

## Chapter 5 Evacuation Application and Evaluation

### 5.1 Evacuation Application in Blacksburg Study

In this chapter we present an evacuation simulation model for the neighborhood that is depicted in Fig. 5.1.

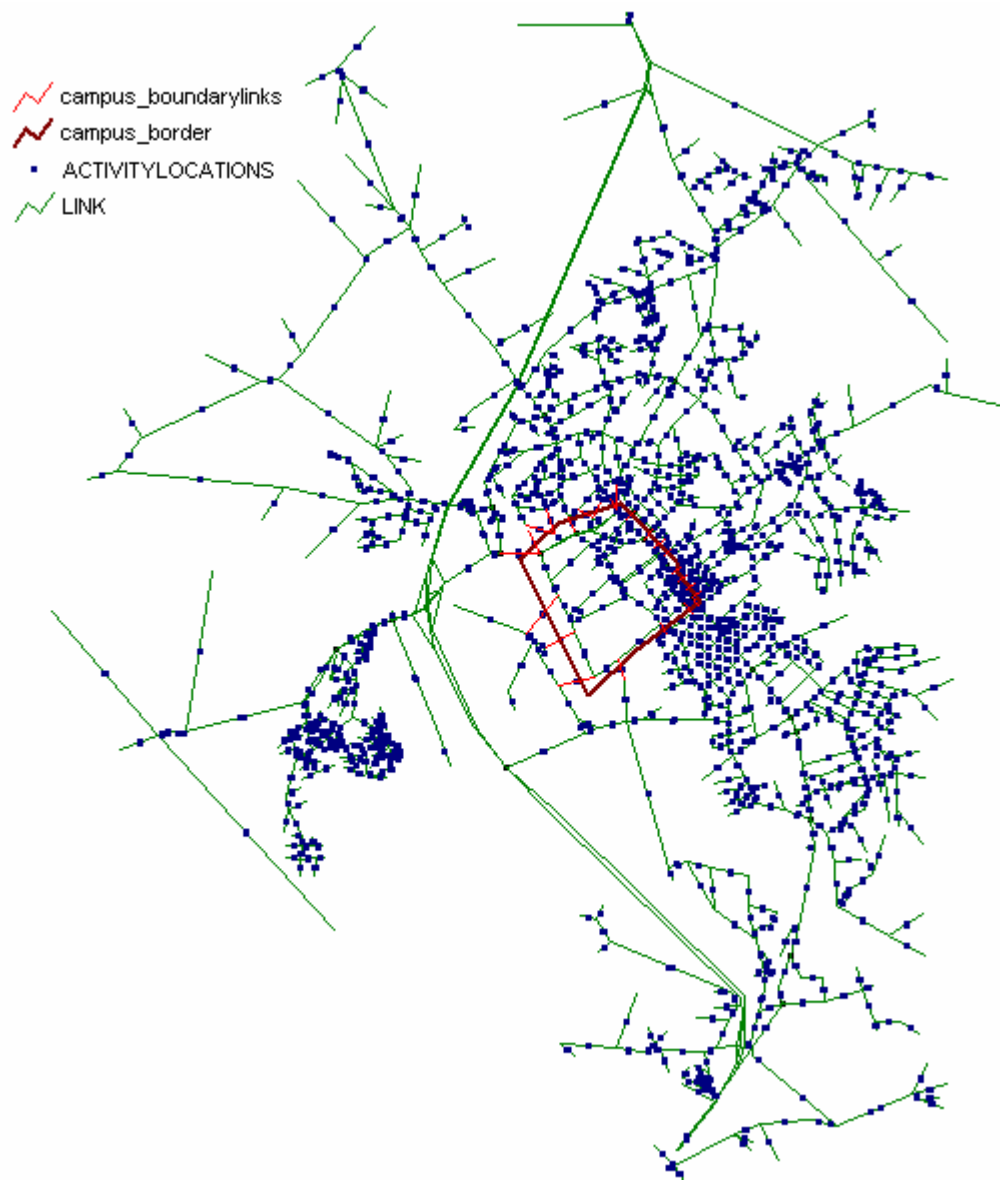


Fig. 5.1 Virginia Tech Campus depicted in Blacksburg, Virginia

Virginia Tech is located at Blacksburg, Virginia. There are more than 25,000 students performing their daily activities in the main campus comprised of 100 buildings. Since Virginia Tech campus has a large student, faculty and staff compared to exit capacity,

there are growing concerns for ensuring that safe evacuation of people in campus. Any disaster event, like a hazardous material spill or incidents of terrorism, can serve as the cause of emergency evacuation.

