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Project Summary Report 7-3943-S

Project 7-3943: Simulation of Congested Dallas Freeways

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# Simulation Model Performance Evaluation for Congested Freeway Operations

PROJECT SUMMARY REPORT

Recent and continuing growth has resulted in increased demand for travel on urban freeways across Texas. Many freeways are operating under congested conditions throughout much of the day. Proposed operational improvements for these freeways are difficult to evaluate or to simulate accurately because of the increased effect of vehicle interactions and impact of design elements on traffic flow, which occur under congestion. Improvements in recent years to traffic models offer promise in the simulation of congested freeways and freeway elements (e.g., ramps, merges, and weaving areas).

The more promising models simulate vehicle interactions, lane changing, car following, and vehicle rerouting; accommodate origin-destination information; and in general try to model driver behavior. However, the lack of a universally accepted model for simulating congested conditions highlights the need for a study to determine which models produce the best results under different congested conditions. See Figures 1 and 2 for sample data output. The objectives of this research were to select appropriate models for simulating congested freeways, test the calibration and validation performance of those models using data collected on Dallas freeways, and provide recommendations for the use of the best model for congested freeways in Texas.

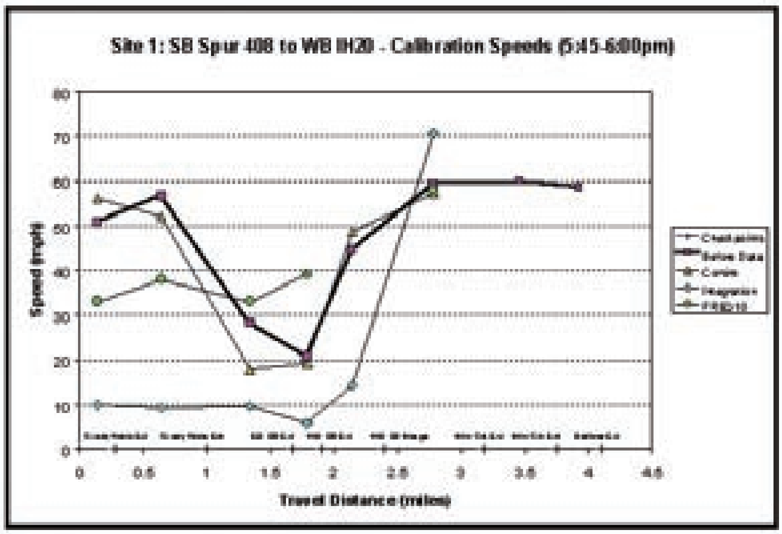


Figure 1. Sample Calibration Data.

## What We Did…

We first performed a comprehensive literature review. This effort focused on reviewing research performed in the previous 10 years that was relevant to project objectives. The primary areas of interest were:

- speed-flow relationships for uncongested and congested conditions on freeway facilities,
- freeway simulation model documentation, and
- studies of freeway simulation model applications.

Two methods were used to gather information for these focus areas. The first method involved obtaining published studies. The second method involved utilizing information from Internet web sites and user guides for the simulation models included in this research.

The next task was to select the simulation models that would be included in this project. We decided to select three simulation models in order to have a good basis for comparison. To choose the most promising models for inclusion in this project, the research team developed several selection criteria and considerations. Based on these criteria and considerations, with input from and approval of the project director and advisory team, we selected FREQ, INTEGRATION, and CORSIM.

