ACTIVITY

25 Microsimulation Models and the Traffic Control System

READING

Purpose

The purpose of this activity is to give you the opportunity to learn more about microsimulation models and how they can be used to study the traffic control system.

Learning Objectives

- Describe the common categories of transportation models and their attributes
- Describe the characteristics of a microscopic simulation model
- Contrast the performance measures produced by a simulation model

Deliverables

- Define the terms and variables in the Glossary and complete all Glossary items
- Prepare a document that includes answers to the Critical Thinking Questions

Glossary

Provide a definition for each of the following terms. Paraphrasing a formal definition (as provided by your text, instructor, or another resource) demonstrates that you understand the meaning of the term or phrase.

microsimulation model	
network	
performance measure	
traffic analysis tool	
VISSIM	

Critical Thinking Questions

When you have completed the reading, prepare answers to the following questions.

1. Why do you think it is important to use a microsimulation model to evaluate the performance of your design network?

2. What performance measures do you think are important to evaluate the signal timing alternatives that you develop?

3. What can you learn from the numerical performance data and the visual observations of the simulation model to help you evaluate the performance of a signal timing alternative?

Information

What is a Model?

A model is a representation of reality that allows us to study a system, to ask questions about the system and its components, and to change the conditions or features of the system and to observe how it will then behave. A model is especially useful for studying transportation systems since we are often asked to consider a range of possible solutions to a given problem and to see how the system will behave under the conditions of each solution. We can classify a model according to a set of categories, each describing attributes or features of a model. Table 11 lists seven ways in which a transportation model can be categorized.

Table 11. Model categories (adapted from Byrne, de Laski, Courage, & Wallace, 1982)

Model categories	Attributes and contrasts
Computational or simulation	○ **Computational:** Directly computes results from equations or tables ○ **Simulation:** Tracks events and processes
Empirical or analytical	○ **Empirical:** Based on field data ○ **Analytical:** Based on theory
Deterministic or stochastic	○ **Deterministic:** Produces same result for given set of inputs ○ **Stochastic:** Results can vary based on statistical distributions
Microscopic or macroscopic	○ **Microscopic:** Individual driver decisions ○ **Macroscopic:** Aggregated flow characteristics
Event scan or time scan	○ **Event scan:** Based on status of events of interest ○ **Time scan:** Updates made every time step
Evaluation or optimization	○ **Evaluation:** Performance data produced ○ **Optimization:** Objective function optimized based on performance data

We can also classify a model according to the complexity of the problem that it is designed to address, which we can see from Figure 96 is directly proportional to the difficulty of a given model to use. Some common problems considered by transportation engineers include:

- How many lanes will be needed to accommodate traffic volumes projected five years in the future?
- How much will delay increase at adjacent intersections if a new hotel or shopping center is constructed on this site?
- What signal timing plan will work best with this intersection design?

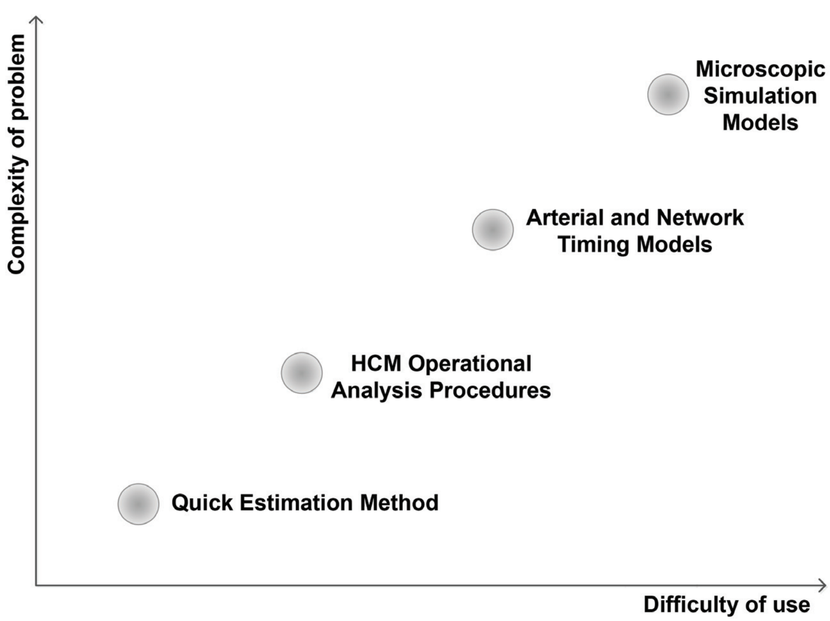

Figure 96. Model classification scheme (adapted from the *Traffic Signal Timing Manual*)