As depicted in Fig. 5.1, North Main St, Kabrich St, Webb St, Orchard St, Toms Creek Rd, McBride Ln, Burrus Dr and Woodland Dr comprise the 8 exits in North West bound of Virginia Tech main campus. And Prices Fork Rd, Duckpond Rd , Washington St serves the 4 exists in South West bound; In South East bound, there are four exits including South Main St, Draper Rd, Kent St and Spring Rd; Eight exits exist in the North East bound, which are Giles Rd, Turner St, Faculty Rd, Wilson Rd, Jackson Rd, Roanoke St, Lee St and Washington St.

The main campus of Virginia Tech has a current parking inventory of approximately 13,020 parking spaces (including motorcycle spaces) in seventy-one surface lots. Of the 13,020 parking spaces, approximately 98% are designated for the use of Virginia Tech students, faculty, and staff members. The parking space numbers are used to estimate the appropriate vehicle occupancy factor range for evacuation purpose.

### **5.1.1 Background of the Research**

TRANSIMS as a regional planning tool that incorporates a microscopic simulation model is ideal for evacuation planning. It addresses some of the shortcomings of the current evacuation planning models mentioned earlier in Chapter 3. Besides, the largest advantage of TRANSIMS is that it traces the movements of all persons between activities over 24-hour period and not vehicles only as in the current planning and evacuation models. This allows the user to know where each person is at different times of the day from his/her activity file. This has an enormous advantage in evacuation planning. For example, if an evacuation happens during the day, the family of a household may want to gather at home and then evacuate. This is particularly true for those families who have children who may want to pick up their children from school and then evacuate. The family evacuation may then take place in one car, easing the load on the network. Since TRANSIMS knows where each person is at different times of the day, all these

movements by different members of the same family could be traced and executed on the network. Currently, no model has the capability that can trace each person travel movements in an evacuation situation as TRANSIMS. The ability to account for all these movements by each individual has a great advantage in terms of accuracy and reliability of the results in terms of evacuation times for people to clear the evacuation area, the expected bottlenecks in the network, and the simulation of different transportation and evacuation strategies that would reduce evacuation times and ease congestion. In addition TRANSIMS tracks each individual that leads to superiority in evacuations that need to identify the evacuee characteristic, such as evacuation around nuclear power plants where the severity of the individual contamination plays a factor to what decontamination site the evacuee would be sent to. Thus, better traffic assignments and consequently better traffic movements are established that would also result in optimal management strategies at the contamination site.

TRANSIMS is capable of identifying the location of activities on each link. These activities on a link would include shelters, hospitals, prisons, mental institutions, military bases that are essential information in an evacuation process. People movements among these places are determined in TRANSIMS and would provide the expected traffic loads on these links leading to these activities. This information would allow the decision maker to evaluate different traffic management strategies at the areas surrounding these locations that would ease traffic congestion and facilitate the access to shelters and hospitals. Most traffic congestions do occur at the access points to the shelter location. This detailed analytical capability is definitely not available in any of the current evacuation models. Because all the traffic loading in these models take place from one aggregate zone centroid to another aggregate zone centroid.

Church and Sexton (2002) presented how a micro-scale traffic simulation models have been applied to a neighborhood evacuation problem using Paramics software, however no effort has been made to benefit from both the demand forecasting capability of a disaggregate planning model and high fidelity operational simulation model to solve the small area evacuation problem . The use of traditional micro simulation models, such as

CORSIM, VISSIM, and INTEGRATION in evacuation modeling is also an option. However, these models lack the O-D matrix input and the feed back process between loading and the travel times. The path following capability in CORSIM was developed to test the Dynamic Traffic Assignment (DTA) prototypes being developed for FHWA. An extensive set of functions was developed to allow the DTA system to interact with CORSIM at run time. It works by reading two input files that specify the paths and the vehicles that follow the paths. If the input file is named case.trf the path file must be named case.pat, and the vehicle file must be named case.veh. Any run of CORSIM will look for these files and try to use them if they are in the same directory with the file that is being run.

The main objective of this chapter is to present an application of a micro-scale transportation planning model (TRANSIMS) and micro-scale traffic simulation model (CORSIM) analyzing evacuation at the neighborhood scale. We will also discuss how such a modeling approach can be useful in not only characterizing the problem but search for mitigation strategies that may be useful in planning for a safe evacuation.

