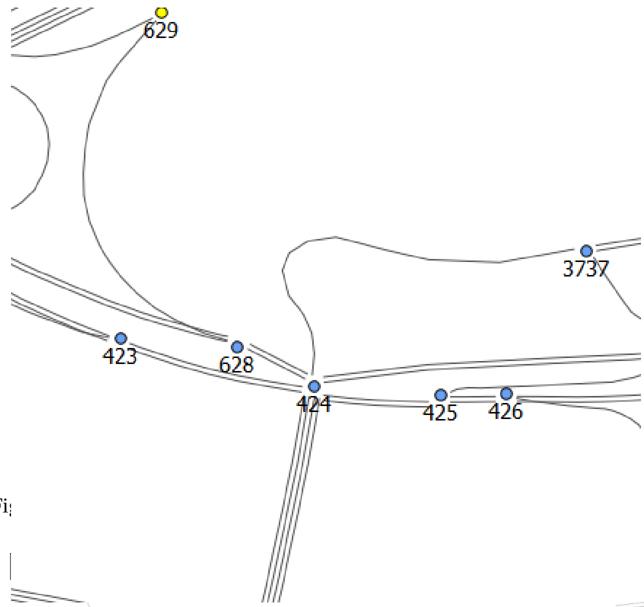


Fig. 2. Static view of traffic intersection with labeled traffic nodes.



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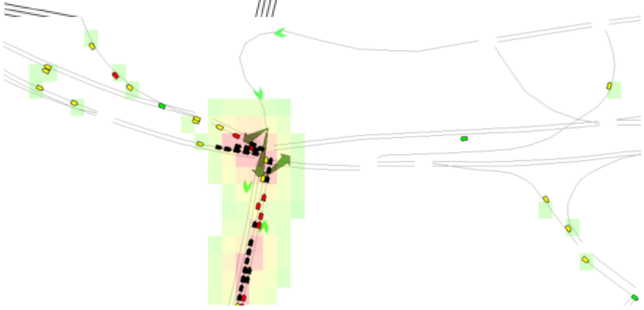

Fig. 4. Animation view in TRANSIMS Visualiser.

V. RESULTS AND DISCUSSION

The visualization results of an intersection with high traffic volume are given in this section. The corresponding links and nodes of the intersection are shown in Fig. 2 and Fig. 3, respectively. Animation output provides a quick view and qualitative assessment of the overall performance of the traffic simulation. The layers of data generated from the micro-simulations are stored as TRANSIMS flat files. The snapshot files can be converted to shape files (GIS data), using the *ArcUilities* type tools (*ArcNet*, *ArcPlan*, etc), and visualized as static images. By stringing up the individual images as frames, a movie can be generated. TRANSIMS Studio and TRANSIMS Visualizer can be used together to create and view the simulation as an animation, Fig. 4.

Numerical results of TRANSIMS are stored in text output files called “reports”, which contain information on simulated traffic activities, summarized over time and/or space. Statistical results can be extracted and analyzed through the outputs of the micro-simulations, the link delay files. From these files, performance reports with various statistics and details can be generated. These include statistics such as summarized network performance values, link volumes and trip times. The module *LinkSum* in TRANSIMS helps to generate the summarized reports from the link delay files. The *LinkSum* reports include: (1) Top 100 Volume Capacity

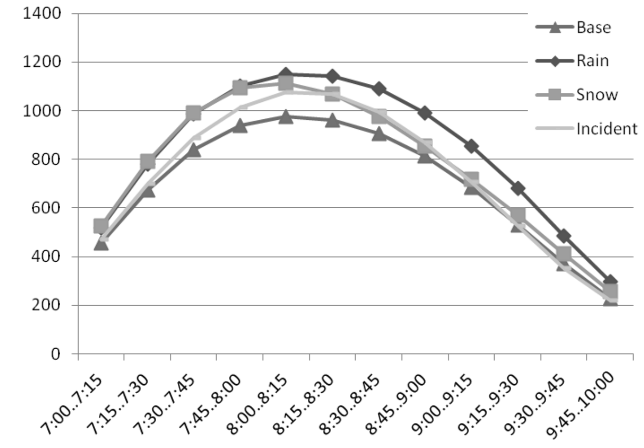

Fig. 5. Time delay under various conditions.

Ratios, (2) Top 100 Link Volume, and (3) Network Performance Summary.