For problems that require only an assessment of whether an intersection has sufficient capacity or not, the Quick Estimation Method (sometimes called the *Critical Movement Analysis*) can be used. For single intersections or when volume is less than capacity, the Highway Capacity Manual (HCM) operational analysis procedures are appropriate. Arterial and network timing models generally produce optimized signal timing plans for a set of signalized intersections. Microscopic simulation models yield a high level of detail on system operation and performance, when details on signal timing plans are important to consider.

It should be noted that the HCM 2010 operational analysis procedure includes a realistic emulation of an actuated signal controller, in which phase sequencing and actuated timing parameters are considered. Thus there is some blurring of the distinctions that appear clear in Figure 96 as the capabilities of models and techniques are increased over time.

Why Use a Microsimulation Model

A microsimulation model *requires* a rich and detailed set of data to describe a traffic facility and its conditions. It requires calibration of the model to these local conditions. But it has the potential to *produce* a rich and complex set of data, both numbers and visuals, which represent how the facility is likely to operate and perform under the given set of conditions. The extent of the data required to run the simulation model, and the time required to develop and test a model network, means that a simulation model should be used to address only the most complex kinds of transportation problems for which very detailed information is needed on system operation and performance. Examples of these kinds of problems include:

- The demand exceeds capacity at an intersection, and the effect of this oversaturation spreads from one intersection to another
- The effect of a specific design element, such as the length of a left turn bay, needs to be tested
- The details of a timing plan for an actuated signal controller needs to be developed, tested, and evaluated

This latter problem is the primary subject of this book and the reason that you will learn to use the VISSIM simulation model.

We also can use a simulation model to visualize the operation of a facility under given conditions, something that is useful for both the traffic engineer and for the general public.

Components of a Simulation Model

A microsimulation model consists of three primary components: (1) input data that describe the facility and conditions of interest, (2) the ways in which users (drivers of passenger cars, pedestrians, or truck drivers, for example) interact with the system or facility, and (3) output data that describe how the system is expected to operate and perform.

There are three kinds of input data describing the facility and conditions, including flow characteristics of the users, the geometry of the facility, and the control system parameters. Examples of these data are given in Figure 97.

User flows	Facility geometry	Control settings
Vehicles/hour	Location of nodes	Phasing plan
Percent trucks	Number of lanes	Timing values
Pedestrians/hour	Lane assignments	Timing settings

Figure 97. Example input data for microsimulation model

A facility is represented by a network, a collection of links (representing streets or arterials) and nodes (representing intersections). Figure 98 shows an aerial view of an intersection while Figure 99 shows its link-node representation. Each link is specified by a length, free-flow travel time, capacity, and other relevant geometric and operational characteristics. A node is represented by its control characteristics such as the type of control and the elements that describe that control.

