MANAGEMENT OF TRAFFIC AT ROAD INTERSECTION USING SOFTWARE MODELLING

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Abstract - *As transportation systems have become more complex with frequently congested roads, traffic management has become a worldwide concern. Engineers install traffic signals to provide safe right of way periodically to competing traffic movements. When two or more traffic signals are located in close vicinity, traffic flow on links joining two signals become dependent on timings at these signals. Coordinating two or more signals on a signalized intersection requires cycle length, green splits, phase sequence and offsets and these can be achieved by using various types of traffic simulation model and optimization model. With the progress of technology, many traffic management packages were developed and traffic model and simulation tools are increasingly used for traffic management by using real time date. The objective of this paper is to study different traffic management and simulation software for signalized intersection and identify the best suited tool for traffic management.*

Key Words: **Traffic management, Software modelling, Traffic simulation, Signal operation, Signalized intersection**

1. INTRODUCTION

The term Traffic congestion influences various aspects of traffic engineering. Many transportation planners and engineers are highly concerned with understanding major causes of traffic congestion. The solution is frequently achieved by proper software application in traffic management. Traffic signal cycle and phasing of each signal at intersection is well designed with the help of different software and optimized model is developed. Result of this is also presented with the help of simulating software.

The need of software application in designing signal cycle and modelling arise due to difficulties faced while calculation due to many mathematical formulas involved in which some of them need to be repeated. Also, due to portability of compacted laptops the work is also becomes very easy, simple and quick.

Choosing right software depends on specific area of interest or problem and required output needed at field.

Available or collected field data also affect this selection. Chosen software outcome should help in effective traffic management and ensuring safety of road users.

Nowadays most of the traffic projects are presented with simulating software to give real idea about actual field condition as a model or abstraction of the system and can be better defined as a simplified representation of a system at some particular point in time or space which is aimed at promoting an understanding of the real system. As the model is the simplification of the real conditions, the level of detail depends on the specific requirements. Simulation is the manipulation of a model in such a way that it operates on time or space to represent the real conditions.

Simulation provides an understanding of the interactions among the key components of a system and the system as a whole. The evolution of computer technology has changed the general understanding of simulation. Nowadays, simulation basically means a computerized version of a model which is run over time to study the implications of the defined interactions.

Simulation tools are ideal tools for public presentation, evaluation of before and after studies, and routine planning and operation analysis. Simulation packages can offer the user a valuable tool to observe animated traffic conditions, and evaluate alternative scenarios for roadway and signal system improvements in urban areas and can be useful for determining the effects of design changes, installing or removing traffic signals, using pre-timed or vehicle actuated signals, etc.

When engineers predicting performances are not able to design and built by using trial and error method alone, they are forced to structure their knowledge of the system in terms of a model. The model should include meaningful measure of effectiveness of a system, such as capacity and delay in the traffic system. Simulation makes possible trial and error manipulation which leads naturally to an optimum design. Thus, a simulation may be necessary to predict future behaviour of the system in traffic studies and design. Table-1 shows the capabilities of various popular simulation software used by researchers.

Table -1: Suitability of Simulation Software

Simulation Software	Researchers	Suitability
Aimsun	Khaki and Pour (2014) Salgadoa et al. (2016) Azlan and Rohani (2018) Liu et al. (2018) Kotusevski and Hawick (2009)	• Active transportation and demand management • Arterial management / traffic signal operations • Congestion pricing • Real-time transportation information • Road weather management • Traffic incident and events management • Work zone mobility and safety • Recreate real traffic conditions of different traffic networks • Modelling traffic demands based on traffic flows and turning proportions, or OD matrix • Modelling different traffic control types • Able to import networks from different platforms (like GIS, AutoCAD, Synchro, VISSIM etc.) • To evaluate delay time, travel time, number of stops, fuel emission, queue length • The gap-acceptance behaviour of drivers is modified based on their delay time • Simultaneous 2D and 3D (micro only) views • Comparison of different scenarios • Assess the interaction of vehicles and pedestrians • Public transport assessments • Safety analysis • Urban environmental studies • Traffic management • Simulates surface street networks, freeways, interchanges, pre-timed and actuated signals, stop controlled intersections and roundabouts. • Suitable for 3D animation, full trip distribution capacities, dynamic traffic assignment, real time vehicle guidance • Used to compare environmental capabilities like emission and fuel economy

