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Urban Road Traffic Simulation Techniques

For achieving a reliable traffic control system it is necessary to first establish a network parameter evaluation system and also a simulation system for the traffic lights plan. In 40 years of history, the computer aided traffic simulation has developed from a small research group to a large scale technology for traffic systems planning and development. In the following thesis, a presentation of the main modeling and simulation road traffic applications will be provided, along with their utility, as well as the practical application of one of the models in a case study.

Keywords: *traffic, simulation, optimization*

1. Introduction

Generally, simulation is defined as a dynamic representation of some parts of reality, through building a computer model and translating it in time.

Simulation programs are continually evolving from a local level application or a single facility offering application to big systems, at a network level, with many facilities integrated within it. Another trend that needs more and more computing power is the very thorough description of the network's physical diagram, which has lately led to the integration of the GIS and CAD systems within the simulation models.

Simulating the traffic control systems is a very important approach once the researches within the telematics in transports area are evolving and intelligent transportation systems like urban traffic control based on traffic responsive schemes are implemented. They are interacting with the traffic, therefore the control systems' reactions as well as the drivers' need to be described in a realistic and precise manner.

Simulation models offer more flexibility than programs designed exclusively for traffic analysis and can be used themselves for a large scope of analysis applications, such as interactions between different types of means of transport, high occupancy vehicles operations or public transport priority systems.

2. Road traffic simulation models

Intelligent traffic management with PTV Platform

PTV Traffic Platform is built on a modular architecture and provides intelligent methods for traffic analyses and forecasts. Thus, it represents the base for a large range of advanced traffic management applications. The platform is capable of modeling the current traffic conditions in a precise and dynamic way, relying on real time information.

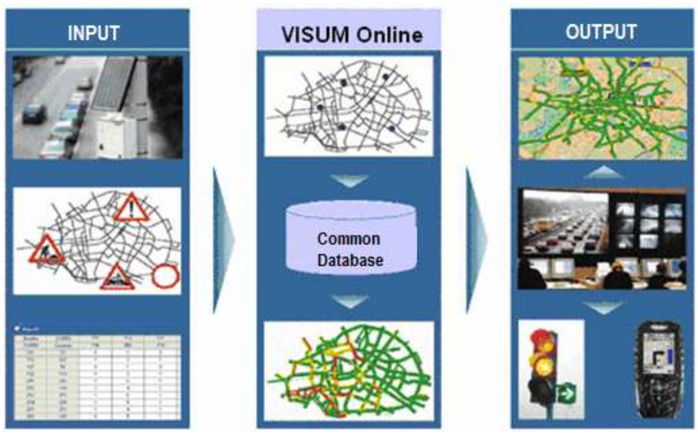

Figure 1. PTV Traffic Platform – Modules and applications

PTV Traffic Platform allows the traffic management centers to access information related to traffic flow and events. Furthermore, it offers the possibility of forecasting traffic conditions on short or medium term. In order to obtain precious inputs regarding the traffic situation, the combination of the data collected from various sources is a must. We can mention in this category: traffic detectors and counters, events related information, FCD (Floating Car Data) and cellular networks' information, messages received from the vehicles in traffic.

Over the last 25 years, PTV focused on developing software tools to satisfy the needs within the transports area, from traffic analyses to real time traffic management. These tools share many common elements, such as: road network geometry, volumes and traffic control systems.

PTV Vision integrates these software tools in order to increase projects' efficiency and offer full scalability for what concerns the transports organizations' requirements.

VISSIM is a microscopic simulation model, part of PTV Vision software set. It is one of the most powerful tools available for simulating multimodal traffic flows, including cars, trucks, buses, trains, trams, bicycles and pedestrians. Its flexible structure offers the possibility of modeling any kind of geometrical configuration or operational behavior of the drivers within the transport system.

VISSUM is a flexible and easy to understand software tool for transports planning, traffic request modeling and road network management. It is used worldwide for planning applications at a metropolitan, regional or national level. Designed for multimodal analysis, VISUM integrates all the relevant transport means (cars, public transport, high occupancy vehicles, trains, motorcycles, bicycles and pedestrians) in a unique network model.

