

# Introduction to Simulation in Cube

An overview of microsimulation and the unique features available only with Cube Dynasim.

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## Introduction

Analytical models are widely used to analyze transportation projects and the many ‘what if’ scenarios that surround them. This is done to optimize projects and to identify solutions that will best meet the goals set forth by the local community. As projects develop from planning to design to construction, the motivations for doing analysis using transportation models will change. Different aspects are considered, different output measures are needed, and therefore different types of models have been developed.

Generally, planning models are developed to answer ‘why’ a particular trip is being made and why the traveler selects a particular mode and route. This is done by modeling the population across an entire region. The behavior of the population is calibrated to existing conditions. Then the model may be used to test the impacts of changes in the population size or composition as well as changes to the transportation network. In contrast, models used to design the facilities and optimize the traffic operations are generally used to answer the questions of ‘how’ a facility will operate given the geometric characteristics of the network and the predicted volume of travel.

## Macro, Micro, and Mesoscopic Models

Practitioners describe different scales of transportation models. These are generally grouped into the three categories: macroscopic, microscopic, or mesoscopic. The difference between them pertains mainly to the scale at which the traffic flow phenomena are being represented.

The term ‘Macroscopic’ is used to describe the largest scale of modeling traditionally employed by planners to model all of the travel over a large regional area. To model an entire region in an efficient manner and complete the analysis in a reasonable amount of time, a macroscopic model makes many aggregations and simplifications of the system.

Generally, only basic roadway sections are considered and simple descriptions of the capacity are used to approximate the impacts of roadway size, intersection configurations, and different types of traffic control which are not explicitly modeled. The capacity of a roadway is an input value that the user supplies and is used to determine the travel speeds as a function of the traffic volume using the roadway. However this capacity will not strictly limit flow. As the volume of vehicles using a roadway approaches or exceeds the roadway’s capacity, the vehicles using that roadway will be slowed but will be allowed to move through. Macroscopic models can highlight roadways where demand exceeds the capacity and consider future conditions where there may simply not be enough capacity available for a growing population. Finally, regional models only consider the average flow throughout an analysis period and do not consider traffic fluctuations within a time period.

Microscopic simulation models on the other hand are at the opposite end of the spectrum. Generally speaking, microscopic models are able to model all modes of transportation found within the study area and explicitly consider each individual vehicle (or pedestrian) as it makes its trip. The simulation analyzes how vehicles behave as they interact with other vehicles, the traffic control, and the network environment. They possess detailed models describing how vehicles behave, taking into account the randomness associated with human behavior and the details of acceleration, deceleration, lane changes, passing maneuvers, turning movement execution, and gap acceptance.

The primary difficulty with microscopic simulation models is the inherent level of detail. The roadways must be described in detail. Each intersection must be defined including all the details of the traffic control operations and approach configurations. Then, all the traffic flow data must be available at the scale associated with the model; this is typically defined in periods of one-hour or less. Finally, the information describing other factors affecting the flow has to be described, including transit stop locations, parking maneuvers, and bike and pedestrian movements.

Mesoscopic models fall between microscopic and macroscopic models. They typically simplify the analysis by modeling vehicles as platoons or groups of vehicles. They can consider the dynamic nature of traffic flows and have the ability to enforce the estimated capacity of a roadway. Usually traffic control and approach configurations are considered although in a much simpler fashion than the microscopic models. Mesoscopic models have been developed to try and find a good balance between the traditional macro and microscopic models.

## **Motivations to Perform Microsimulation Analysis**

Microsimulation provides the ultimate in detailed analysis. Although they require more investment in time and detailed data, the benefit is that they very accurately reflect the operation that would be observed in the field. When properly calibrated, speeds, travel times, delays, and queuing results will be extremely reliable. In addition to the detailed numeric data results, one of the many side benefits of the detailed calculations is the ability to animate the movements of individual vehicles.

The network or flows may be changed and new technologies may be added in the simulated environment. Lots of scenarios and options can be analyzed. Once the simulation has been run, the user can 'see' the vehicles moving and witness the impact that decisions have on the traffic flow. These visualizations are simply the best technology available to convey to a non-technical the impacts of decisions that are being made. Practitioners may be to 'sell' an unconventional solution or to stimulate ideas and discussion. The tool allows the public to suggest their own solutions and then 'see' why their ideas may or may not work and what a better solution might be.