SIDRA	Rajnitkar et al. (2014) Mohammed et al. (2017) Alshetwiet al. (2018)	• Signal timings can be determined accordingly with advantages over approach-based and lane group-based methods. • Analysis of single-lane and multi-lane roundabouts • Estimates the cost, energy and air pollution • To model lane-based congestion • For lane by lane analysis, lane flow calculation, capacities of short lanes variable cycle lengths, variable flow scale and modelling of unequal lane utilization
SUMO	Castro et al. (2017) Liang et al. (2017) Azlanand Rohani (2018) Jang and Seung-Ju (2018) Kotusevski and Hawick (2009)	• Road network generation • Noise emission and a pollutant emission / fuel consumption model • For Simulation of ○ Space-continuous and time-discrete vehicle movement ○ Multi-lane streets with lane changing ○ Different right-of-way rules, traffic lights • Interoperability with other application at run-time • Network-wide, edge-based, vehicle-based, and detector-based outputs • Imports visum, VISSIM, shapefiles, osm, robocup, matsim, opendrive, and xml-descriptions • Traffic lights evaluation • Route choice and re-routing • Evaluation of traffic surveillance methods • simulation of vehicular communications • Traffic forecasting • Suitable for urban traffic management, traffic emission and other issues • Modelling of intermodal traffic system including road vehicles, public transport and pedestrians

CORSIM	Mystkowski and Khan (2000) Tian and Wu (2006) Feng et al. (2014) Shah et al. (2015) Azlanand Rohani (2018)	- Supports different HOT (High Occupancy Toll) lane pricing algorithms - To customize vehicle behaviours near toll plazas - ability to pass a vehicle by temporarily moving into the opposing traffic stream on a two-lane highway. - Emergency vehicles (EV) can be simulated - To evaluate the impacts of a variety of pricing strategies on freeway traffic operations - Suitable to model more complex situations - Model the impacts of traffic incidents and traffic management strategies - To simulate the impacts of transit and parking on traffic operations - Suitable for reporting system performance in terms of total delay, stop delay, total stops, travel distance and time, fuel consumption, emission, and max queue length - Simulation capabilities include: - Arterial networks; - Freeway and surface street interchanges; - Pre-timed and actuated signals, coordination, and pre-emption; - Freeway weaving sections, lane adds and lane drops; - Stop and yield controlled intersections; - Simulation of queue length, queue blockage, and spillback; - Origin-destination traffic flow patterns and traffic assignment; - Network animation

| DynaMit | Milkovits et al. (2010)

Ben-Akivaet al. (2010) | Estimates of network conditions Predictions of network conditions in response to various traffic control measures and information dissemination strategies Generation of traveller information to guide drivers towards optimal decisions Detailed network representation Individually simulates each trip, to generate detailed vehicle trajectories Generation of unbiased and consistent information to drivers. Efficient operation of variable message signs Real-time incident management and control. Off-line evaluation of real-time incident management strategies. Evaluation of alternative traffic signals and ramp meters operation strategies. Co-ordination of evacuation and rescue operations in real-time emergencies (natural disasters, etc.) That could block highway links. Generating historical databases. |
| HCS | Sabra et al. (2000)

HCS Manual | Signalized Intersections: Unsignalized Movements; Combined Grade/Heavy Vehicle Adjustment; Animation Urban Streets: Travel Time Reliability; Parking Adjustment and Calibration Terms; LOS A/B Threshold Alternative Intersection: Median U-Turn, Restricted Crossing U-Turn, Displaced Left-Turn Analyses Interchange Ramp Terminals: Experienced Travel Time, Diverging Diamond Interchange Analysis Roundabouts: Revised Capacity Equations; Segment Analysis Freeway Segments: Managed Lane Analysis; Capacity and Speed Adjustments; Truck Procedures Weaving Segments: Cross Weave Adjustment; Capacity and Speed Adjustments; Truck Procedures Merge & Diverge Segments: Density |