PTV Vision brings together macroscopic analyses within VISUM and microscopic traffic simulation offered by VISSIM. The two programs cooperate very well, allowing error minimization and time sparing. The traffic volumes can be obtained with VISUM and then exported to a microscopic simulation. Together, VISUM and VISSIM help at analyzing the transport scenarios efficiency, including multimodal transport, route selection and operational impact. VISUM users can take advantage of the microscopic details of VISSIM in order to better understand the critical and crowded parts of the network. Or, they can only use VISSIM for graphical processing and 3D visualizing of its results.

CORSIM – microscopic traffic simulation model

CORSIM application comprises 2 microscopic simulation sets, which together create the entire traffic environment. NETSIM represents urban traffic and FRESIM highway traffic.

Microscopic models simulate the individual vehicles' movements, including the influence of the driver. The effect of the very detailed strategies such as moving the bus stations or changing the parking restrictions can also be studied with this kind of models.

CORSIM applies a time steps simulation technique in order to describe traffic operations. Each step is equal to a second and each vehicle is a distinct object that is moving during this second. All the traffic control systems and events within the network are updated every second.

CORSIM is a stochastic model, meaning that random numbers are assigned to each driver, vehicle or decision process. The efficiency measures obtained are the result of a specific set of random numbers used by the model.

Synchro and SimTrafic – a software set for urban traffic networks modeling and optimization

Over the last years, Traficware developed some of the most powerful and used traffic simulation tools. Synchro and SimTrafic create the software set that provides a complete solution for modeling and optimizing urban road traffic networks.

Synchro is a macroscopic analysis and optimization model that allows the user to introduce information in a single file. Other tools require a different data file for each signalized junction, hardening the data management. Having all the information needed in a single place, a direct analysis of the network capacity can be obtained, allowing the user to achieve a measure of delays, traffic queues and other traffic parameters based on mathematical equations. Synchro can also optimize traffic signals within a controlled traffic network and will try to minimize the delays and unplanned stops.

SimTrafic applies micro-simulations and animated representations on vehicles within the traffic network, modeling journeys through signalized or non-signalized intersections, on urban roads or highways, using cars, buses, bicycles and pedestrians. SimTrafic is generally used for analyzing traffic signals systems and queues estimation, especially in critical areas within the network.

Synchro 6 introduces a new type of traffic analysis called *Queue Interactions*, used for approaching the topic of capacity reduction caused by the traffic queues which are extended between consecutive intersections or which are blocking one or more traffic lanes.

TRANSYT simulation and optimization model

TRANSYT is an offline, macroscopic and deterministic model developed by TRL for simulating and optimizing traffic viewed as cyclic flow profiles (CFP) and following the evolution of these CFPs within the network.

TRANSYT applies systematic changes for what concerns the offsets of the signals (the stage change time when the change to green for stage number 1 is initiated), phase separation and cycle times, simulating the attached traffic conditions in order to estimate a performance index (PI).

The performance index is a weighted combination of the delay and stops on all the links in a network, representing the cost of the traffic congestion. The PI is calculated using the following formula:

$$PI = \sum_{i=1}^{N}\left(W \cdot w_i d_i + \left(\left(\frac{K}{100}\right) \cdot k_i s_i\right)\right)$$

where:
N = number of links
W = total cost for the average delay (Passenger Car Unit per hour)
K = total cost at 100 PCU/h
w_i = compensation for the delay on link i
d_i = delay on link i
k_i = compensation for the stops on link i
s_i = number of stops on link i