Since TRANSIMS is an activity based modeling system, we have the capability of tracing activities of each individual twenty-four hours a day. In contrast to TRANSIMS, CORSIM is considered as high fidelity because it attempts to represent the spatial interaction of drivers on a continuous, instead of a discrete, basis and because it attempts to model the car-following logic of the drivers in detail. Because the overall goal is to mimic both the small- and large-scale dynamics of traffic, the modeler has control over a large number of parameters concerning operation analysis including driver aggressiveness. Since people tend to drive more aggressively than usual, it is reasonable that the analyst adjusts the driver aggressiveness factors during emergency evacuation.

### **5.1.2 Specification of Evacuation Model**

Before we discuss details of the simulation process, we need to discuss the assumptions under which this model and application was developed. First, it should be recognized that good data on small emergency evacuations does not exist. It is virtually impossible to

collect traffic data in a residential neighborhood during an emergency evacuation without having a monitoring system deployed in advance. Second, it should also be understood that the type of data normally collected in system monitoring and management does not fulfill the needs for data to fully characterize and model an evacuation event. Such characterizations include driver behavior under possible panic conditions, the degree to which the emergency overwhelms the environment, unusual driver behavior, etc. This means that the calibration is not possible at the neighborhood scale for an evacuation event given the paucity of data. But a micro-scale traffic simulation model can be used under certain assumptions to estimate clearing time. First, an orderly evacuation as modeled with a traffic simulation model is likely to produce a neighborhood clearing time that is a lower bound on what might occur in the real event. The main reason for this is that accidents are more likely to occur when unpredictable behavior occurs. Accidents are the most likely element that will cause significant delay. Further, since environmental conditions like reduced visibility due to smoke is not considered, simulated flow is likely to be faster and safer with less accidents. Thus, the simulation model can be used to estimate the best possible outcome. If the best possible outcome (as represented by clearing time to handle all vehicles leaving the neighborhood) is too high in comparison to the amount of time before an event like hazardous material spill overwhelms a neighborhood, then a major safety problem exists.

### **5.1.3 Implementation of Evacuation Application in Blacksburg Study**

First, we implemented the proposed methodology in TRANSIMS using base year data for model validation after we got it from calibration process.