There are various traffic performance measures that can be utilized to measure the degree of traffic congestion in the target road intersection. The traffic delays are tabulated and plotted to show the impact of each complex situation on the traffic efficiency, during the morning peak period from 7:00 AM to 10:00 AM. The results collected from the network performance summary, generated from the *LinkSum* print report, are shown in Fig. 5. The peak delay occurs at around 8:00 AM to 8:45 AM. This matches the animation output where the target intersection is visibly much more congested. The convergence at the end of the peak period suggests that complex traffic situations have a much lesser impact when the congestion level is already low. This marginal effect due to varying degree of congestion is critical to transportation professionals in traffic forecasting studies. In our study, heavy rainfall and snow conditions were modeled, and they were found to have the most impact on travel times. All the parameters were adjusted with reference to previous traffic studies such as the HCM and other best educated approximations. Table 7 below shows the parameters adjusted for raining and snowing.

Calibrating traffic parameters allows us to model complex situations which was not possible with traditional macro-level analysis. Traffic modeling with micro-simulation requires a well-developed micro-simulator package and detailed network data files. Census data such as population, travel activities and trip tables are also required to simulate an accurate travelling population. An accurate database for simulation purpose requires huge data collection over long periods of time by traffic engineers. In this study, availability of traffic data has been the main limitation, affecting the accuracy and practicality of the results. To compensate we used the best estimates available in the field.

In our study using TRANSIMS, the effects of complex situations are captured by proxy mechanisms that allow the user to modify certain parameters in order to achieve similar resulting effects. The proposed calibration framework is limited as a form of proxy mechanism. Also, the calibration approach does not capture the effects on lane-changing and acceleration in congested conditions, where maximum and desired speeds are of marginal importance. Even for these mechanisms that exist in other traffic simulation models, there are very few empirical results in the literature to guide the user in setting up and changing the values of the relevant parameters to quantify the effect of various factors [19]. Moreover, in real world, there is often a combination of complex traffic situations such as inclement weather coupled with traffic incidents. For these different situations to be captured and modeled accurately, the observed field values for calibration must be determined to be correct for the right combination of complex factors. In our proposed framework, complex situations are modeled individually and independently. Other than micro-simulations to capture complex external factors, it is also important to model the travel demand in the overall area at macroscopic scale. Regression models for each complex situations can be developed to validate the model used. For example, a linear regression model could be proposed to quantify and predict the combined weather impact on average freeway operating speed [20].

TABLE VII. KEY PARAMETER SETTINGS

Parameter	Base Value	Raining	Snowing
Look Ahead Distance	260 meters	500 meters	500 meters
Look Ahead Lane Factor	4.0	8.0	8.0
Look Ahead Time Factor	1.0	0.5	0.5
Permission Probability	55.0 percent	55.0 percent	55.0 percent
Plan Following Distance	525	650	650
Driver Reaction Time	0.7, 0.8, 0.9, 1	1.4, 1.6, 1.8, 2	1.4, 1.6, 1.8, 2
Slow down Percentage	10, 20	20, 30	25, 35
Slow Down Probability	10, 15, 20	20, 25, 30	20, 25, 30
Maximum Speed	37.5 m/s	37.5 m/s	37.5 m/s
Maximum Acceleration	7.5 m/s^2	6 m/s^2	3.8 m/s^2
Maximum Deceleration	7.5 m/s^2	6 m/s^2	3.8 m/s^2

VI. CONCLUSION

One aspect of future work is to include finer details of information and traveller responses in the model. Existing route choice models are primarily travel time based [19]. This is significant as a better model in route choice behaviour of travellers will provide better simulation results. In the case of TRANSIMS, the route choice is based on perceived impedance. In particular, a planning tool could be used in tandem with simulation packages to achieve better accuracy and practicality. Popular planning tools include TransCAD and TransModeler.

Additionally, other than traffic planning, the concept of using micro-simulation results to improve traffic controls using Intelligent Transport Systems (ITS) can be explored. ITS plays a critical role in many of the current world research in traffic engineering [21]. Many of the traffic studies performed today seek to integrate their results with ITS systems in their local cities. This project can be extended to explore how micro-simulations can be best integrated with an ITS system. The main idea is to build traffic sensors at various traffic intersections and major links. These traffic sensors will collect real time data and sent them over to the back end servers for processing. The servers at the back end could perform fast micro-simulations and relay the results back to the travellers. The travellers would be able to receive critical traffic information such as expected travel time/delay through their smart phones.

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