Figure 98. Aerial view of intersection

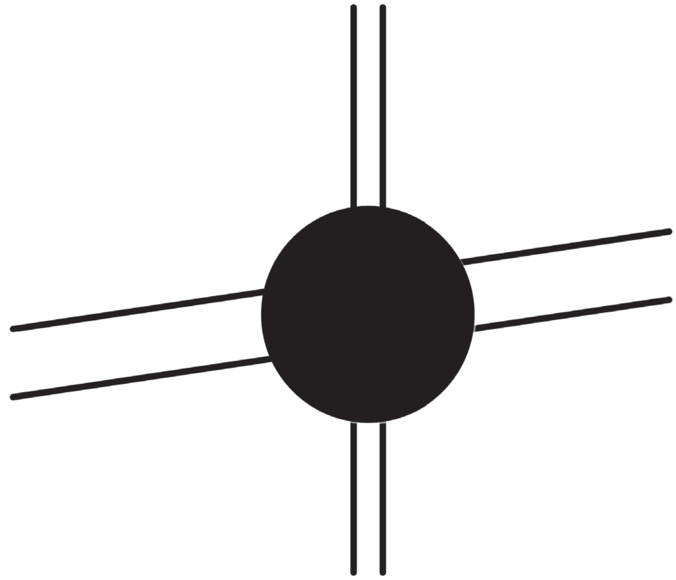

Figure 99. Link-node representation of intersection

Three of the ways in which the users interact with the facility include a range of driver behavior types, the ways in which a "following" vehicle responds to a "leading" vehicle, and the ways in which the user responds to the facility geometry and control system. For example, a user will decide to respond to a change in the control system display (a change in the display from green to yellow) depending on the driver behavior type, the speed that the vehicle is traveling, and the distance that the vehicle is upstream of the intersection. This latter factor was described earlier in this book (in Chapter 1 on the elements of the traffic control system) and is the basis for the construction of the traffic control process diagram.

Performance Analysis Using a Simulation Model

The data produced by a microsimulation model can be extremely detailed. For example, VISSIM can produce performance data for the network, for each intersection and its approaches, and for each movement on the approach. In the system view (Figure 100), the overall speed and delay are shown, as is the time that it takes to travel from one end of the system to the other. The average delay for the intersection approaches and for the individual movements (Figure 101 and Figure 102) provide additional detail that is important in evaluating how the individual components of the system are performing. These figures show a visual comparison of these three levels of data aggregation, each with an important part of the story on how the system is performing.

