8 TRANSIT-DEPENDENT AND SPECIAL FACILITY EVACUATION TIME ESTIMATES

This section details the analyses applied and the results obtained in the form of evacuation time estimates for transit vehicles. The demand for transit service reflects the needs of two population groups: (1) residents with no vehicles available; and (2) residents of special facilities such as schools and health support facilities.

These transit vehicles mix with the general evacuation traffic that is comprised mostly of "passenger cars" (pc's). The presence of each transit vehicle in the evacuating traffic stream is represented within the modeling paradigm described in Appendix D as equivalent to two pc's. This equivalence factor represents the longer size and more sluggish operating characteristics of a transit vehicle, relative to those of a pc.

Transit vehicles must be mobilized in preparation for their respective evacuation missions. Specifically:

- Bus drivers must be alerted
- They must travel to the bus depot
- They must be briefed there and assigned to a route or facility

These activities consume time. Based on experience at other plants, it is estimated that bus mobilization time will average approximately 90 minutes extending from the Advisory to Evacuate to the time when buses arrive at the facility to be evacuated.

During this mobilization period, other mobilization activities are taking place. One of these is the action taken by parents, neighbors, relatives and friends to pick up children from school prior to the arrival of buses, so that they may join their families. Virtually all studies of evacuations have concluded that this "bonding" process of uniting family units is universally prevalent during emergencies and should be anticipated in the planning process. The current emergency plan information disseminated to residents of the Davis-Besse Nuclear Power Station's EPZ indicates that parents should not pick up children at school; rather, they should pick up children at the receiving school. Picking up children at school could add to traffic congestion at the schools, delaying the departure of the buses evacuating schoolchildren, which may have to return in a subsequent "wave" to the EPZ to evacuate the transit-dependent population. Based on discussions with FirstEnergy and the OROs, this report provides estimates of buses under the assumption that all schoolchildren will be evacuated by bus (no children will be picked up by their parents and no high school students will evacuate in personal vehicles) to present an upper bound estimate of buses required. It is assumed that children at day-care centers are picked up by parents or guardians and that the time to perform this activity is included in the trip generation times discussed in Section 5.

The procedure is:

- Estimate demand for transit service
- Estimate time to perform all transit functions
- Estimate route travel times to the EPZ boundary and to the school reception centers

8.1 Transit Dependent People Demand Estimate

The telephone survey (see Appendix F) results were used to estimate the portion of the population requiring transit service:

- Those persons in households that do not have a vehicle available.
- Those persons in households that do have vehicle(s) that would not be available at the time the evacuation is advised.

In the latter group, the vehicle(s) may be used by a commuter(s) who does not return (or is not expected to return) home to evacuate the household.

Table 8-1 presents estimates of transit-dependent people. Note:

- Estimates of persons requiring transit vehicles include schoolchildren. For those evacuation scenarios where children are at school when an evacuation is ordered, separate transportation is provided for the schoolchildren. The actual need for transit vehicles by residents is thereby less than the given estimates. The estimates of transit vehicles presented herein are not reduced to account for schoolchildren evacuated separately.
- It is reasonable and appropriate to consider that many transit-dependent persons will evacuate by ride-sharing with neighbors, friends or family. For example, nearly 80 percent of those who evacuated from Mississauga, Ontario who did not use their own cars, shared a ride with neighbors or friends. Other documents report that approximately 70 percent of transit dependent persons were evacuated via ride sharing. **We will adopt a conservative estimate that 50 percent of transit dependent persons will ride share, in accordance with NUREG/CR-7002.**

The estimated number of bus trips needed to service transit-dependent persons is based on an estimate of average bus occupancy of 30 persons at the conclusion of the bus run. Transit vehicle seating capacities typically equal or exceed 60 children (roughly equivalent to 40 adults). If transit vehicle evacuees are two thirds adults and one third children, then the number of "adult seats" taken by 30 persons is 20 + (2/3 x10) = 27. On this basis, the average load factor anticipated is (27/40) x 100 = 68 percent. Thus, if the actual demand for service exceeds the estimates of Table 8-1 by 50 percent, the demand for service can still be accommodated by the available bus seating capacity. Additional persons could be accommodated as standees.

Table 8-1 indicates that transportation must be provided for 427 people. Therefore, a total of 14 bus runs are required to transport this population to reception centers.