The next task was the selection of sites to test and evaluate the chosen simulation models. As with the model selection process, we decided that three sites would be selected for the model evaluation in order to have a good

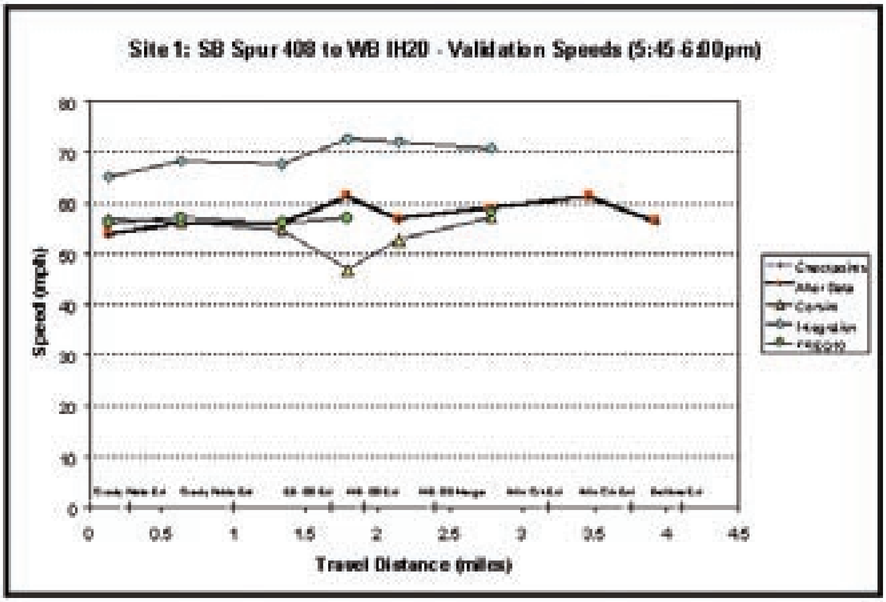


Figure 2. Sample Validation Data.

basis for comparison. Out of a candidate list of 10 sites developed by the research team and presented to the project director and advisory team, three sites were selected for this project:

**Site 1** – southbound Spur 408 to westbound Interstate 20

**Site 2** – eastbound Interstate 635 (LBJ Freeway) to northbound US 75 (Central Expressway)

**Site 3** – northbound State Highway 360 between Mayfield and Randol Mill

FREQ, INTEGRATION, and CORSIM were used to simulate the base case conditions (i.e., before the bottleneck improvement) for each of the three sites. The base case used the default parameters contained within each simulation model. The base case evaluation of the models for the three sites shows how well they perform without any adjustments or other calibration measures.

We then attempted to calibrate the three models using the data collected before the implementation of any bottleneck improvements. For FREQ we made adjustments to the design (i.e., free-flow) speed and the main lane and ramp capacities at each site. For INTEGRATION we made numerous adjustments to the jam density, free-flow, and speed-at-capacity values within the model. The ramp and main lane volume capacities were increased based on the recommended values in the *Highway Capacity Manual*. For CORSIM we varied several parameters during the calibration process. Specifically, we lowered default values to produce more aggressive driver behavior. We also modified the time to execute a lane change, the minimum separation for generation of vehicles, and the percentage of drivers desiring to yield the right-of-way.

We compared the output from the three calibrated models with the speed and volume data for each site. We validated the models at each of the sites by applying the calibrated parameters for each model. We changed only the input volumes and the physical freeway networks within the calibrated models for each of the project sites to reflect the geometry after TxDOT constructed the bottleneck improvement. The speed and volume output from the three validated models was compared with the data collected during field studies after the implementation of the bottleneck improvements at each site.

## What We Found…

The models all performed relatively well for uncongested conditions; however, the performance became sporadic and mostly unreliable for congested conditions. It appears that the models function better when allowed to begin simulation prior to the onset of congestion. Having data upstream and downstream of a freeway bottleneck (each of the three sites in this project had congestion caused by geometric bottlenecks) or for a location of recurrent congestion helps the models perform better. Having data for several time periods before congestion starts (e.g., having data for 6:00 to 6:30 a.m. when congestion begins at approximately 6:30 a.m.) is also helpful.

It is apparent that people drive differently in congested versus uncongested conditions. None of the models tested allowed the user to dynamically change key model parameters (e.g., headway, lane changing, and driver behavior) to account for this driving difference.