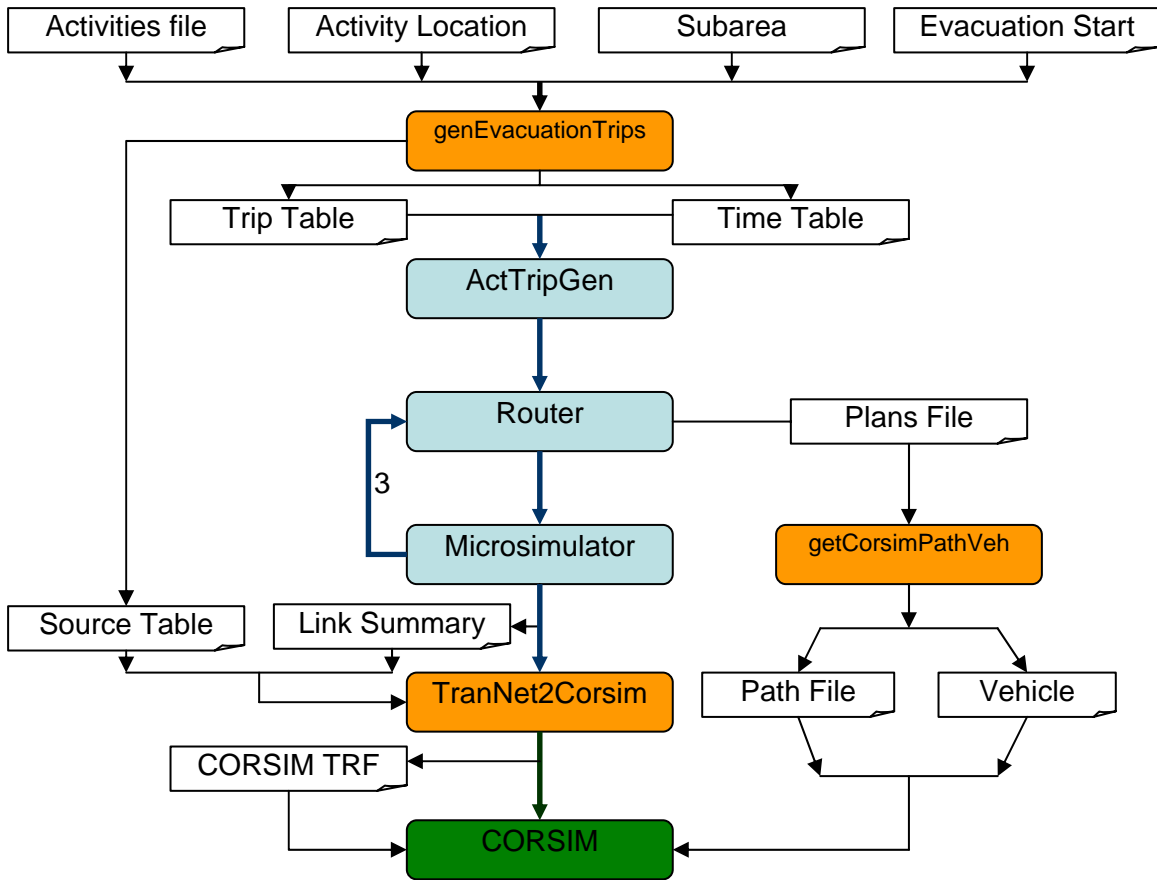


Fig. 5.2 Illustration of evacuation modeling frame work

### STEP 1: Preparation on sub area demand collection

TRANSIMS twenty-four activity file is used as the base for evacuation vehicle volume generation. TRANSIMS Activity Location table, an evacuation area links file and an evacuation area nodes file are used to define the evacuation area and find evacuation exits.

### STEP 2: Evacuation Modeling

We assumed that 30% of the demand leaves in the first 5 minutes, 50% leaves within the next 5 minutes and the other 20% leaves in the subsequent 5 minutes. For example, if an evacuation scenario was set up in which approximately 1000 cars were to exit the neighborhood, approximately 300 would begin their trip out of the neighborhood in the

first five minutes, 500 in the next five minutes and 200 in the subsequent five minutes. This time distribution could be changed by the modeler depends on specific emergency scenario. Fig. 5.3 shows the vehicles loading time distribution.

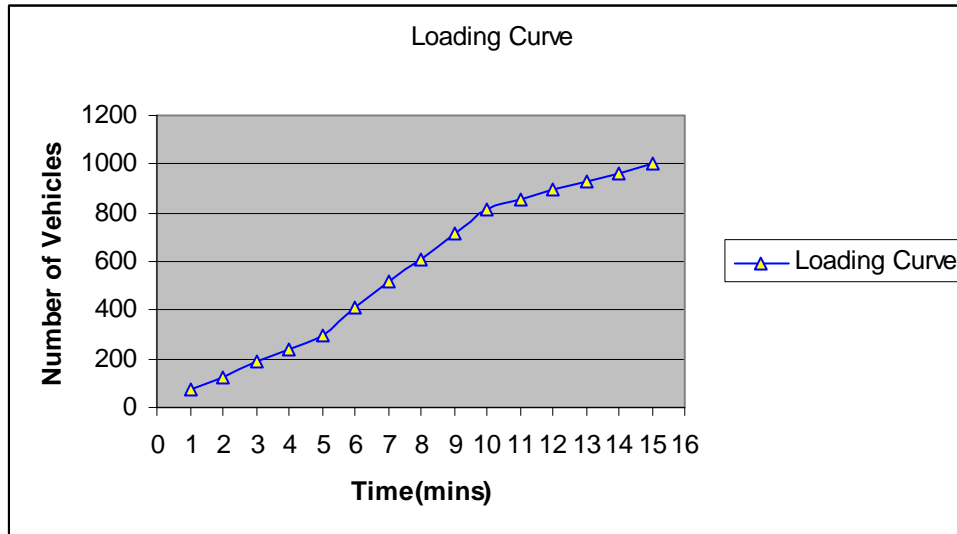


Fig. 5.3 Vehicles loading time distribution of 1000 vehicle trips

For each vehicle trip, since the starting location is known and the trip starting time can be calculated based on the demand loading distribution, we need to determine the trip destination in order to completely define the trip. In the study, we assume all the residents have full knowledge of the evacuation area. So the nearest boundary outgoing activity location is used as the destination of the evacuation trip, which is calculated using the direct distance between the trip starting location and the boundary outgoing activity location.

A utility program – *genEvacuationTrips* is created to search the nearest evacuation exit and generate evacuation vehicle trips. See Appendix-D for detail usage of this utility. The outputs are three files including Trip table, Time table and Volume Source table. Both Trip table and Time table will be used by TRANSIMS *ActTripGen* to generate evacuation trips, where Trip table contains number of trips generated from each activity location in the evacuation area and Time table provides the distribution of starting time for evacuation trips. The Volume Source table will be served as an input to generate

CORSIM internal volumes. Table 5.1-5.3 shows example of the outputs mentioned above.

