Improving Simulation Analysis with Cube Dynasim

An overview of how scenario-based simulation
increases efficiency and improves the quality of results

By Matthew Martimo

Introduction

Cube Dynasim is perhaps the most contemporary traffic microsimulation software available, and it embraces many advanced computing technologies and design approaches. Why? From the beginning, Cube Dynasim was designed with the user in mind. A question always foremost in the mind of the development team is: "How do end users want to work with simulation?" The Citilabs development team has worked hard to minimize the amount of time it takes to effectively build, run, manage, and complete simulation studies. To this end, one of Cube Dynasim's key benefits is that it is a *scenario-based* simulation. This feature also makes it a marketplace exclusive, as Cube Dynasim offers a completely different user experience than any other simulation. It provides a way to build, manage, and run an unlimited number of simulation alternatives. A scenario-based simulation system can save users huge amounts of time, effort, and money. In addition to improving workflow and usability, the scenario analysis capabilities of Cube Dynasim give the users the ability to provide a more in-depth analysis with more robust results than ever before.

Scenario-Based Simulation

Cube Dynasim provides a way to build, manage, and run an unlimited number of simulation alternatives in part by eliminating redundant data re-creation. Instead of managing directories of redundant simulations, the entire simulation project is built and managed within one file. Only changed parameters (e.g. traffic flows) need be entered for the new scenario, for the entire life-cycle of the project. This reduces the sheer volume of tedious data entry, as well as the chance to introduce human error.

Every element that is placed in a Cube Dynasim simulation is assigned to a layer (similar to any CAD system). When it comes to analyzing different network scenarios, the user simply incorporates the changes into a new layer. The actual network that is simulated is simply a compilation of the layers that are appropriate for that alternative. Similarly, scenarios may be created for Vehicle Flows, Signal Timings, and Public Transit Systems.

When running a simulation alternative, the user simply mixes and matches what Network, Vehicle Flows, Signal Timings, and Public Transit System should be used for that alternative. So, very quickly, all the Networks in the project (Base, w/public transport Line A, w/public transport Lines A+B, …) may be tested with all of the different Flow scenarios (AM peak, PM peak, Weekend Peak, Forecast Year, …).

Network Scenarios

The Network Scenario may be assembled in Cube Dynasim or linked to network data available in GIS files, traffic analysis data files, or other Cube functional libraries. A network scenario is composed of:

1. A layer set defined as a subset of the available layers, which contain all the network elements for a particular alternative.
   Layers allow the analyst to generate any number of geometric alternatives for evaluation by combining the different layers in different combinations. For instance, a Base layer may be used to code up all portions of the network that will remain unchanged throughout the scenarios. Then, the area under consideration may be coded in separate layers for each alternative. In this way, all the network scenarios share the Base layer and only differ in the area under development. If an error is found in the Base layer, the fix is automatically propagated through all the scenarios sharing that layer. Redundancy is eliminated. File maintenance and data verification become negligible. There is never a need to maintain separate files of the same network.
2. A background map input as either DXF CAD files or image files in nearly any format. Construction or as-built CAD drawings may be used directly by Cube Dynasim and the displayed layer set may be selected within Cube Dynasim. Multiple background maps may be developed from a single DXF file by employing different layer sets. Multiple images may be used within a single background map to tile large areas or establish images to be viewed at different resolutions. Cube Dynasim provides for scale dependent display. It will automatically determine which images are appropriate for the viewable area. Large low resolution images will be automatically selected while zoomed out and smaller high resolution tiles will be used when zoomed into a single intersection.

Flow Scenarios

In many studies, it is important to evaluate the study area during different times of the day, days of the week, or seasons of the year to learn the broad effect of a project or design alternative on an area. Special event traffic or forecasted traffic volumes may also be evaluated to determine the impacts from proposed changes to the geometry or operating characteristics of the transportation network. Cube Dynasim makes this simple by managing the different periods as unique vehicle flow scenarios. These flow scenarios can then be associated with any of the network scenarios within the same Cube Dynasim project

Vehicle Flows are entered as origin-destination matrices. Separate matrices are provided for each vehicle class by time period. Cube Dynasim links directly to information available from other functional libraries within Citilabs' Cube suite. Cube Dynasim can also read matrix information from any other program in a text format.

Signal Scenarios

Cube Dynasim has an extremely flexible graphical interface for designing signal operations to be implemented within the simulation. Signal scenarios may also be linked directly to available data from other functional libraries within Citilabs' Cube suite or to common traffic engineering and analysis software. In addition, Cube Dynasim provides a customized user interface to easily handle the ring-based signals commonly found in North America and Asia.

