Tools for Operations Planning (TOPL2)

Pravin Varaiya  
*University of California, Berkeley*

California PATH Research Report  
UCB-ITS-PRR-2009-39

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation, and the United States Department of Transportation, Federal Highway Administration.

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Final Report for Task Order 6614

September 2009  
ISSN 1055-1425
**Tools for Operations Planning (TOPL2)**

**Final Report for PATH TO 6614**

**Pravin Varaiya**

Department of Electrical Engineering and Computer Science

University of California, Berkeley CA 94720

Tel: (510) 642-5270, Fax: (510) 642-7815

varaiya@eecs.berkeley.edu

July 25, 2009

**Abstract**

TOPL is a suite of tools to specify operational improvements including ramp metering, incident and demand management, auxiliary lanes, traveler information, and to quickly estimate the benefits that such improvements can realize. TOPL is based on the macroscopic cell transmission model (CTM). Advances under TOPL2 can be classified under (1) theory, (2) software and algorithms, and (3) applications.

In terms of theory, the CTM model for a freeway was thoroughly analyzed and extended to arterials. In software, the major advance was the development of Aurora—an object-oriented simulation framework. The major application of the theory was to congestion pricing and control. Aurora was used to simulate I-880. The versatility of Aurora was exhibited by its use to simulate an arterial, signal control, and to model sensors. Significant theoretical and empirical progress was made in the statistical imputation of ramp data in the absence of actual measurements.

The website of the TOPL project is [http://path.berkeley.edu/topl/](http://path.berkeley.edu/topl/)

*Keywords: corridor management, macroscopic simulation, cell transmission model, model calibration; imputation of ramp flows; arterial simulation; Aurora; object-oriented macroscopic simulation*
2. Summary of accomplishments

TOPL is a suite of tools to specify, design and evaluate operational improvements. Central to TOPL is the simulation package, Aurora, based on the macroscopic Cell Transmission Model or CTM. The accomplishments under TO 6614 can be classified under three headings: theory and application of CTM; development of Aurora; application of Aurora.

During the period of performance project reviews were held with Caltrans staff and others on March 23 [11] and June 22, 2007 [14], March 8 [6] and June 20, 2008 [1]. The cited presentations give a summary of progress.

2.1 CTM theory

A complete mathematical analysis of CTM is conducted in [16]. The most important finding is a structural property that the freeway divides into segments delimited by bottleneck links. A bottleneck link is defined by flow equal to capacity. In each segment, congestion proceeds upstream from the bottleneck. Figure 1 illustrates the property: the freeway is divided into three segments, $S^0$ is uncongested; $S^1$ and $S^2$ are congested; links $I_1$ and $I_2$ are bottleneck links with flow $f$ equal to capacity. This structural property simplifies the study of the traffic flow.

![Figure 1 Freeway is divided into segments delimited by bottleneck links.](image)

2.1.1 Tolls

This property provides the basis of a proposal for tolls, presented in [15], which presents a scheme that combines ramp metering and tolls. The scheme offers drivers two options. A driver may choose to pay a toll and bypass the ramp queue or not pay a toll but wait in the queue. This scheme is more efficient and more equitable than the common practice of converting an entire lane into a toll lane (as done e.g. in SR91). It also requires less costly infrastructure to implement. However, it does assume that the entire freeway is managed.

2.1.2 Arterials

An important extension of the CTM freeway model is the CTM model for arterials. The basic idea is that the signal phase determines the capacity of the link: in the green phase the capacity equals the saturation flow and in the red phase the capacity is zero [18]. This model has been incorporated into Aurora.

2.1.3 Signal control

Modeling for signal control has started with very preliminary work in [2,18,21].

2.1.4 Sensor models

References are listed at the end of this report.
Controller performance based on simulation models can be unrealistic because the controller has direct access to the roadway state in the simulator. A better simulation requires a model of the sensor. A preliminary model is found in [18].

### 2.2 Aurora Development

Aurora is the simulation engine for TOPL [10,12,24]. It supersedes CTMSIM, the simulation engine developed under TOPL1 [13].

![Figure 2 Aurora architecture. Source [6].](image)

Figure 2 summarizes the Aurora architecture. It comprises three parts. The first part imports GIS (or other) data from which the “GIS Importer” extracts the freeway network geometry in the Aurora XML format that describes the network in terms of links and nodes. The second part is the “Aurora Configurator” which is used to make manual changes in the network necessitated either because of errors in the GIS data or for modeling convenience. The output of the Configurator is the Aurora XML configuration. Together with various scenarios of demand and incidents, the resulting application is run by the Simulator. The results are used in performance reports. Presentation [6] illustrates how this system is used.

In summary, Aurora comprises three sets of tools. OpenJUMP and GIS Importer are used to create the preliminary network. The Configurator is used to make corrections and produce the final network. The Simulator runs the application.