Figure 100. System performance data

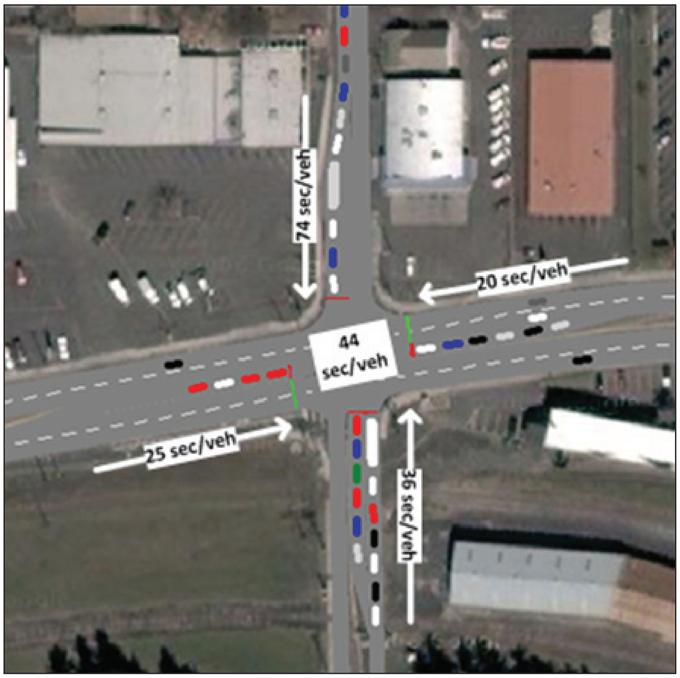

Figure 101. Intersection and approach performance data

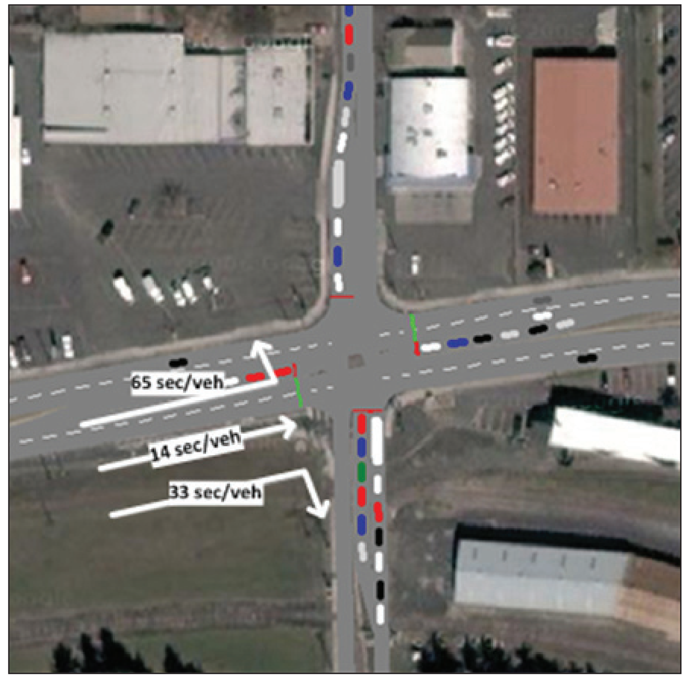

Figure 102. Movement performance data

An even more detailed representation of the system operation is shown in Figure 103 and Figure 104, where the position and speed of a single vehicle is shown. On the left, the table shows the position and speed of the vehicle every 0.1 second over a 1.8 second time interval. The figure on the right shows the time-space representation of these data over this same time interval.

Simulation time	x-coordinates	y-coordinates	Vehicle speed
10.0	-31.5	-347.0	33
10.1	-46.3	-344.5	34
10.2	-61.5	-343.1	34
10.3	-76.7	-342.7	33
10.4	-91.5	-343.2	33
10.5	-106.0	-344.8	32
10.6	-120.3	-346.3	32
10.7	-134.7	-348.9	33
10.8	-149.3	-351.4	33
10.9	-164.2	-353.8	34
11.0	-179.2	-356.2	34
11.1	-193.8	-358.9	33
11.2	-208.2	-361.5	32
11.3	-222.3	-364.0	32
11.4	-236.6	-366.6	33
11.5	-251.0	-369.2	33
11.6	-265.8	-371.9	34
11.7	-280.7	-374.5	34
11.8	-295.5	-377.2	33

Figure 103. Position and speed data for a vehicle

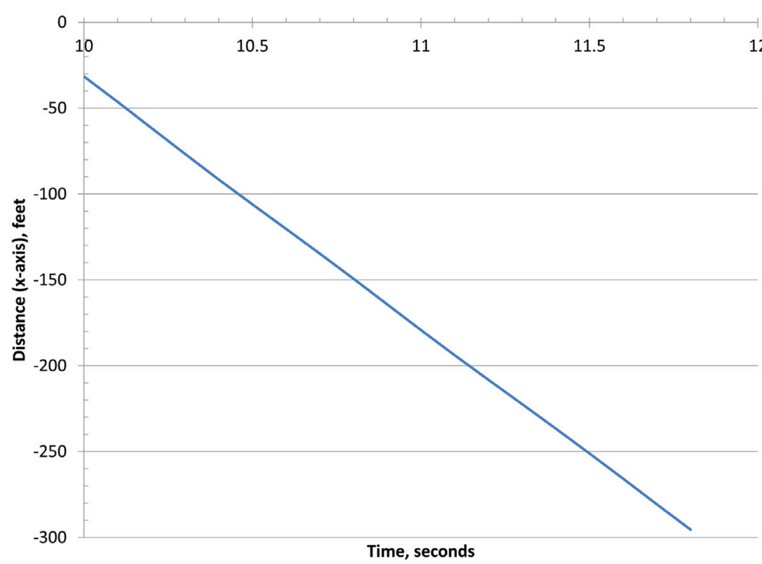

Figure 104. Time-space representation of position and speed

The fact that a microscopic simulation model produces a rich and detailed set of output data is both a strength and a weakness. The strength is clear: we can get a detailed picture of the performance of the system at a variety of levels. The downside is that the construction of this picture is difficult and often time consuming.

For example, suppose we are comparing two alternatives, a base case in which the cycle length has been set to 90 seconds, and a new option in which the cycle length is reduced to 60 seconds and the proportion of green time devoted to each movement is changed. Table 12 shows three system level performance measures in which these alternatives are compared.