These realistic animations of vehicle movements may be combined with a 3D streetscape to create virtual worlds where not only operational changes may be discussed but also the audience can see what an entire development (or redevelopment) might be like and get a feeling of what it means to live, work, and play in the area. New roadways and bridges can be inserted into existing landscapes to show residents how the project will affect their property, view, or privacy.

The animations can mean a lot to technical audiences as well. There are many times that a project shows a moderate change to an output measure like the volume to capacity ratio. But it can still be very hard to truly understand the impact of the results. What does a V/C of 0.94 really mean? It is very near capacity. There is certainly congestion and queuing. But does it mean that there are 15 cars in the queue or 115? This is heavily dependant on the mix of traffic, their driving behavior, familiarity with the area, and the detailed roadway geometries and traffic control operation. There are many questions which are simply not able to be answered by conventional analysis or summarized with aggregate results. Only a microsimulation analysis can take into account the variations in traffic day to day, the variations in human behavior, and all the details of the transportation system.

The microsimulation models are forced to work within the constraints of our physical world. Even though a roundabout or loop ramp has two lanes, when a heavy truck is present there is very little room for any other vehicles. The impacts of the roadway geometries and the physical size of the vehicles have a tremendous impact that is not taken into account with macro or mesoscopic analysis. Only with a microsimulation can you adequately quantify:

- Benefits of new ITS and traffic control technologies
- Impacts of pedestrian and bicycle movements
- Operations of complex transit facilities
- Impacts of incidents and event traffic flows
- Parking lot operations
- On street parking alternatives

## How is Dynasim Different than other Simulations?

From the beginning, Cube Dynasim was designed with user productivity in mind. A question always foremost in the mind of the development team is: “What tasks or activities do end users perform in the course of preparing and running their simulations?” Citilabs has worked hard to minimize the amount of time it takes to effectively build, run, manage, and complete simulation studies.

Dynasim provides four key benefits that make it truly unique.

1. Dynasim is completely integrated within the Cube system. This provides seamless data transfer from other GIS systems, databases, traffic analysis software programs, as well as the other Cube libraries.
2. Dynasim is a scenario-based simulation. Dynasim offers a completely different user experience than any other simulation providing a way to build, manage, and run an unlimited number of simulation alternatives. Instead of managing directories of redundant simulations, the entire simulation project is built and managed within a single file. A scenario-based simulation system saves users huge amounts of time, effort, and money.
3. With any microsimulation the numeric results are paramount. But because of the randomness in human behavior, any microsimulation model must be run a number of times for any particular scenario. Dynasim is unique in that whether the

## Introduction to Simulation in Cube

simulation has to be run five, ten, or one-hundred times, the amount of work for the user is the same. Tell Dynasim how many runs to perform and it does the runs, compiles the results, and generates summary statistics.

4. One of the terrific byproduct of the microscopic simulation is the animations that provide the analyst and decision makers with a clear understanding of the consequences of alternatives. What makes Dynasim unique is that Cube Dynasim allows users to export and compile animations and results into a single executable file. This DynaViews file may be freely distributed and shared with clients, decision makers, or the public.

### ***Integration with Cube***

Dynasim is a fully functional stand-alone simulation. However the integration with Citilabs' Cube suite has many advantages.

The primary advantage is that Cube provides a gateway that allows the user to take data from any source and link it to the microsimulation. Agencies have invested so much in creating GIS databases. Now that data can be put to work and used to expedite the simulation process. Data from other data sources, files, traffic and planning programs can be accessed and used for simulation.

Most of that data we have access to is not natively prepared for the microsimulation. The other Cube functional libraries like Cube Voyager and Cube Analyst can be utilized to perform many types of preprocessing and analysis to prepare input data for the simulation. All of these processes once defined by the user are then available to be used day to day in an agency as part of the standard work flow. Applications are frequently developed to automate standard tasks such as:

- Corridor and sub-area studies
- Disaggregating and enhancing macroscopic model results
- Smoothing traffic count data
- Estimating origin-destination matrices from traffic counts and origin-destination surveys
- Preparing for 'special event traffic'
- Estimating impacts of construction activities
- Forecasting traffic count data using the regional model
- Calculating realistic traffic flows to be generated by new developments
- Quickly running deterministic analyses across entire networks
- Performing sensitivity analysis
- Creating GIS based maps of simulation results
- Comparing simulation results across scenarios
- Archiving data

This integration provides a complete transportation software solution.