Much of the theory of flow in congested conditions is relatively new and therefore is still evolving. This evolution means that many of the findings of the research that is occurring internationally have not been incorporated into the logic of any of the simulation models evaluated in this project.

None of the models fared particularly well in the validation phase, even when the model calibration results were promising. This result could be occurring because the volumes used in the validation phase are higher and the model does not fully recognize the benefit of the capacity provided by the bottleneck improvement. The unpredictable and less-than-desirable performance of the models in congested conditions leads to the conclusion that the members of the research team would trust engineering judgment over the simulation model output in most cases. This is because each of the sites selected was, in fact, a success story for bottleneck removals that the models did not predict.

### FREQ Model Results

The inability of the FREQ program to model vehicle speeds on freeway-to-freeway ramps was a significant detriment. This inability caused the evaluation of Sites 1 and 2 to be less complete than the other two models. The FREQ model seemed to perform its best on Site 3 because it involved simulation on only one freeway facility whereas the other sites required simulation on two facilities.

The FREQ program was the most user friendly in terms of ease of use and application. The ability to specify capacity on a link-by-link and ramp-by-ramp basis was also a feature that made the model attractive for freeway operations applications. In most cases, FREQ could not be calibrated to replicate known field conditions (especially link speeds) within a reasonable accuracy level (±5 mph).

**INTEGRATION Model Results**

The INTEGRATION model required the most effort in terms of network coding and execution. The requirement that input volumes be specified in terms of origin-destination data made it more difficult than either CORSIM or FREQ. INTEGRATION also was difficult to run (i.e., long execution times) and even failed to run for the Site 3 network because it was too large and complex. INTEGRATION exhibited the worst overall performance in terms of being able to replicate known speed and volume profiles.

A variety of measures were attempted to improve the model; however, none of the adjustments significantly improved the overall performance of the model. One explanation for the poor performance may be that the version of INTEGRATION used in this project (purchased from McTRANS in September of 1998) is not the most recent version available. An updated and improved version of the INTEGRATION program (Windows based, August 1999) became available too late to be used within the scope of this project.

**CORSIM Model Results**

The CORSIM simulation model was the most robust in terms of input and output capabilities. The TRAF-VU animation program is an invaluable source of information to the user when attempting to determine if the model is performing as expected and for verifying that the network is coded properly (see Figure 3). Several limitations were identified during the use of the FRESIM component of the CORSIM software.

The limitation that was most frustrating was that capacity is not an input or output variable. This distinction made the model hard to calibrate because the user never knows capacity. Capacity could not be adjusted on a link-by-link basis as with the other two models included in this project. Another frustration encountered while using this model was the fact that output values were reported on a cumulative basis over the time periods. This made it difficult to examine each time slice separately.

The calibration of CORSIM was most easily done by modifying parameters such as car-following sensitivity, lane changing, driver aggressiveness, etc., which are all very important in evaluating operations in a congested environment. The calibration adjustments suggested that drivers in the Dallas/Fort Worth area are more aggressive than the default driver distribution in the model. CORSIM still seems to have a problem with a significant number of vehicles missing their assigned destinations (i.e., exit ramp).

The CORSIM program had the best overall performance in this project and shows promise for future application for the operational evaluation of congested freeway facilities. CORSIM has dramatically improved in the past several years and is continuing to be refined and updated under the direction of the Federal Highway Administration (FHWA).

## The Researchers Recommend...

Of the models available to the research team the CORSIM model, which is part of the *Traffic Software Integrated System Version 4.2* (TSIS 4.2) from FHWA, showed promise in simulating congested freeway operations. We recommend that CORSIM be used at locations that are fairly simple geometrically, such as single freeway-to-freeway direct connection ramps similar to the direct connection studied at the southbound Spur 408 to westbound Interstate 20. More complex interchanges where ramps connect to other ramps, such as the eastbound and westbound ramp connection to northbound US 75, are difficult to code and may not be effectively simulated by the model.