		All Lanes; Capacity and Speed Adjustments; Truck Procedures • Freeway Facilities: Travel Time Reliability; Managed Lanes; Cross Weave Adjustment; Animation • Tools: Highway Safety Software; HCM Reference Guide; MUTCD Signal Warrants; Service Volumes
TRANSIM	Saidallah et al. (2016)	
CORFLO	Sabra et al. (2000)	
Quadstone Paramics Modeller	Kotusevski and Hawick (2009)	• Roundabout creation • Up to 16 connected arms to each intersection • Signalised or priority • Up to 32 signalised phases per intersection • Public transport priority schemes • Ferry / port operations • Signalised crossings • Urban streetscape
MITSIMLab	Saidallah et al. (2016)	
INTEGRATION	Sabra et al. (2000)	
MATLAB	Ishak-Thomas et al. (2018)	
Texas	Sabra et al. (2000)	

Table -2: Suitability of Signal Timing Analysis and Design Software

Signal Timing Analysis and Design Software	Researchers	Suitability
TRANSYT-7F	Mystkowski and Khan (2000) Chen and Chang (2014)	• Genetic algorithm optimization of cycle length, phasing sequence, splits, and offsets • Detailed multi-cycle simulation • Simulation of existing conditions and future conditions • Multi-period optimization, hill-climb optimization • Lane-by-lane analysis, actuated control analysis • Direct CORSIM optimization, CORSIM post-processing • Optimization based on a wide variety of objective functions • Used to analyse a street network • Flexibility in accepting U.S. customary units or metric units, right-hand drive or left-hand drive

		• To simulate traffic flow in small time increment • To evaluate existing timings and optimize proposed condition to minimize stops, delay, fuel consumption and cost • To optimize traffic signal system for arteries and network
PASSER IV	Mystkowski and Khan (2000)	• Simultaneously optimizing progression bandwidth in multi-arterial traffic signal networks • Determines all four signal timing parameters: cycle length, green split, offset, and phasing sequence • To optimize the flow of traffic on a single arterial or through entire network • To choose the best signal timings given certain traffic data

VISSIM	Gupta and Patel (2014)
	
	Oskarbski et al. (2016)
	
	Salgado et al. (2016)
	
	Hossain et al. (2017)
	
	Azlan and Rohani (2018)
	
	Nyame-Baafi et al. (2018)
		• To evaluate delay time, travel time, number of stops, fuel emission, queue length
		• To model the behaviour of every single vehicle through car following and lane changing logic
		• Complex modelling of junction behaviour, including friendly merging (situations where following vehicles will slow for merging vehicles to create a gap), as it occurs in the real world.
		• Representation of on-street parking behaviour and double parking
		• 3D capabilities which helps to understand complex transport flows and intersections
		• Suitable for modelling both motorized and non-motorised traffic flows (like pedestrian, cyclist and wheelchair users)
		• Suitable for roundabouts, signalized and unsignalized intersection, and grade separate interchanges
		• To analyse toll plaza facilities, conduct traffic impact studies, and to test the operability of ramp metering and interchange design
		
		• PTV Vissim can be used to simulate the following processes and systems:
		   ○ Fixed-time control schemes
		   ○ Traffic-actuated control schemes
		   ○ Coordinated green phases