To illustrate this estimation procedure, we calculate the number of persons, P, requiring public transit or ride-share, and the number of buses, B, required for the Davis-Besse Site EPZ:

$$P = No.of\ HH\ \times \sum_{i=0}^{n} \{(\%\ HH\ with\ i\ vehicles) \times [(Average\ HH\ Size) - i]\} \times A^i C^i$$

Where,

A = Percent of households with commuters

C = Percent of households who will not await the return of a commuter

$$P = 9{,}191 \times [.0252 \times 1.6 + 0.2651 \times (1.7 - 1) \times 0.47 \times 0.56 + 0.4966 \times (2.1 - 2) \times (0.47 \times 0.56)^2] = 9{,}191 \times 0.0926 = 853$$

$B = (0.5 \times P) \div 30 = 14$, rounded down.

These calculations are explained as follows:

- All members (1.6 avg.) of households (HH) with no vehicles (2.52%) will evacuate by public transit or ride-share. The term 9,191 (number of households) x 0.0252 x 1.6, accounts for these people.
- The members of HH with 1 vehicle away (26.51%), who are at home, equal (1.7-1). The number of HH where the commuter will not return home is equal to (9,191 x 0.2651 x 0.47 x 0.56), as 47% of EPZ households have a commuter, 56% of which would not return home in the event of an emergency. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms.
- The members of HH with 2 vehicles that are away (49.66%), who are at home, equal (2.1 – 2). The number of HH where neither commuter will return home is equal to 9,191 x 0.4966 x $(0.47 \times 0.56)^2$. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms (the last term is squared to represent the probability that neither commuter will return).
- Households with 3 or more vehicles are assumed to have no need for transit vehicles.
- The total number of persons requiring public transit is the sum of such people in HH with no vehicles, or with 1 or 2 vehicles that are away from home.

8.2 School Population – Transit Demand

Table 8-2 presents the school population and transportation requirements for the direct evacuation of all schools within the EPZ for the 2010-2011 school year. Note that Jerusalem Elementary School is outside of the EPZ but was included because is it stated in the Lucas County Radiological Emergency Response Plans that the school will also be evacuated. The column in Table 8-2 entitled "Bus Runs Required" specifies the number of buses required for each school under the following set of assumptions and estimates:

- No students will be picked up by their parents prior to the arrival of the buses.
- While many high school students commute to school using private automobiles (as discussed in Section 2.4 of NUREG/CR-7002), the estimate of buses required for school evacuation do not consider the use of these private vehicles.
- Bus capacity, expressed in students per bus, is set to 70 for primary schools and 50 for middle and high schools.
- Those staff members who do not accompany the students will evacuate in their private vehicles.
- No allowance is made for student absenteeism typically a few percent daily.

Consideration should be given that the counties in the EPZ introduce procedures whereby the schools are contacted prior to the dispatch of buses from the depot (approximately one hour after the Advisory to Evacuate), to ascertain the current estimate of students to be evacuated. In this way, the number of buses dispatched to the schools will reflect the actual number needed. Those buses originally allocated to evacuate schoolchildren that are not needed due to children being absent or picked up by their parents, can be gainfully assigned to service other facilities or those persons who do not have access to private vehicles or to ride-sharing.

Table 8-3 presents a list of the school reception centers for each school in the EPZ. Students will be transported to these centers where they will be subsequently retrieved by their respective families.

8.3 Special Facility Demand

Table 8-4 presents the census of special facilities in the EPZ. Approximately 184 people have been identified as living in, or being treated in these facilities. This census also indicates the number of wheelchair-bound people and the number of bed-ridden people at each facility.

The transportation requirements for this group are also presented. The number of ambulance runs is determined by assuming that 2 patients can be accommodated per ambulance trip; the number of wheelchair van runs assumes 4 wheelchairs per trip; the number of wheelchair bus runs assumes 15 wheelchairs per trip and the number of bus runs estimated assumes 30 ambulatory patients per trip.

Table 8-5 summarizes transportation resources available and transportation resources needs. It can be seen that there are not sufficient resources to evacuate these facilities in one wave. Mutual Aid Agreements exist with Ottawa County Transportation Agency for additional transportation resources to assist during an emergency.