Performance measure	Base case (C = 90 sec)	Option 1 (C = 60 sec; green times changed)	Percent change
Speed (mi/hr)	10	14	+37%
Travel time on arterial (sec)	29	21	–27%
Average delay/vehicle	24	16	–33%

Table 12. Example of system level performance data

It can be concluded from this comparison that the average delay per vehicle was reduced by 33 percent and that the average speed was improved by 37 percent. However, we need to look more deeply into the data to get a more comprehensive picture of the results of these changes. Evaluating the performance at the system level may mean that we miss some of the important changes and trade-offs that would occur in this change to the signal timing.

Table 13 shows the average delay per vehicle for each of the four approaches at this intersection. We can begin to see the trade-offs that would actually result from this change. Users on the main street (eastbound and westbound) would see reduction in their delay, while side street users would see an increase in theirs. Two points should be made here. First, we need to be able to define what amount of change in delay is significant and could be perceived by the user. Second, some increase in delay for the minor street may be acceptable for both policy reasons (we often emphasize the quality of flow on the main street) and because volumes are often significantly lower on the side street than on the main street.

Approach	Delay (sec/veh)	
	Base case (C = 90 sec)	Option 1 (C = 60 sec; green times changed)
Northbound	8	13
Southbound	14	21
Eastbound	22	13
Westbound	30	18
Average for system	24	16

Table 13. Example of approach level performance data

Drilling down one more level provides even more insights on the difference in performance of the base case and the signal timing change as shown in Table 14. We can now see that the main street through movements (eastbound and westbound) have improved more significantly than was evident when just looking at the approach data. Further, we may have made delay to the minor street left turn movement too high, unfairly penalizing these users. This may point to a further refinement that is needed to the timing plan that we have developed as part of Option 1.

How do we know the quality of service that is delivered to the various users of this intersection? One standard, given in the Highway Capacity Manual (HCM), provides level of service ranges that can be used to provide a relative performance standard that we can use to compare the base case with Option 1. In this case, the level of service improves for some of the main street (the east-west) movements, while it stays the same or degrades from some of the minor street (north-south) movements.

System component	Delay, sec/veh (level of service)	
	Base case (C = 90 sec)	Option 1 (C = 60 sec; green times changed)
Approach		
Northbound	7 (A)	11 (B)
Southbound	13 (B)	19 (B)
Eastbound	12 (B)	19 (B)
Westbound	13 (B)	17 (B)
Movement		
NBLT	5 (A)	10 (A)
NBTH	11 (B)	15 (B)
NBRT	5 (A)	10 (A)
SBLT	4 (A)	8 (A)
SBTH	20 (B)	30 (C)
SBRT	4 (A)	4 (A)
EBLT	10 (A)	5 (A)
EBTH	30 (C)	15 (B)
EBRT	10 (A)	10 (A)
WBLT	25 (C)	19 (B)
WBTH	35 (C)	20 (B)
WBRT	5 (A)	5 (A)

Table 14. Performance data

Visualization and Numeric Data

The final step in the description of the performance of a system, and in the comparison of a base case with a proposed change, is what you would "see" in the field and how you would describe what you see. You could use such descriptions as:

- The standing queue on the eastbound through lanes clears before the end of green
- The traffic on the southbound left turn lane backs up out of the left turn pocket, thus delaying all traffic on the southbound approach
- Much of the green time on the eastbound through lanes is not utilized indicating a possible misallocation of time for this approach and the others
- Vehicles on the westbound through lane must wait through two cycles

This gets us to the final step in the "learning to see" process, integrating the visual observations that you make (and your description of them) with the numerical data that you collect in the field or from a simulation model. You will learn in this chapter when you construct your simulation model to see both the "visual" and the "numbers" and the conclusions that you can make from one reinforcing the other.

Learning to integrate the visual and the numbers also takes us to the experience of the traffic engineer, and understanding the connection between the traffic controller and its effect on the user. What do you see in the field and thus what should you change in the traffic controller? This is learning to be in the mode of the traffic engineer standing in the field: one eye on the traffic flow and other on the controller. Making these connections is what this chapter is all about.