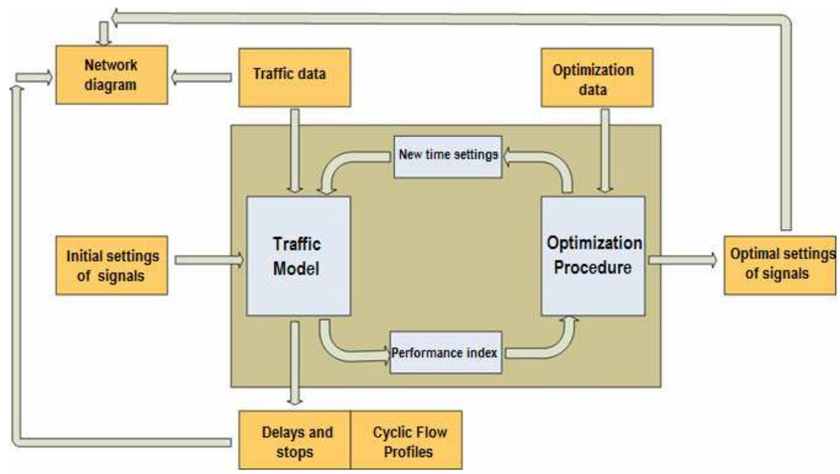

Figure 2. TRANSYT modeling tool main structure

TRANSYT has 2 main components: a traffic model and an optimization procedure.

The traffic model refers to the traffic within a network where the majority of the intersections are signalized and it estimates a performance index for the entire network, for any fixed traffic signal plan and average traffic flow.

The optimization technique adjusts the signal times and checks whether the proposed modifications improve the performance index. By exclusively adopting the changes that minimize the value of the performance index, efficient settings of the signal times can be achieved.

3. Urban traffic modeling and optimization application using TRANSYT 12 simulation tool

TRANSYT 12 modeling tool will be used in the current section to simulate 3 consecutive intersections and find efficient solutions for optimizing the local traffic flow.

The model will first use the real data collected from the field in order to highlight their impact on the chosen network, the size of the vehicles queues and the performance index value. Then, we shall study the outputs provided by the 2 optimization options available in TRANSYT:

- EQUISAT routine results – EQUISAT produces a specific sets of times based on the cycle length initially established by the user (ignoring the sets of stage change times used as an input) so that the saturation flows on the critical links is equalized and the overall cost of the network (PI) is reduced;

- CYOP optimization application results – CYOP modifies both the stage change times and cycle length in order to decrease the total network load degree; in its output file there are two tables with proposed values for the cycle lengths for each intersection (node) together with the corresponding saturation flows and performance index values. CYOP doesn't impose the usage of a particular time set, but offers the user the possibility to choose one or try different options.

Table 1. Stage change times for the 3 nodes

Semaphore	Node	G	Y	R	Y
1	Node 1	40	2	30	3
2	Node 1	30	2	40	3
3	Node 1	40	2	30	3
4	Node 2	30	2	40	3
5	Node 2	40	2	30	3
6	Node 2	40	2	30	3
7	Node 3	40	2	30	3
8	Node 3	40	2	30	3
9	Node 3	30	2	40	3
10	Node 3	30	2	40	3

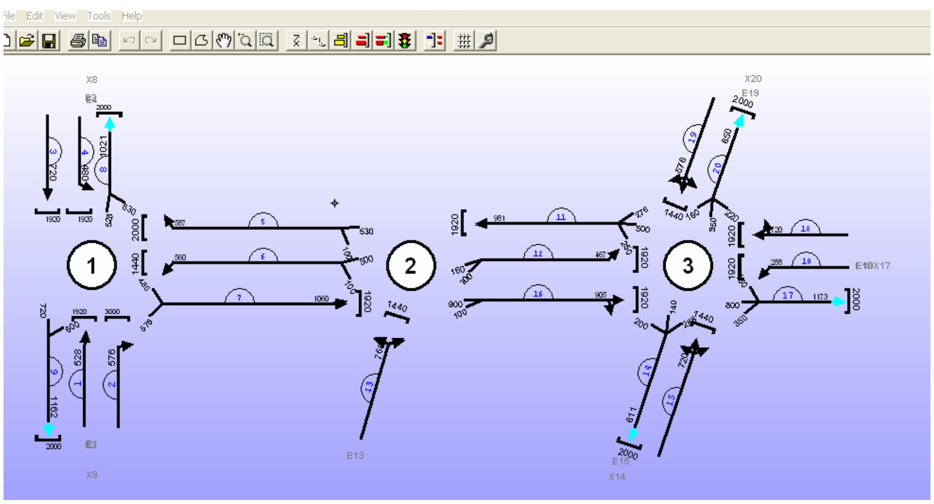

Figure 3. NetCon diagram – graphical representation of the network

After designing the network using the graphical user interface of the tool (Net-Con diagram) and running the simulation we get an output file that specifies the input data, calculations related to traffic emissions evaluation, travel time estimations, delays, fuel consumption and the performance index (PI).