8.4 Evacuation Time Estimates for Transit Dependent People

EPZ bus resources are assigned to evacuating schoolchildren (if school is in session at the time of the ATE) as the first priority in the event of an emergency. In the event that the allocation of buses dispatched from the depots to the various facilities and to the bus routes is somewhat "inefficient", or if there is a shortfall of available drivers, then there may be a need for some buses to return to the EPZ from the reception center after completing their first evacuation trip, to complete a "second wave" of providing transport service to evacuees. For this reason, the ETE for the transit-dependent population will be calculated for both a one wave transit evacuation and for two waves. Of course, if the impacted Evacuation Region is other than R03 (the entire EPZ), then there will likely be ample transit resources relative to demand in the impacted Region and the ETE calculated for a second wave would likely not apply.

When school evacuation needs are satisfied, subsequent assignments of buses to service the transit-dependent should be sensitive to their mobilization time. Clearly, the buses should be dispatched after people have completed their mobilization activities and are in position to board the buses when they arrive at the pick-up points.

Evacuation Time Estimates for Transit Trips were developed using both good weather and adverse weather conditions. Figure 8-1 presents the chronology of events relevant to transit operations. The elapsed time for each activity will now be discussed with reference to Figure 8-1.

Activity: Mobilize Drivers (A→B→C)

Mobilization is the elapsed time from the Advisory to Evacuate until the time the buses arrive at the facility to be evacuated. It is assumed that for a rapidly escalating radiological emergency with no observable indication before the fact, drivers would likely require 90 minutes to be contacted, to travel to the depot, be briefed, and to travel to the transit-dependent facilities. Mobilization time is slightly longer – 100 minutes when raining, 110 minutes when snowing.

Activity: Board Passengers (C→D)

Based on discussions with offsite agencies, a loading time of 15 minutes (20 minutes for rain and 25 minutes for snow) for school buses is used.

For multiple stops along a pick-up route (transit-dependent bus routes) allowance is made for the additional time associated with stopping and starting the bus at each pick-up point. The time, t, required for a bus to decelerate at a rate, "a", expressed in ft/sec/sec, from a speed, "v", expressed in ft/sec, to a stop, is t = v/a. Assuming the same acceleration rate and final speed following the stop yields a total time, T, to service boarding passengers:

$$T = t + B + t = B + 2t = B + \frac{2v}{a}, \text{where B = dwell time to service passengers.}$$

The total distance, "s" in feet, travelled during the deceleration and acceleration activities is:

$$s = v^2/a.$$

If the bus had not stopped to service passengers, but had continued to travel at speed, v, then its travel time over the distance, s, would be:

$$s/v, \text{ or } (v^2/a)/v = v/a.$$

Then the net pickup time, P, to service passengers at a stop is:

$$P = T - \frac{v}{a} = B + \frac{v}{a}$$

Assigning reasonable estimates yields:

- B = 50 seconds: a generous value for a few passengers, carrying personal items, to board per stop
- v = 25 mph = 37 ft/sec
- a = 4 ft/sec/sec, a moderate average rate

Then, P ≈ 1 minute per stop. Allowing 30 minutes pick-up time per bus run implies 30 stops per run, for good weather. It is assumed that bus acceleration and speed will be less in rain; loading time is 40 minutes per bus in rain, 50 minutes in snow.

Activity: Travel to EPZ Boundary (D→E)

School Evacuation

Transportation resources available were provided by the EPZ county emergency management agencies and are summarized in Table 8-5. Also included in the table is the number of buses needed to evacuate medical facilities, transit-dependent population, homebound special needs (discussed below in Section 8.5) and correctional facilities (discussed below in Section 8.6).

Comparison of the available bus resources with the number of buses needed in Table 8-2 indicates that Ottawa County Schools and the Lucas County School do not have sufficient bus resources to evacuate school children in a single wave. However, it is assumed that these school districts will be assisted through Mutual Aid Agreements, as outlined in Lucas County and Ottawa County Radiological Emergency Response Plans.

The buses servicing the schools are ready to begin their evacuation trips at 105 minutes after the advisory to evacuate – 90 minutes mobilization time plus 15 minutes loading time. The UNITES software discussed in Section 1.3 was used to define bus routes along the most likely paths from a school being evacuated to the EPZ boundary, traveling toward the appropriate reception center. This is done in UNITES by interactively selecting the series of nodes from the school to the EPZ boundary. The bus route is given an identification number and is written to the DYNEV II input stream. DYNEV computes the route length and outputs the average speed for each bus route. The bus routes are documented in Table 8-6 (refer to the maps of the link-node analysis network in Appendix K for node locations). Data describing traffic operations at the time from 100 to 110 minutes after the advisory to evacuate were used. The average speed along the path using the data generated by DYNEV was computed as follows:

$$Average\ Speed\ \left(\frac{mi.}{hr}\right) = \left[\frac{\sum_{i-1}^{n} length\ of\ link\ i\ (mi)}{\sum_{i-1}^{n} Delay\ on\ link\ i\ (min.) + \frac{length\ of\ link\ i\ (mi.)}{current\ speed\ on\ link\ i\ \left(\frac{mi.}{hr.}\right)} \times \frac{60\ min.}{1\ hr.}}\right] \times \frac{60\ min.}{1\ hr.}$$