From_ActLoc	Nearest_Boundary_ActLoc	Volume
21628	3579	16
21635	3455	74
21636	3455	10

Table 5.1 a Sample Evacuation Trip Table

Time 1	Time 2	Probability
10	10.08	0.3
10.08	10.17	0.5
10.17	10.25	0.2

Table 5.2 a Sample Evacuation Time Table

LINK	TNODE	TIME	COUNT
3169	3147	0	9
3169	3147	5	16
3169	3147	10	6

Table 5.3 a Sample Evacuation Volume Source Table

### **STEP 3: Use Router to find routes for evacuation trips**

Run Route Planner with the activity file as input to find the shortest path for each evacuation trip.

### **STEP 4: Simulating the Traffic using TRANSIMS**

Simulate the movements of every traveler and every vehicle seconds by seconds in Traffic Microsimulator according to their evacuation plans from Route Planner. Since Route Planner does not take the interaction between travelers on congestion into account, we need to run several loops between Route Planner and Traffic Microsimulator to get stabilized evacuation traffic. Route Planner Module will use the updated travel time obtained from simulation by Traffic Microsimulator Module automatically since the configuration key ROUTER\_LINK\_DELAY\_FILE is defined.

### **STEP 5: Simulating the Traffic using CORSIM**

Using the *TranNet2Corsim* conversion tool, we can extract both the demand and the subarea network for this neighborhood evacuation problem and be able to use CORSIM for evacuation simulation. Next, we are ready to make adjustment on driver behavior during emergency by increasing driver aggressiveness factors. In Record Type 81 for lane change parameters, the other default parameters were left alone except driver type factor used to compute driver aggressiveness, which was changed from the default value of 25 to 35 in order to make the drivers more aggressive. The acceptable gap in near-side cross traffic for vehicles at a sign (Record Type 142) was adjusted from the default setting of (56, 50, 46, 42, 39, 37, 34, 30, 26, 20) for driver types 1 through 10, respectively, to (40, 40, 40, 30, 30, 30, 30, 20, 20, 20).

As stated earlier, the path following capability of CORSIM can be used as an alternative to implement the evacuation model. A utility *getCorsimPathVeh* is created to generate the path file and vehicle file to simulating evacuation traffic in CORSIM taking as input the plan file obtained from TRANSIMS Route Planner. The following shows the format and example of the path file and vehicle file mentioned above. The detailed usage of *getCorsimPathVeh* utility program can be found in Appendix-E.

The format for the path file is:

```
node1 node2 node3 ... node n for path 1
node1 node2 node3 ... node n for path N
{repeat for each path}
```

For example;

```
1088  8026
1063  1066  8021
32    33    1063  1066  1065  1055  42    1083  36    38    34    8011
32    33    1063  1066  1065  1067  1055  40    36    38    34    8011
1071  30    1052  8017
```

The format for the vehicle file is:

entry time(the second that the vehicle enters the network), entry node, path ID (path IDs are the sequence number in the path file), driver type, vehicle fleet, vehicle type (all entries on one line separated by spaces)

{repeat for each vehicle}

For example;

36433	1006	1	1	0	1
36572	1035	26	1	0	1
36049	1035	26	1	0	1
36748	1045	31	1	0	1
36416	16	2	1	0	1

The number of paths is limited to 5000, which should be more than enough for any network that CORSIM could model. The vehicles will be injected into the stream of vehicles at the time specified. These vehicles can interact with other vehicles created by CORSIM via the RT 50 if entry volumes are input. If the entry volumes are zero, only the injected vehicles will be present on the network.

During CORSIM simulation, we found a few vehicles choose paths that are directed into the evacuation area due to the stochastic nature of CORSIM microsimulation. We manually adjust the turn percentage on such links to avoid traffics coming toward the center of the evacuation area.

### **STEP 6: Retrieve the clearing time and identify the bottle neck location**

After traffic stabilization, which means no person could further reduce his/her travel time by selecting a different route, we can collect the information of clearing time from simulation output and identify the bottle neck location from the visualization of the snapshots. .

In order to examine a broad scope of possible evacuation outcomes for the Virginia Tech Campus, multiple scenarios were modeled. Each scenario represented a set of model assumptions. Three principal variables were used in this evacuation model:

1. The vehicle occupancy factor: 1.0, 1.5 and 2.0 persons per vehicle
2. The gap acceptance factor: CORSIM default values and adjusted higher driver aggressiveness values
3. Traffic Control: When traffic control is invoked, the critical intersections near the exits of the neighborhood are optimized. This involves converting some links to one-way out of evacuation area, adjusting the timing in signal intersections and signs in unsignalized intersections to move the traffic efficiently.