The proper and effective calibration of CORSIM for a congested site requires that the users have good and extensive volume and travel time data, as well as origin and destination data. The user must collect data over a time period that begins prior to the onset of congestion and ends after the congestion has dissipated. Also, the data collection effort must extend over an area that covers the length of the traffic queues formed by the congestion. If the user cannot provide existing data or project future conditions, then the calibration and results of the CORSIM model cannot be expected to be reliable.

FHWA continues to improve CORSIM. Future versions should be more user friendly and should provide more reliable simulation of congested conditions. Improved versions of INTEGRATION as well as other models being developed may also provide effective and reliable simulations of congested freeways.

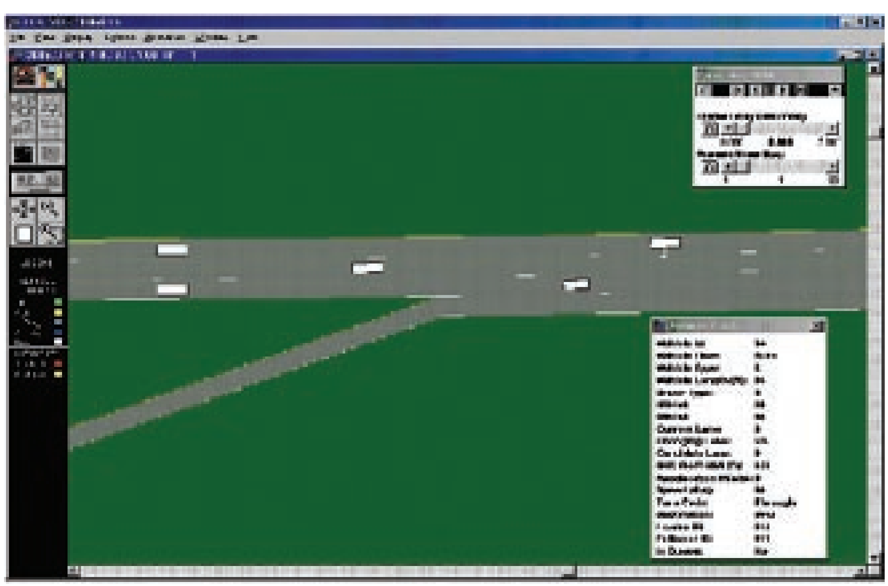

Figure 3. Example TRAF-VU Animation of CORSIM Network.

## For More Details . . .

The research is documented in Report 3943-1, *Evaluation of Simulation Models for Congested Dallas Freeways*.

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## TxDOT Implementation Status — December 2003

This research compared the performance of the CORSIM, FREQ, and INTEGRATION traffic simulation programs for modeling congested urban freeways in Dallas. Three different freeway sections with bottlenecks that caused recurrent congestion were selected to test and evaluate model performance. Before and after operational data, i.e., speeds and volumes, at each of the sites were used in the attempt to calibrate and validate the chosen models. The research team determined that all of the models performed relatively well for uncongested conditions; however, the performance became sporadic and mostly unreliable for congested conditions. None of the models was successfully calibrated or validated for all of the test sites. The CORSIM model had the best overall performance in this project, but it was effective only on the simplest site.

Since the project terminated, TTI, TxDOT, and others have primarily utilized the CORSIM model to evaluate improvement options and existing conditions on freeway facilities in Texas. The CORSIM model, developed and supported by the FHWA, has continued to improve and be refined to better serve users. The results of Project 7-3943 assisted in the development of the Beginning CORSIM 5.0 and Advanced CORSIM training courses taught as part of the TRICOM implementation project. The beginning level course has been taught multiple times to TxDOT district and division staff to assist them in the application and review of CORSIM models.

For more information, contact Mr. Wade Odell, P.E., RTI Research Engineer, at (512) 465-7403 or e-mail wodell@dot.state.tx.us.

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