The average speed computed (using this methodology) for the buses servicing each of the schools in the EPZ is shown in Table 8-7 , Table 8-8, and Table 8-9, and in Table 8-11, Table 8-12, and Table 8-13 for the transit vehicles evacuating transit-dependent persons, which are discussed later. The travel time to the EPZ boundary was computed for each bus route using the computed average speed and the distance to the EPZ boundary. The travel time from the EPZ boundary to the Reception Center was computed using an average speed of 45 mph, 40 mph, and 35 mph for good weather, rain and snow, respectively. Speeds were reduced in Table 8-7, Table 8-8, and Table 8-9 to 35 mph (31.5 mph for rain – 10% decrease - and 28 mph for snow – 20% decrease) for those calculated bus speeds which exceed 35 mph (the school bus speed limit for Ohio State routes is 35 mph).

Table 8-7 (good weather), Table 8-8 (rain) and Table 8-9 (snow) present the following evacuation time estimates (rounded up to the nearest 5 minutes) for schools in the EPZ: (1) The elapsed time from the Advisory to Evacuate until the bus exits the EPZ; and (2) The elapsed time until the bus reaches the School Reception Center. The evacuation time out of the EPZ can be computed as the sum of travel times associated with Activities A→B→C, C→D, and D→E (For example: 90 min. + 15 + 10 = 1:55 for Bataan Memorial Elementary School, with good weather, rounded up to the nearest 5 minutes). The evacuation time to the School Reception Center is determined by adding the time associated with Activity E→F (discussed below), to this EPZ evacuation time.

Evacuation of Transit-Dependent Population

The buses dispatched from the depots to service the transit-dependent evacuees will be scheduled so that they arrive at their respective routes after their passengers have completed their mobilization. As shown in Figure 5-4 (residents without commuters), 90 percent of the evacuees will complete their mobilization when the buses will begin their routes, approximately 120 minutes after the Advisory to Evacuate. Headways of 20 minutes are used for those routes which require multiple buses; buses begin traversing some of these routes at 90 minutes to service those people who mobilize more quickly.

Discussions with local OROs indicated that fixed bus routes would not be used at Davis-Besse. Rather, people would call the local ORO to request transportation assistance. Buses would then be dispatched to individual homes. We modeled this approach by defining a set of routes that would encompass the most populated areas of the EPZ. Buses servicing the transit-dependent evacuees will first travel along their pick-up routes, then proceed out of the EPZ. Buses will travel along the major routes in the EPZ as described in Table 8-10 and shown graphically in Figure 8-2. No pre-established transit dependent bus routes exist in the county emergency plans. On page II-J-4 of the Ottawa and Lucas County Radiological Emergency Response Plans, it states that local fire/EMS personnel will assist volunteer bus drivers in the pickup of persons without transportation; residents can designate their need for transportation by not displaying a towel or "WE HAVE BEEN NOTIFIED" place card in front of their homes.

As previously discussed, a pickup time of 30 minutes is estimated for 30 individual stops to pick up passengers, with an average of one minute associated with each stop.

The travel distance along the respective pick-up routes within the EPZ is estimated using the UNITES software. Bus travel times within the EPZ are computed using average speeds computed by DYNEV, using the aforementioned methodology that was used for school evacuation.

Table 8-11, Table 8-12, and Table 8-13 present the transit-dependent population evacuation time estimates for each bus route calculated using the above procedures for good weather and rain, respectively.

For example, the ETE for the Port Clinton Bus Route Number 20 is computed as 90 + 11.32 + 30 = 2:15 for good weather (rounded to nearest 5 minutes). Here, 11.32 minutes is the time to travel 2.98 miles at 15.8 mph, the average speed output by the model for this route at 90 minutes. The ETE for a second wave (discussed below) is presented in the event there is a shortfall of available buses or bus drivers.