Using different values of the three principal variables, twelve scenarios were generated and modeled in this thesis. The results of the simulation are summarized in the next section.

## ***5.2 Evaluation of the Methodology in Blacksburg Study***

The results of the simulation runs are summarized in two tables, each concerning a given level of evacuation volume. The total number of person trips retrieved from TRANSIMS demand is 8580 and number of evacuation vehicle trips are determined by vehicle occupancy factor. The following figures and tables illustrate the condition of evacuation scenario with vehicle occupancy factor equals to 2. Figs. 5.4-5.6 shows the snapshot of traffic at different time-step (15min, 30min and 45min) and Table 5.4-5.5 shows number of vehicles in the system versus time-step and percentage of vehicles versus time-step. Table 5.6-5.8 gives results of five evacuation scenarios involving different number of persons per vehicle leaving the evacuation area, 1, 1.5 and 2.0 respectively. For each scenario, the table gives time taken for certain percentages of vehicles to clear the campus and reach an exit.

Figs. 5.5 and 5.6 depict several queues that form as vehicles attempt to leave the evacuation area. The critical intersections identified by this simulation are located in the north east bound of the campus, which include the intersection of Jackson Rd and South Main, the intersection of College Ave and South Main, the intersection of Turner St and Main St and the intersection of Roanoke St and South Main. Traffic control is suggested at these critical intersections. For example, we reverse the Roanoke St to be a two lane outgoing link and increase the green phase time for Roanoke St from 15 seconds to 25 seconds per cycle.

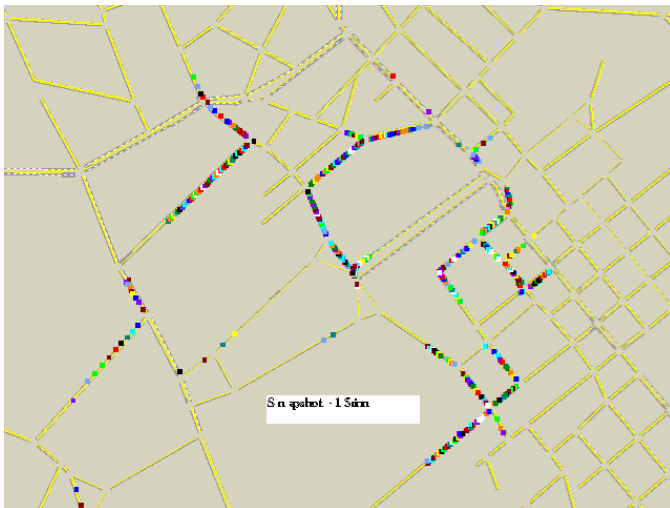


Fig. 5.4 Evacuation Snapshot (15 minute)

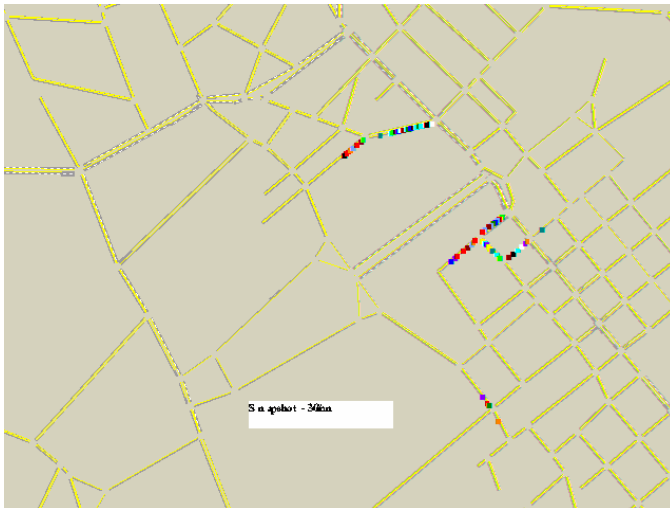


Fig. 5.5 Evacuation Snapshot (30 minute)