### 2.3 Applications

During the period of performance two freeways were modeled: 210E/W and 880N/S. The results are presented in [6], from which we reproduce the findings for 880N of Figure 3. This 48 mile long freeway is modeled as an Aurora network with 148 links, 42 source nodes (on-ramps) and 35 destination nodes (off-ramps). Noted on the map are two major bottlenecks at 23/29 Ave and Tennessee.
Figure 4 shows the results of one simulation. The contour plots on the right of the figure depict flow, density and speed for a 24-hour period across the entire freeway. Clearly visible are the two major bottlenecks.

The panel on the left of figure 4 gives performance in terms of travel time, VMT, VHT, delay and productivity loss. These plots are produced as the simulation runs. Therefore “travel time” is instantaneous travel time calculated under the assumptions that anyone departing at the current simulation time will face the current speed profile for the entire journey. This is incorrect of course. The true travel time can only be evaluated at the end of the simulation. However, this instantaneous travel time is what is posted in the 511 system. The other performance plots can indeed be calculated as the simulation proceeds.

It is important to observe that the simulation over a 24-hour period is completed in less than one minute. This will be important in the use of Aurora to assist real-time operations as several scenarios can be simulated to provide strategic decision support for operations.

The presentation [6] explains how Aurora could be used to evaluate ramp metering policies as well as the impact of changes in demand.
2.4 Data concerns

Aurora is data-driven. The CTM model fundamental diagrams are automatically calibrated from freeway data [1]. The demand profiles at each on-ramp are automatically obtained from ramp data. The ‘split ratios’ are automatically computed from off-ramp and mainline data. That is the ideal picture. In practice, the effort is plagued by poor data.

There are no off-ramp data for 880 and 210. This appears to be the case throughout Caltrans freeways. In many cases, especially in D4, on-ramp data are missing. As a result, both on- and off-ramp data have to be imputed from the available mainline data. We have a procedure for doing this [3].

Even mainline detectors often have poor data: detectors are not functioning or they report erroneous measurements. It is time-consuming to detect erroneous detectors.

The result is that instead of being data-driven, Aurora is data-with-manual-adjustment-driven, which is undesirable. (The data problems with microsimulation are obviously orders of magnitude worse.)

Lastly, although arterials were not seriously modeled in this period, the lack of arterial data will be an obstacle in the next period.

If Caltrans is planning to move towards corridor management in a serious way, attention towards a comprehensive and reliable data measurement system should have the first priority. Furthermore, a good
detection plan should be based on the needs of ramp metering as well as performance assessment. This is not at present the case.

2.5 Other work
In addition to the main tasks summarized above, the TOPL team initiated several other directions of work.

2.5.1 Training
Three training sessions were held to make interested Caltrans personnel familiar with TOPL. Two of these were ‘webinars’ conducted over the internet. In addition there was a training session in D7 [2] and one in D4. Although a great deal of effort was expended in preparing the training material, it is fair to say that the reception was mediocre: there did not seem to be any appreciation of what the tools could provide.

2.5.2 Swarm
We have implemented an early version of Swarm in Aurora. Its performance compares poorly with Alinea, also implemented in Aurora.

2.5.3 Traffic assignment
Although O-D estimation and resulting trip or traffic assignment is outside the TOPL principle of data-driven models, we have initiated a theoretical study [8,23].

2.5.4 Transmodeler
The CSMP program has been committed to the use of microsimulation models, chiefly based on Paramics, although Transmodeler is gaining attention because it offers both ‘microscopic’ and ‘mesoscopic’ simulation models. (In that terminology, Aurora is a mesoscopic.) We have compared Transmodeler mesoscopic and Aurora simulations of a very simple CTM network which can be directly mathematically analyzed [1]. The Transmodeler simulation is poor, primarily because it models congestion via ‘point’ queues, so that spatial propagation of congestion is not visible. The Aurora simulation is faithful.

3. Conclusions
At the end of the second year of the TOPL project, the Aurora freeway simulation framework has been established, many features have been added for performance evaluation, and preliminary investigation of arterials has begun. In comparison with micro-simulation and the Transmodeler mesoscopic simulation packages, TOPL provides a much more versatile tool for CSMP studies.

Two outstanding concerns remain. First, the current freeway detection system simply does not provide reliable, comprehensive data on which a serious freeway management program can be based. (Arterial data are virtually non-existent.) Second, there appears not to be a commitment or capacity to ameliorate freeway congestion that the corridor program intends.

Acknowledgement
TOPL is supported by the California Department of Transportation through the California PATH Program. The contents of this paper reflect the views of the author and not necessarily the official views
or policy of the California Department of Transportation. The results reported here are due to the TOPL Group, especially Andy Chow, Gunes Dervisoglu, Gabriel Gomes, Roberto Horowitz, Alex Kurzhanskiy, Jaimyoung Kwon, Xiao-Yun Lu and Ajith Muralidharan.. It is a pleasure to acknowledge the criticisms and encouragement of John Wolf, Pat Weston, Nicholas Compin and Carlos Ruiz of Caltrans; Alex Skabardonis of PATH; Tarek Hatata of System Metrics Group; and Vassili Alexiadis of Cambridge Systematics.

References
All references are online at http://path.berkeley.edu/topl/docs.html.

Presentations

Papers

Tech Reports

**Dissertations**