<u>Activity: Travel to School Reception Centers (E→F)</u>

The distances from the EPZ boundary to the school reception centers are measured using Geographical Information Systems (GIS) software along the most likely route from the EPZ to the reception center. The reception centers are identified in Table 8-3. For a one-wave evacuation, this travel time outside the EPZ does not contribute to the ETE. For a two-wave evacuation, the ETE for buses must be considered separately, since it could exceed the ETE for the general public. Assumed bus speeds of 45 mph, 40 mph, and 35 mph for good weather, rain, and snow, respectively, will be applied for this activity for buses servicing the transit-dependent population.

<u>Activity: Passengers Leave Bus (F→G)</u>

A bus can empty within 5 minutes. The driver takes a 10 minute break.

<u>Activity: Bus Returns to Route for Second Wave Evacuation (G→C)</u>

The buses assigned to return to the EPZ to perform a "second wave" evacuation of transit-dependent evacuees will be those that have already evacuated transit-dependent people who mobilized more quickly. The first wave of transit-dependent people depart the bus, and the bus then returns to the EPZ, travels to its route and proceeds to pick up more transit-dependent evacuees along the route. The travel time back to the EPZ is equal to the travel time to the reception center.

The second-wave ETE for the Port Clinton Bus Route Number 20 is computed as follows for good weather (see Table 8-12), rounding times:

- Bus leaves the EPZ boundary for the first wave at 2:15 (135 minutes).
- Bus arrives at the reception center at 2:34 (135 minutes + 18.5 minute travel time to reception center).
- Bus discharges passengers (5 minutes) and driver takes a 10-minute rest: 15 minutes.
- Bus returns to EPZ and completes second route: 19 minutes (Travel Time to Reception Center) + 6 minutes (2.98 miles @ 28.5 mph) = 25 minutes
- Bus completes pick-ups along route: 30 minutes.
- Bus exits EPZ at time 2:15 + 0:19 + 0:15 + 0:25 + 0:30 = 3:45 (rounded to nearest 5 minutes) after the Advisory to Evacuate.

The ETE for the completion of the second wave for all transit-dependent bus routes are provided in Table 8-11, Table 8-12 and Table 8-13.

Evacuation of Ambulatory Persons from Special Facilities

The bus operations for this group are similar to those for school evacuation except:

- Bus occupancy is assumed to be 30 patients to allow for staff to accompany the patients.
- The passenger loading time will be longer at approximately one minute per patient to account for the time to move patients from inside the facility to the vehicles.

Table 8-4 indicates that 3 bus runs, 9 wheelchair bus runs and 17 ambulance runs are needed to service all of the special facilities in the EPZ. According to Table 8-5, the counties can collectively provide 59 buses and 1 van. Details on the number of wheelchair-accessible buses and ambulances were not available.

As is done for the schools, it is estimated that mobilization time averages 90 minutes. Specially trained medical support staff (working their regular shift) will be on site to assist in the evacuation of patients. Additional staff (if needed) could be mobilized over this same 90 minute timeframe.

In the event there is a shortfall of transit vehicles for a "single-wave" evacuation, then buses used to evacuate schools will have to return to evacuate the special facilities. The average time school buses arrive at the reception center is 2:10 (say 130 minutes) in good weather. Add about 20 minutes of inbound travel time to the special facility from the reception center, 30 minutes for loading the bus, and travel time to the EPZ boundary. Thus, a second wave, if needed, would add about 1 hour to the calculated ETE for special facilities.

Based on the locations of the medical facilities in Figure E-2, it is estimated that buses will have to travel 5 miles, on average, to leave the EPZ. The average speed output by the model at 90 minutes for Region 3, Scenario 6 is 55.7; thus, travel time out of the EPZ is approximately 5 minutes.

The ETE for buses evacuating ambulatory patients at medical facilities is the sum of the mobilization time, total passenger loading time, and travel time out of the EPZ. For example, the calculation of ETE for the Riverview Healthcare Campus with 26 ambulatory residents is:

ETE: 90 + 26 x 1 +5 = 121 min. or 2:00 rounded

Loading times are estimated at 5 minutes per wheelchair bound person as staff will have to assist them in boarding the bus. For example, the ETE for the wheelchair bound at Riverview Healthcare Campus with 49 wheelchair-bound patients is (assuming concurrent loading on multiple buses with a capacity of 15 patients):