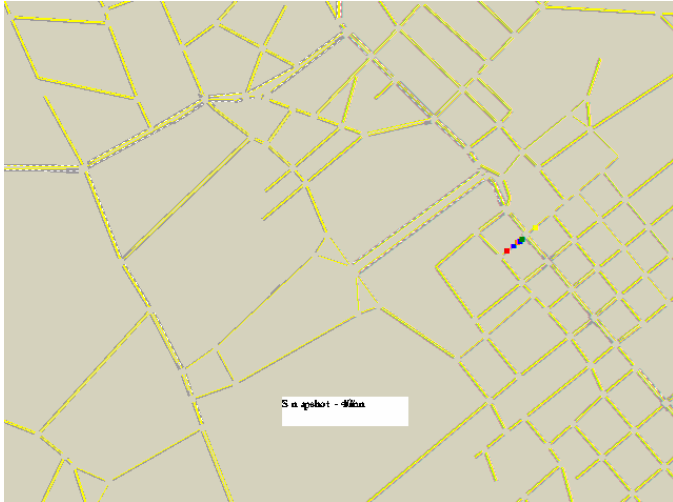


Fig. 5.6 Evacuation Snapshot (40 minute)

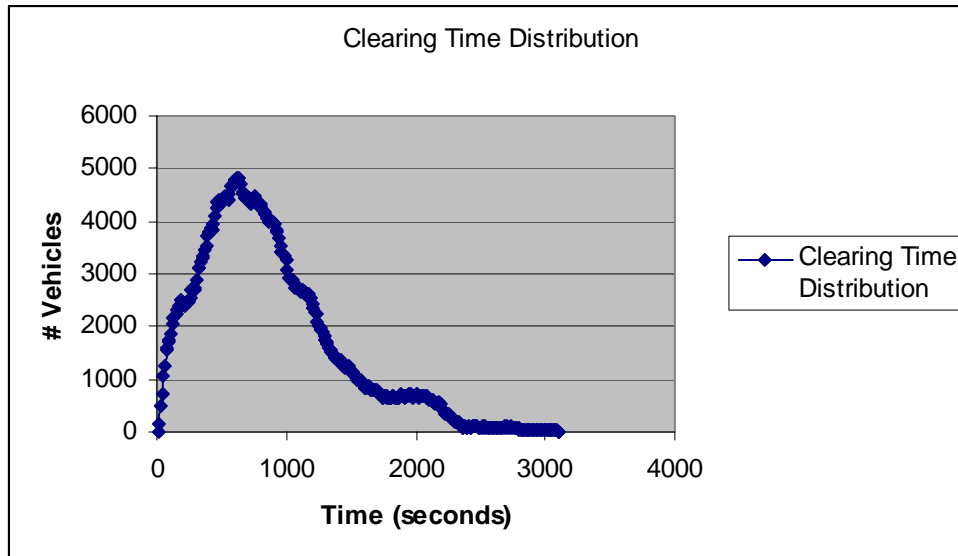


Table 5.4 Number of vehicles loaded on the network vs. Time step

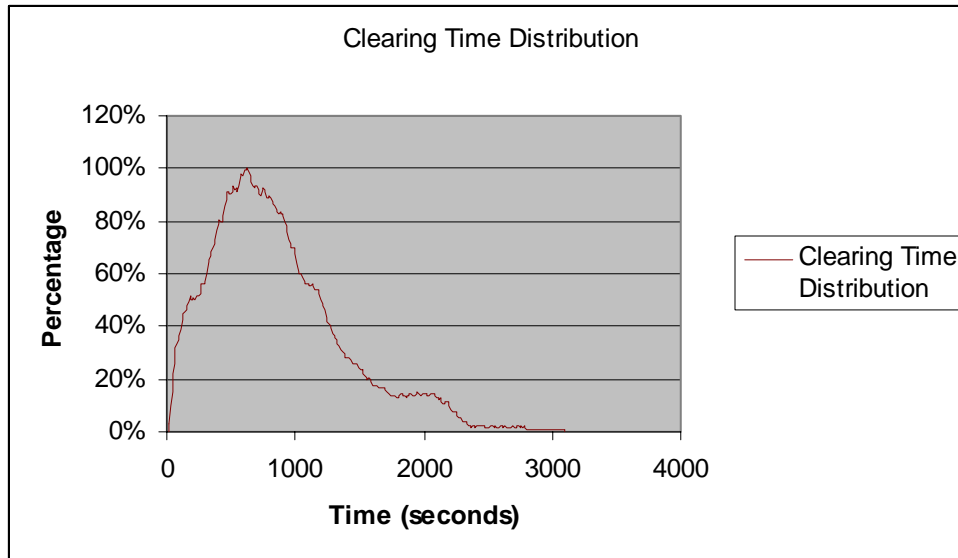


Table 5.5 Percentage of vehicles loaded on the network vs. Time step

Traffic Management Measures	none	none	none	yes	yes
Adjust driver aggressiveness	no	no	yes	no	yes
% of total vehicles cleared	TRANSIMS Time	CORSIM Time	CORSIM Time	CORSIM Time	CORSIM Time
50%	0:32:48	0:33:30	0:32:48	0:25:54	0:23:54
75%	0:46:00	0:45:24	0:44:30	0:34:36	0:32:24
90%	0:57:06	0:59:24	0:58:06	0:46:42	0:42:24
95%	1:05:42	1:08:48	1:07:18	0:53:36	0:49:06
100%	1:38:48	1:38:06	1:36:00	1:15:42	1:06:18
# vehiles cleared					
1000	0:18:42	0:18:30	0:18:00	0:13:30	0:13:12
2000	0:24:48	0:25:48	0:25:12	0:20:36	0:18:24
3000	0:30:12	0:31:00	0:30:06	0:23:36	0:22:12
4000	0:36:18	0:35:48	0:34:54	0:27:12	0:25:30
5000	0:45:24	0:45:54	0:44:36	0:35:48	0:32:42
6000	0:54:00	0:54:54	0:53:18	0:39:30	0:39:06
7000	N/A	N/A	N/A	N/A	N/A

Table 5.6 clearing time for average 1 person per vehicle leaving the evacuation area

Traffic Management Measures	none	none	none	yes	yes
Adjust driver aggressiveness	no	no	yes	no	yes
% of total vehicles cleared	TRANSIMS Time	CORSIM Time	CORSIM Time	CORSIM Time	CORSIM Time
50%	0:23:06	0:23:54	0:23:24	0:17:48	0:17:00
75%	0:30:30	0:31:42	0:31:00	0:23:00	0:22:36
90%	0:38:36	0:39:24	0:38:36	0:30:12	0:28:12
95%	0:56:12	0:56:42	0:55:24	0:45:00	0:40:24
100%	1:04:48	1:04:30	1:02:42	0:47:06	0:46:00
# vehiles cleared					
1000	0:15:00	0:15:06	0:14:42	0:11:30	0:10:48
2000	0:19:48	0:19:06	0:18:42	0:14:30	0:13:36
3000	0:23:42	0:22:48	0:22:18	0:17:12	0:16:18