For the values used in this simulation (table 1), the resulting PI is 1,076.3 $/h.

Next we will analyze the traffic queues charts on some links inside the network, indicating their evolution during the cycle time countdown. The vertical axis represents the queue limit measured in PCU (Passenger Car Unit) and the horizontal axis represents the cycle time, separated on green and red time. Several parameters, such as green capacity, PI for the current link and for the entire network, are mentioned on the left hand side of the chart.

On top of the chart there is a green/red representation of the upstream links (if any) also mentioning the traffic flow injected on the current link.

Figures 4 and 5 show the way queues are formed on links 1, 6, 4 and 13.

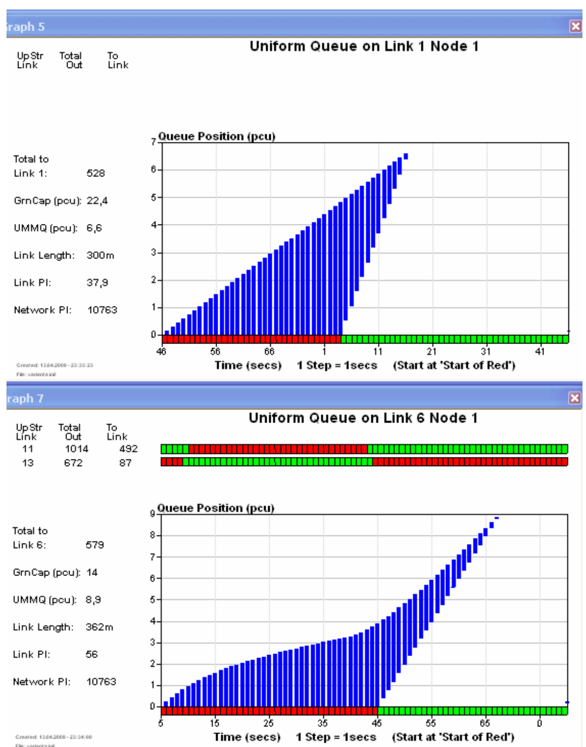

Figure 4. Traffic queue length on link 1 and 6

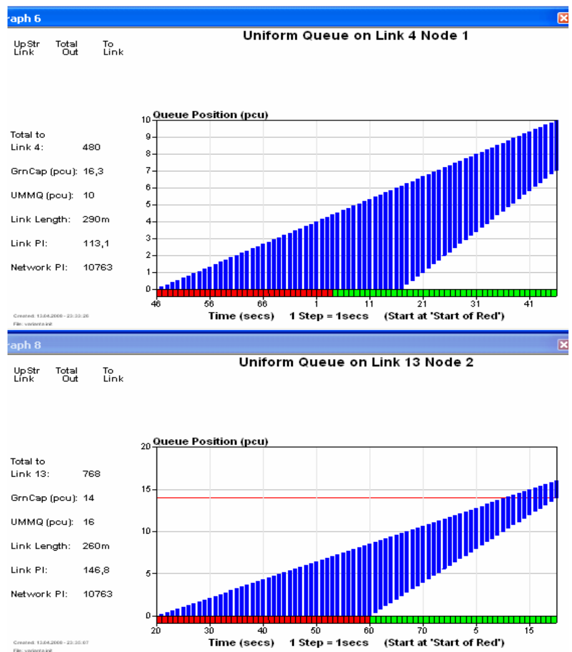

Figure 5. Traffic queue length on link 4 and 13

The traffic queues formed during the red light on the links number 1 and 6 (figure 4) are discharged during the next green light, therefore these 2 links are not congested.