- o Public transport priority schemes
- o Rail transport control processes
- o Priority schemes for emergency
- o Vehicles
- o Ramp metering processes
- o Round-about
- o U-turns, mixed-flow lanes, separate (multi-lane) turn lanes
- o Bicycle paths as well as lanes shared
- By different modes (bicycles and Motorized vehicles)
  - o Public transport stops and terminals
  - o Pedestrian-vehicle interaction
  - o Multi-lane motorways with user defined
  - o Dynamic lane opening signs
- Complex signalized and non-signalized intersections
- For the widest range of traffic engineering issues like…
  - o Road works: optimum set-up and coordination of roadwork sites
- Site development:
  - o creation of site development plans, for instance for supermarkets, malls or entire urban districts
  - o Airport links: design of transport links simulation of airport apron traffic
- Pedestrian flows:
  - o modelling of pedestrian behaviour in different environments as well as evacuation
- strategy planning
- Intelligent transport systems:
  - o Evaluation and optimization of Intelligent Transport Systems
- Junctions: design and dimensioning of intersections and nodes
- Optimization of traffic flows at logistics centres
- Toll stations: performance maximization for toll plazas and tolling lanes

		• PT nodes: modelling of complex public transport nodes • PT priority schemes: analysis of public transport prioritization measures • Parking: planning of parking facilities and modelling of parking-related traffic • Rail transport: performance analyses of rail transport systems • Environmental impact: environmental impact studies, including emissions modelling • Traffic-actuated control schemes: o design, testing and evaluation of traffic-actuated signal control systems • Traffic calming: analysis of traffic calming measures • Visualization: visualization of planning alternatives to support the political decision-making process
SYNCHRO Studio (SimTraffic)	Mystkowski and Khan (2000) Khaki and Pour (2014) Udomsilp et al. (2017)	• To design, model, optimize, simulate, and animate signalized and un-signalized intersection • For project information description and note input fields • To create custom trip rates, including pass-by and internal trip rates • To compare number of trips based on average rates vs. Equations • To determine whether a traffic signal is needed for an intersection. • To analyse roundabouts and evaluate performance of an arterial network • For modelling and optimizing traffic signal timing
Atak	Gundogan et al. (2014)	
Keysignals	Keysignals Brochure	• To create complex signal design schemes including a large library of symbols • To draw cables, ducting and detector loops • To export data rich scheme design models to IFC, GIS (SHP) or Navisworks • Quantify markings and equipment for cost analysis and produce schematic and phasing diagrams

LITERATURE REVIEW:

Bloomberg and Dale (2000) discuss about the accuracy of CORSIM and VISSIM model and provide a technical comparison of these two traffic simulation models. VISSIM and CORSIM have been compared on the aspect of network coding process, car following logic, gap acceptance, signal timing, animation features and output data. The main difference observed is the variability of the models, which should be addressed by making multiple runs. The analysis suggested that both models are appropriate for modelling congested arterial and congested street condition, but suggested the value of using more than one model for traffic analysis.

Ratrout and Rahman (2008) reviewed the features of traditionally used macroscopic and microscopic traffic simulation models along with a comparative analysis focusing on freeway operations, urban congested networks, variations in delay and capacity estimates. The increasing use of virtual reality system in simulation will greatly benefit traffic safety related simulation. Newly developed object-oriented programming approaches were found to be very suitable for modelling transportation system. Authors suggested the suitable tools or approaches for the local condition of Saudi Arabia. The analysis revealed that AIMSUN, CORSIM and VISSIM are suitable for congested arterials and freeways, but AIMSUN is less user friendly compared to others.

Maciejewski (2010) compared the result of application of three selected systems i.e. TRANSIMS, SUMO and VISSIM to the microscopic simulation of traffic flow for a fragment of an urban road network of Grunwald, a south-western district of Poznan City. The result revealed some dissimilarities like, the model in SUMO had too low capacity as compared to the real network capacity, but on other hand, capacities of both VISSIM and TRANSIMS models were higher than the real one. In VISSIM model, a lot of attention was given to the proper localization of all road transportation infrastructure elements and logical elements. Also, it was very important to correctly define conflict areas, particularly when running simulations with high traffic volume.