4000	0:30:24	0:30:54	0:30:06	0:21:42	0:22:00
5000	0:42:42	0:41:24	0:40:36	0:29:48	0:29:42
6000	N/A	N/A	N/A	N/A	N/A
7000	N/A	N/A	N/A	N/A	N/A

Table 5.7 Clearing time for average 1.5 persons per vehicle leaving the evacuation area

Traffic Management Measures	none	none	none	yes	yes
Adjust driver aggressiveness	no	no	yes	no	yes
% of total vehicles cleared	TRANSIMS Time	CORSIM Time	CORSIM Time	CORSIM Time	CORSIM Time
50%	0:20:00	0:20:24	0:19:54	0:16:18	0:14:30
75%	0:24:48	0:25:00	0:24:24	0:18:18	0:17:48
90%	0:36:42	0:35:48	0:34:48	0:26:12	0:25:30
95%	0:38:12	0:39:18	0:38:12	0:28:06	0:28:00
100%	0:51:42	0:49:12	0:47:48	0:35:06	0:35:06
# vehiles cleared					
1000	0:15:24	0:15:30	0:15:06	0:11:06	0:11:06
2000	0:17:42	0:17:18	0:16:54	0:12:42	0:12:18
3000	0:21:30	0:20:42	0:20:06	0:16:30	0:14:48
4000	0:27:30	0:27:48	0:27:06	0:20:30	0:19:48
5000	N/A	N/A	N/A	N/A	N/A
6000	N/A	N/A	N/A	N/A	N/A
7000	N/A	N/A	N/A	N/A	N/A

Table 5.8 clearing time for average 2 persons per vehicle leaving the evacuation area

An examination of the scenario results given in Table 5.6-5.8 suggests that traffic control at the critical intersections improve about 25% of the clearing time. The adjustment of the driver behavior shows little or no system-wise improvement on clearing time. This result could be expected since more aggressive driver behavior will result in more deceleration maneuvers of the affected traffic.

Since the intention of the evacuation application on Virginia Tech main campus is mainly to show how the subarea focusing methodology can be applied to real-world problem. More sophisticated evacuation model is recommended concerning parking capacity, accident possibility and unforeseen roadway exits etc.