It's not the case on links 4 and 13 (figure 5), where the queues formed during the red light are not able to completely discharge during the green light. One valid explanation for this situation would be that vehicles on link 4 are executing a left turn but are using the same green time as the traffic flow going straight ahead, therefore are obliged to give way to the traffic on the opposite direction. If this one is considerably high, it is only natural that the link number 4 won't be discharged during the green light.

Another difficult situation is on link number 13. This link has a dedicated green light stage, but comprises only one lane for traffic executing both turns and going straight ahead. The red line in figure 5 means that the traffic queue exceeds the green capacity anyway, so this is truly a critical link.

Traffic optimization using EQUISAT routine

After having analyzed the output of the model using the stage change times implemented in the field, the next step is to run the application again, choosing EQUISAT optimization option. As a result, the stage change times have been modified and the performance index value is now 1039.8 $/h. In order to achieve this reduction of the PI, other links have been sacrificed. Figures 6 and 7 show how congestion on links number 4 and 13 and continues to be high as they are not able to discharge during the green light.

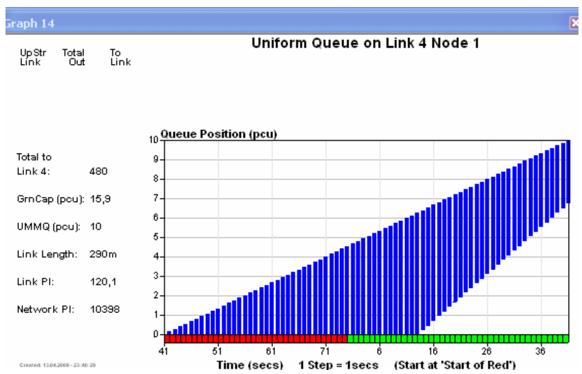

Figure 6. Traffic queue discharge rate on link 4

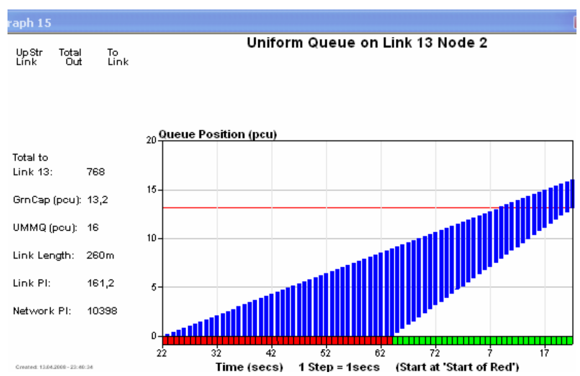

Figure 7. Traffic queue on link 13 stays critical

Traffic optimization using CYOP program

CYOP modifies the cycle length to 180 seconds, increasing consequently the stage change times of each node.

Analyzing the queue lengths charts, there is an obvious improvement on link number 4 in comparison with the previous 2 runs of the program. It's not the case for link 13 nor of the performance index which has gone considerably up, to 1812.8 $/h.