Pell et al. (2013) observed the growing field of applications and the increase of supported functionalities, and conducted a comparison study of 12 widely used simulation software tools. Existing studies, product reviews and technical product specification documents have been analysed. They concluded that there are just a few traffic simulators which can be used for real time simulation of transportation management. One simulation system, which meets all requirements and is often used for traffic management in Austrian and German Cities, is OPTIMA by PTV, which simulates in real time with better

performances and modelled objects compared to other 11 software.

Sun et al. (2013) conducted a comparative analysis of two popular simulation models i.e. VISSIM and CORSIM, based on their simulation performances on an urban network of North Bund, Shanghai, China. Analysis was carried out to compare the performance of both models based on four key indices software usability, average control delay, average queuing length and cross-sectional traffic volume by different levels of congestion, intersection geospatial scale and level of saturation. The conclusion was made that for software usability, average control delay and average queue length, VISSIM is more appropriate and has closer simulation results to the real situation.

Tianzi et al. (2013) focused on two popular simulation software: VISSIM and SIDRA. Based on the road traffic data of West Wenhua Road and Changchun Road of Xianyang City, their features and evaluation results of signalized intersections have been analysed by operation simplicity and the output error. The conclusion was made that from simplicity of operation, SIDRA is superior to VISSIM (in terms of network construction, phase setting, output speed etc.) but VISSIM is closer to the actual value compared to SIDRA and the error of output result is minimum. So, when simulating a signalized intersection, if accurate vehicle average delay is needed, VISSIM is a desirable choice; if vehicle average delay is only used as reference data, then SIDRA is preferred, for its convenience of output.

Shah et al. (2015) focused to ameliorate the operating condition of Mirpur road by setting appropriate signal timing at the intersections along this road using CORSIM. Collection of traffic volume data was conducted by video recording during peak periods. The existing condition of the Mirpur road was modelled in CORSIM, calibrated with the collected data and optimum signal timings were set at the intersections to make the condition better. First optimum signal timing was tested and later further improvements were achieved with the help of visualization in CORSIM model.

Pell et al. (2016) analysed scientific papers and technical specifications and conducted comparison of 17 simulation software considering six no. of aspects including functionalities which proved to be important for the use of real time traffic simulation models in heterogeneous road networks. It also reveals a further development of some products to adapt them to new field of application. The conclusion was made that most of the simulation tools are designed for urban, interurban or combined road networks and can deal with real time data. No system delivers all functionalities; no system seems to

have a focus on single field of application. So, selection of software tool depends on specific requirements of user.

Saidallah et al. (2016) carried out comparative study of eleven mostly used and mostly mature simulation software and compared them according to new opportunities for ITS (Intelligent Transport System), as well as the integration of GIS which are effective tools for decision support in the field of road traffic, providing accurate data on the real world, and following the establishment of the road network infrastructure. The conclusion was made that the open source simulators do not simulates wireless sensors. VISSIM and SimTraffic offers easy coding of road network. AIMSUN, Paramics, and VISSIM use wireless sensors which are more efficient and

cheaper and are more flexible for coding. MATsim, TransModeler and VISSIM supports GIS, while other don't.

Talevska (2016) performed an overview that combines both – current traffic simulation system-TSS capabilities and customer expectations. Therefore, a comparison of simulation tools (SFStreetSIModel, Freesim, Aimsun, PTV optima and CORSIM) as well as SWOT analysis had been conducted. In order to compare, describe and evaluate the capabilities of microsimulation model SFStreetSIModel, version 1.1, a state-of-the-art review is drawn in table-3. All five simulation models have strength and weakness that make it suitable for certain applications for use in urban road networks.