### **Scenario-Based Simulation**

Cube Dynasim provides a way to build, manage, and run an unlimited number of simulation alternatives. Instead of managing directories of redundant simulations, the entire simulation project is built and managed within one file. A scenario-based simulation system saves users huge amounts of time, effort, and money.

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 determines the specific scenario make-up using the following key elements:

- Network
- Vehicle Flows
- Signal Timings
- Public Transit System

This allows many Network configurations in the project to be tested quickly. (e.g. Base, w/public transport Line A, w/public transport Lines A+B) with all of the different Flow scenarios (e.g. AM peak, PM peak, Weekend Peak, Forecast Year). A scenario-based simulation system is an extremely powerful tool that saves large amounts of time developing and maintaining the simulation alternatives.

### **Network Scenarios**

The Network Scenario may be assembled in Cube Dynasim or linked to network data available in 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 very easily 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 (BMP, JPG, TIF, SID). Construction or as-built CAD drawings may be used directly by Cube Dynasim and the displayed layer set may be selected within

## Introduction to Simulation in Cube

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 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 simulate the study area during different times of the day, days of the week, or seasons of the year. 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 (NEMA/170) signals found in North America.

Cube Dynasim has an entire library of detectors including Passage, Presence, Queuing, and Check-in-Check-out detectors. These, combined with the graphical signal system, allow users to perfectly 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 of vehicles

### ***Automation of Repetitive Tasks***

In real life, traffic flows vary from one day to the next but fluctuate around an average value. Cube Dynasim performs a microscopic, stochastic, event based simulation. The simulation produces vehicle movements on the network according to realistic driver behavior based on statistical observations. The fluctuations experienced day to day are reflected run to run. It is necessary with ANY stochastic microsimulation to perform multiple runs and statistical analyses of the results.

The ability to simulate multiple runs of a scenario is inherent to Cube Dynasim and all results are compiled and necessary statistics are calculated automatically saving the user time in compiling and analyzing results. Statistics can be calculated anywhere in the system by placing data collection points in the strategic areas of the simulation. Graphics are provided showing Vehicle Flows, Travel Times, Queues, Speeds, Delays, etc. All statistics may be stratified by time of day and location. These charts may be saved for incorporation into study reports.

### ***Animations and DynaViews***

The 2D and 3D animation produced by Dynasim may be viewed separately or together as the vehicle movements are identical in all views. These visualizations provide the analyst and decision makers with a clear understanding of the consequences of alternatives. The animations are 'live' and may be viewed at any speed. The user is free to maneuver about the 3D space. There is no need to compile the animations or create movie files. Animations played in the 2D view may be visualized on background maps. Images from any view may be captured and used in reports and presentations.

The 3D animations may be visualized on the background maps or the user may supply their own 3D landscapes. These little or as much detail as is appropriate for the project. Users may choose to include terrain features or building heights to create cityscapes which provide realistic viewsheds from any particular visual point of reference. Digital photos of existing buildings and other infrastructure may be added as facades to the 3D shapes to enhance the simulation of reality. Dynasim uses landscapes in 3DS format, a standard format similar to DXF or SHP and written by any 3D creation program. Users can easily create their own 3D landscape using whatever program they prefer.

After a simulation project is complete or throughout the review process, Dynasim allows users to export and compile the animations and results into a single executable file. This executable file may be freely distributed and shared with clients, decision makers, or the public. When the DynaViews file is run a menu appears showing all the exported scenarios. The animations can then be played and the data reports and graphs for the scenarios can be viewed.

## Introduction to Simulation in Cube

With DynaViews, a virtual visit of the site is provided and is the perfect solution for public presentations. Kiosks can be set up at project open houses and the public can be allowed to run and view the simulation. The animations in DynaViews offer all the same features as Cube Dynasim and the users are free to maneuver about and zoom-in on what is most critical for them.