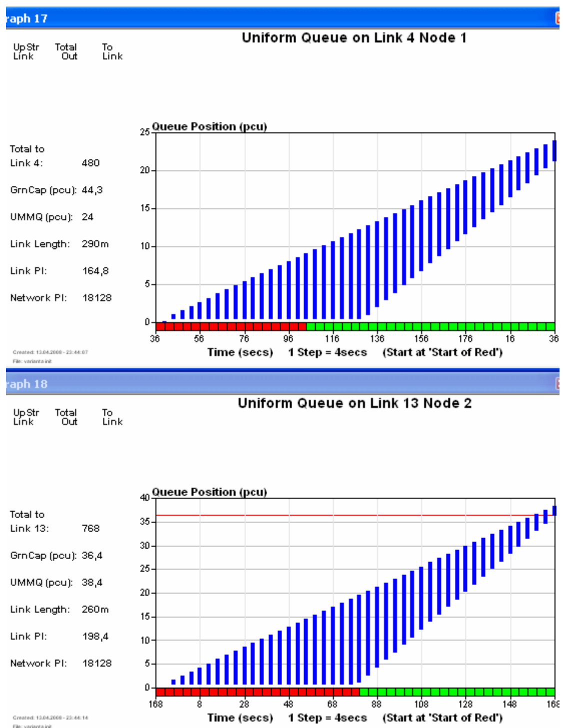

Figure 8. Traffic queues on links 4 and 13 after running CYOP

The big advantage of CYOP is the range of options it provides for the network cycle length in its output file, along with the saturation and performance index value. Based on this file, the traffic engineer can try different cycle times and also take an action on other signaling parameters such as sub-areas combinations, double cycling, repeated green possibilities and stage sequences.

Taking again the steps followed in the first part of the analysis and running TRANSYT once more, a lower PI can be obtained (1014.2 $/h). Then, if we choose to use EQUISAT for the optimization process, we get an even lower PI of 930.5 $/h and with a double cycling option for the nodes, the level of congestion on the critical links of the network can be efficiently reduced (figure 9).

Table 2. New stage times using a cycle length suggested by CYOP

Semaphore	Node	G	Y	R	Y
1	Node 1	50	2	40	3
2	Node 1	40	2	50	3
3	Node 1	50	2	40	3
4	Node 2	40	2	50	3
5	Node 2	50	2	40	3
6	Node 2	50	2	40	3
7	Node 3	50	2	40	3
8	Node 3	50	2	40	3
9	Node 3	40	2	50	3
10	Node 3	40	2	50	3

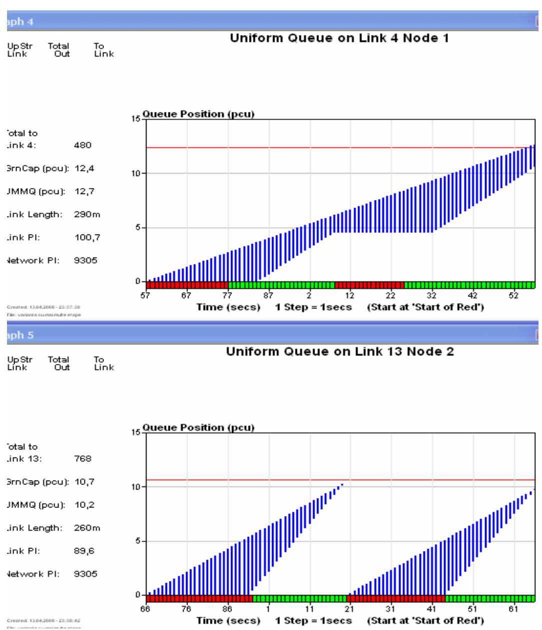

Figure 9. Traffic queues on links 4 and 13 after running EQUISAT with the new cycle length selection

4. Conclusions

In conclusion, the recommended signaling option for the 3 intersections after the optimization steps followed in the simulation and optimization application above, is, at user's choice, one of the last two alternatives offered by TRANSYT using EQUISAT and CYOP, starting from a set of times and cycle length suggested by CYOP after modeling the real values in the field and also the usage of double cycling for the simulated nodes.

Of course, the optimization may continue by trying other cycling lengths suggested by CYOP and different sets of stage change times that might improve even more the traffic flow and decrease the congestion level within the network.

Currently, it is a matter of judgment when certain modifications can bring general benefits to a network. The traffic engineer has to decide what stage change times sequence can represent a viable solution for the considered traffic network and then use TRANSYT in order to analyze and compare the optimization options.

Traffic simulation models play a vital role in evaluating the complex traffic situations that cannot be analyzed through other means. Simulation tools offer the possibility of evaluating traffic planning and control strategies without wasting important time and financial resources required by their physical implementation in the field. By using these modeling applications, traffic engineers can study multiple alternatives in a fast and uninterrupted way, by avoiding risks, costs or time consuming field experiments.

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