Table -3: Comparison of Software Based on common design parameters

Object / phenomenon	SFStreetSIModel	FreeSim	Aimsun 7	PTV Optima	CORSIM
Cars	Yes	Yes	Yes	Yes	Yes
Commercial vehicle/trucks	Yes	Yes	Yes	Yes	Yes
Bicycles	No	No	Yes	Yes	Yes
Pedestrians	Yes**	No	Yes	Yes	Yes
Public transports	No	Yes	Yes	Yes	Yes
Parked vehicle	Yes	No	No	No	Yes
Car-following, overtaking and lane changing logic	Yes	Yes	Yes	Yes	Yes
Weather conditions	No	Planned	No	Yes	No
Variable travel time	Yes	Yes	Yes	Yes	Yes
Variable acceleration	Yes*	Yes	Yes	No	No
Headway	Yes	No	Yes	No	Yes
Incidents	No	Yes	No	Yes	Yes

 * in function of the concentration of the side obstacles and distance to them
 ** on sidewalk

Udomslip et al. (2017) used SYNCHRO platform to initialize optimal cycle length of the intersections on Sathom road and to assist in the implementation of reversible lane that involves two traffic signal lights in short distance. A comparative analysis was conducted between optimal cycle length and the actual signal timing as operated by traffic police from real data collection to see the improvements of travel times in various cases. The travel time suggested that periodic signal timing control

from SYNCHRO was better during peak hours since the outcomes displayed the decreased travel time.

Liu et al. (2018) studied the issues with respect to oversaturated signal intersections and demonstrated the consistency based on analytical studies and microscopic simulations with AIMSUN. Deterministic (vertical) and shockwave (horizontal) queuing models are widely used in traffic operation to estimate vertical queue

length and delays at intersections. This paper also intended to develop an efficient approach to the reconstruction of the deterministic and shockwave queuing profile in quasi-real time manner using very limited mobile sensing data. The efficiency of the approach was demonstrated by microsimulation with AIMSUN.

Alshetwi et al. (2018) focused on traffic jam evaluation with the capability of improving the level of service (LOS), the intersection light signal volume, fuel consumption, average delay, operating cost, CO_2 emissions and travel speed at one of Kuala Lumpur's most crowded intersection using SIDRA 4.0 software. The study lead to evaluate capacity assessment of the existing intersection equated with the high-volume traffic per hour at the intersection during peak hours. The data were collected using a video camera from the site at peak hours for a period of 15 min, and then analysed using SIDRA 4.0 package. The use of SIDRA 4.0 showed that by increasing speed travel system, the average of delay and fuel consumption reduced.

Jang and Seung-Ju (2018) designed a traffic simulation system for minimizing intersection waiting time using SUMO and tried to reduce the time required for vehicle to arrive at their destination by making traffic flow smoothly without any expense such as road expansion through the limited system. The starting point for simulation was set at Dang Eui University and the terminal point was set at the entrance to the Hwangryung Tunnel of Busan Metropolitan City and constructed road information link with e-World. The study will be extended to estimate the actual time required for future research.

Nyame-Baafi et al. (2018) established study of volume warrants, based on a delay threshold, to guide the installation of left turn lanes at un-signalized T-intersections by calibrating VISSIM model using traffic flow, delay, average and maximum queue length data obtained from a two-hour video recording during the morning peak period. Measured data were recorded and averaged over 10 simulation runs. After calibration, the VISSIM tool was used to perform two simulation experiments which were designed for the development of the minor road left turn volume warrant and major road left turn volume warrant based on delay threshold. This study serves as a guide that can be used by metropolitan and municipal road engineers to assess the need for left turn lanes. The conclusion was made that the VISSIM intersection model of the study T-intersection was successfully calibrated to reflect field flow conditions indicating that there was no significant difference between the field and the simulated results.

3. CONCLUSION

Digital simulation of traffic flow is virtually essential to traffic control at a near-optimum level. Only from a simulation analysis, analytical decisions can be made concerning street development, type of intersection control, and the feasibility of computerized traffic control. The objective of this study was to compare and contrast the traffic simulators for traffic simulation. All software programs have the ability to perform traffic simulations for the various operational conditions. It was felt that each package has strengths and weaknesses that made it suitable for certain applications, depending on the type of transportation improvement or planning analysis being considered, specific area of interest or problem and required output needed at field; available or collected field data. Though most software can perform equally well, VISSIM and CORSIM are two widely analysed and used traffic simulation software. These have found to be performing quite well in varied scenarios.

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