Cube Dynasim has a library of detectors including Passage, Presence, Queuing, and Check-in-Check-out detectors. These, combined with the graphical signal system, allow users to emulate nearly any type of signal control including actuated signals and preemption systems.

Like the other aspects of the simulation, as many different signal scenarios as desired may be created within a Cube Dynasim project to evaluate the effects of optimizing or adding signals as well as implementing new technologies for actuation or preemption.

Public Transport Scenarios

A public transport scenario contains all the rail and bus services. These are coded with the routes, stops, and the volume and mix of vehicle types on that route. Any type of vehicle may be represented including buses, articulated busses, light-rail and heavy-rail vehicles.

Public transport data may be linked to other functional libraries within Citilabs' Cube suite. By employing a scenario based approach for simulation, separate scenarios may be created to quickly test the impacts of:

- Increased frequencies
- Route changes
- Additional routes
- Changes in the fleet or types or vehicles

Project Management

In order to demonstrate the process of managing a simulation project in Cube Dynasim, a small project will be used as an example. In this project, a small study is being conducted to evaluate the reconstruction of a 3 mile section of a major arterial roadway which currently has two-lanes in each direction and 5 signalized intersections. The project will examine the possibility of replacing the existing geometry with a smaller roadway with one lane in each direction and replacing the signalized intersections with roundabouts.

As work on this project begins, traffic volume counts are conducted in the AM and PM peak period. Therefore, the simulation geometry representing the 'Existing Scenario' conditions is developed and this is tested with the AM and PM traffic volumes. The simulation is calibrated to the observed delay and queuing data. Then, the traffic for the forecast years is entered to create AM and PM alternatives for the years 2008 and 2028. Finally, the alternative network geometry, 'Scenario 4', with one-lane each direction and roundabout in the place of signalized junctions is developed. In the end, 12 simulation alternatives are being considered.

With most traffic analysis and simulation software packages these 12 alternatives would each exist in their own data file. However this process of developing each alternative independently results in a tremendous amount of redundancy. Contrast this to Cube Dynasim where the entire project is developed and maintained in a single project file. When examining this small project, there are two different networks. With Cube Dynasim, redundancy is eliminated. Instead of maintaining these networks over and over again in 12 files, they exist only once. As do the unique flow scenarios. When it comes time to run the simulations, each of the flow scenarios can be paired to both networks.

This method of simulation development saves a great deal of time by eliminating all the redundancy. However, as work on this project continues, it is found that in order to properly design these roundabouts, additional land must be acquired by the city as the intersection at the extreme southern end of the corridor. Because of the additional time and expense involved with

this acquisition, it is requested that the simulation analysis be expanded to include a new 'Scenario 4a' which will evaluate replacing the intersection control with roundabouts at only four of the five intersections and leaving the existing signalized configuration at the last junction.

Because this will be evaluated with the six different unique flow scenarios that were applied to the previous two scenarios, six new simulation alternatives must be developed. In most traffic analysis and simulation programs this would mean six additional data files and at a minimum additional work to develop the new network alternative and import each of the traffic flows. In Cube Dynasim all the data required for the new scenarios is already available. The network scenario is created by selecting the layers for the roundabout geometries at the first four intersections and that is matched with the layer containing the existing geometry at the last junction. No additional coding of any kind is required. This new network scenario is then matched to the already developed flow scenarios to set up the six additional simulation alternatives. Because all the data already existed in the project, these new scenarios were able to be created, simulated, and the output data compiled in less than an hour.

Data Maintenance

The time and effort saved using Cube Dynasim's scenario-based approach to network development can be significant. In addition to that, the amount of time saved in maintaining the simulation alternatives can also be significant, even exceeding the savings had during network development. In almost every project, mistakes will be made and later discovered in the simulation. In most traffic analysis and simulation programs the effort involved in correcting an error in a network that exists in more than one alternative becomes a significant effort. However, as error replication becomes a big issue, the bigger issues become issues of consistency where several independent scenarios need to be changed in the same way. With Cube Dynasim this is never an issue because as the scenario-based simulation eliminates redundancy, it also guarantees consistency. If a mistake is found, it is updated in one place. The change automatically is incorporated into all the dependent simulation alternatives.

With the project described here, as the roundabout design team was evaluating the completed simulations, they found the following result. The simulated traffic making the west-bound-through and left movements at the third roundabout was intended to employ a process of two-stage gap acceptance. Drivers were able to yield to the exiting traffic and then move out onto an island where they could then yield to the circulating traffic independently. This was a small change to the network which required updating the results from all the roundabout scenarios related to both Scenario 4 and Scenario 4a. In most traffic analysis and simulation programs this would mean that 12 independent data files had to be updated. With Cube Dynasim, the network layer was updated and as a result, the twelve simulation alternatives were updated automatically. Cube Dynasim highlighted the simulation results that were no longer consistent with the network and they were re-simulated.

Improving Results

Cube Dynasim saves users a great deal of time and effort when they are:

1. Building simulation alternatives
2. Adding additional simulation scenarios
3. Updating and correcting existing data

For consultants and other private sector users, these efficiencies make users more competitive by enabling them to bid less for projects using Cube Dynasim than they would if they had to complete the project in another software package. However, the competitive edge goes much farther than a simple savings in man hours. Cube Dynasim allows the user to produce much more robust results than what could be produced in most traffic analysis and simulation programs in the same amount of time. For public sector users, while they may not have the same competitive issue, they still benefit, by being able to do much more analyses in the same time period. Instead of spending their time on data preparation and maintenance, they can spend the time on more analysis, which can yield better decision making.

In the case of the project discussed above, the simulation demonstrated that the roundabout alternatives were a very viable alternative to the existing signalized arterial even though the roadway was being reduced from two-lanes to one. However, the decision makers remained somewhat skeptical. The concept of roundabouts at these junctions had not gained overwhelming support from the local residents. The decision makers feared that the roundabouts would not be able to perform as well as the simulation predicted. To ease some of the concerns and skepticism around 'forecast' traffic volumes, it was decided that additional flow scenarios could be analyzed to examine what would happen if the traffic volumes grew beyond the rate expected. Again in less than an hour, 10 new flow scenarios were evaluated incrementally increasing the 2028 forecast traffic volumes to discover at what point the traffic operation at the roundabouts begins to degrade. This resulted in 20 new simulation alternatives that were analyzed and it was found was that the roundabouts would continue to operate at acceptable levels even if the traffic forecasts were more than 20% off. These results were presented in a supplement to the analysis the following day.

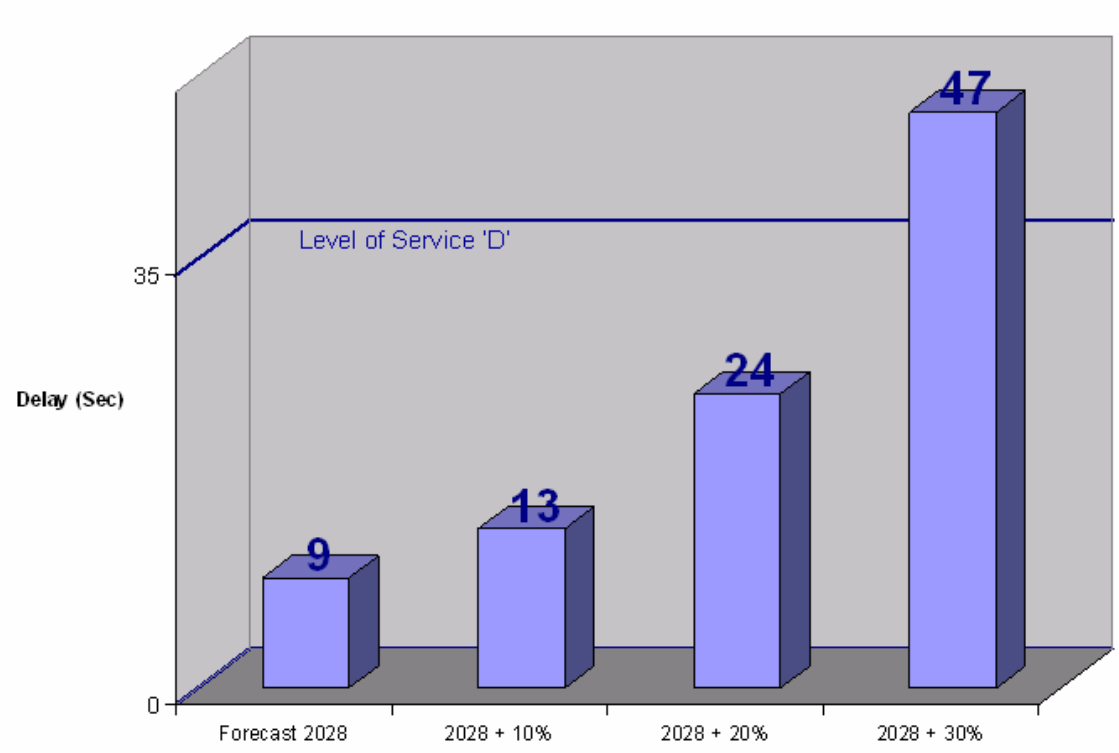

Figure 1 – Sensitivity Analysis of Alternative 4

Sensitivity analysis can add a great deal to almost any simulation project and is one of the best ways to test the robustness of proposed geometric designs. It is possible for a design to be adequate for the forecast year but shown to become inadequate when even a small change in assumptions is made. In this case, a sensitivity analysis would show the design fails if the traffic level is raised a few percentage points. However it is possible that some small changes during the construction could create a roadway that was proven against unexpected increases in the traffic levels. It is almost always a great deal less expensive to make some modifications during the initial construction than to have to go back out in the field after a few years and begin adding or lengthening exclusive lanes.

Analysis of the updated alternative 'Scenario 4a' with four roundabouts and one remaining signalized junction showed that although no additional land would be necessary the signalized junction failed in the forecast year 2028. With most projects that would be all the information delivered to the client: "The Alternative 4A was analyzed and determined to not be feasible for the forecast traffic in the year 2028 with a predicted delay of more that 180seconds for the Northbound traffic during the PM peak period."

However with Cube Dynasim in less than an hour an analysis was done to test the operations in 2010, 2015 and 2020. These results were also included in the supplemental report documenting the results for Alternative 4a. It was found that through 2015 the intersection behaved with an acceptable level of service. It was not until 2020 that it began to fail and from that point on worsened exponentially. The decision makers were pleased and it was decided that the rest of the corridor would be updated and that this intersection would be left to be examined again as part of the next transportation plan.

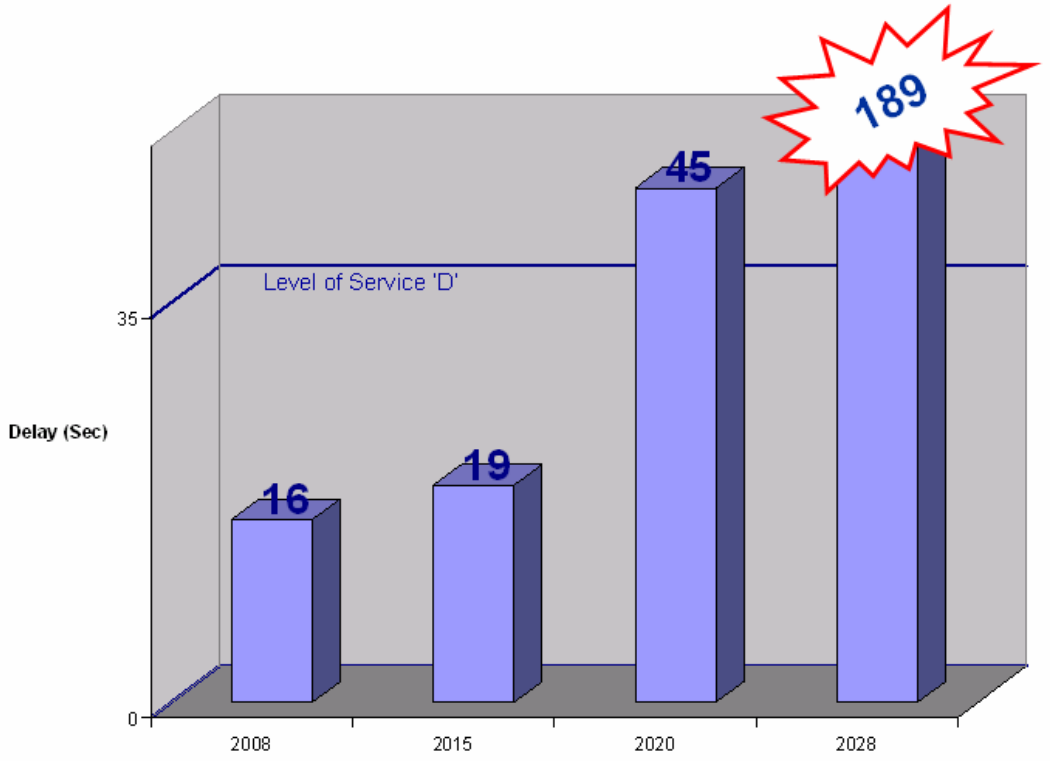

Figure 2 – Sensitivity Analysis of Alternative 4a

Conclusion

By incorporating the latest design trends and new information technologies, and coupling that with a development team which works very closely with traffic simulation software users, Cube Dynasim makes a large leap forward over many older, less robust traffic simulation packages. Its business case is not simply made by the questions: “What does this cost?” or “What does it do?” Rather, the key to understanding the benefits of Cube Dynasim are provided in the answers to these questions instead: “How much does it save by making *Professionals more Productive*?” and “How does it make communities better by allowing those same *Professionals to do more* analyses, and less data management?”