ETE: 90 + 15 x 5 + 5 = 2:50

The ETE for ambulances evacuating bedridden patients at medical facilities assumes 30 minutes loading time per bedridden person as staff will have to assist them in boarding an ambulance. For example, the ETE for the bedridden patients at Riverview Healthcare Campus with 18 bedridden patients is (assuming concurrent loading on multiple ambulances with a capacity of 2 patients):

ETE: 90 + 2 x 30 + 5 = 2:35

If a second wave is needed, assume 30 minutes travel time to host facility, 30 minutes to unload passengers at host facility, 30 minutes travel time back to original medical facility, a loading time of 30 minutes per bedridden person and a travel time of 10 minutes (5 miles @ 30 mph - assumed)

Second Wave ETE: 2:40 + 30 + 30 + 30 + 2 x 30 + 10 = 5:15

It is assumed that special facility population is directly evacuated to appropriate host medical facilities. Relocation of this population to permanent facilities and/or passing through the reception center before arriving at the host facility is not considered in this analysis.

8.5 Special Needs Population

Based on data provided by the counties, there are an estimated 25 homebound special needs people within the Lucas County portion of the Davis-Besse EPZ and 100 homebound special needs people within the Ottawa County portion of the Davis-Besse EPZ. Details on the number of ambulatory, wheelchair-bound and bedridden people were not available. It is assumed that the percentage of ambulatory (28%), wheelchair-bound (54%) and bedridden (17%) populations are similar to the percentages at the medical facilities within the EPZ. This results in 35 ambulatory, 68 wheelchair-bound and 22 bedridden homebound special needs residents within the Davis-Besse EPZ.

Mobility impaired people unable to ride on a bus will be transported by local fire department/emergency medical service ambulance units, supported by Ohio National Guard ambulance units, to reception centers or hospitals in reception areas (Memorial Hospital in Sandusky County or Firelands Community Hospital in Erie County) depending upon their needs (Ottawa Co. RERP Plan (Rev. 24) Page II-J-5).

ETE for Homebound Special Needs Persons

Wheel-Chair Vans

Section 8.3 identifies a wheelchair van capacity of 4 wheelchairs per trip. As discussed above, there are 68 homebound special needs persons within the EPZ requiring wheelchair van transportation; therefore 17 wheelchair van trips are needed. Assuming one special needs person per household, each wheelchair van will service about 4 households. It is conservatively assumed that the households are spaced 5 miles apart and that van speeds approximate 20 mph between households in good weather (10% slower in rain, 20% slower in snow). The last HH is assumed to be 5 miles from the EPZ boundary, and the network-wide average speed (Scenario6, Region 3) after the last pickup is used to compute travel time. All ETE are rounded to the nearest 5 minutes.

a. Assumed mobilization time for wheelchair van resources to arrive at first household: 1:30 (1:40 in rain, 1:50 in snow)
b. Loading time at first household: 5 minutes (as discussed above in Section 8.4)
c. Travel to next household: 3 @ 15 minutes (5 miles @ 20 mph, 18 mph in rain; 16 mph in snow) = 45 minutes (50 minutes in rain; 56 minutes in snow)
d. Loading time at subsequent households: 3 @ 5 minutes = 15 minutes
e. Travel time to EPZ boundary at 2:35 (2:40 in rain, 2:45 in snow): 5 miles @ 55 mph = 5 minutes (6 minutes in rain, 7 minutes in snow)

ETE: 1:30 + 5 + 45 + 15 + 5 = 2:40

Rain ETE: 1:40 + 5 + 50 + 15 + 6 = 2:55 (rounded up to nearest 5 minutes)

Snow ETE: 1:50 + 5 + 56 + 15 + 7 = 3:15 (rounded up to nearest 5 minutes)

Buses

Assuming no more than one special needs person per household implies that 35 households (HH) need to be serviced. While only 2 buses are needed from a capacity perspective, if 7 buses are deployed to service these special needs HH, then each would require 5 stops. The following outlines the ETE calculations:

1. Assume 7 buses are deployed, each with 5 stops, to service a total of 35 Households.
2. The ETE is calculated as follows:
    a. Buses arrive at the first pickup location: 90 minutes
    b. Load HH members at first pickup: 2 minutes
    c. Travel to subsequent pickup locations: 4 @ 9 minutes = 36 minutes
    d. Load HH members at subsequent pickup locations: 4 @ 2 minutes = 8 minutes
    e. Travel to EPZ boundary at 2:15: 8 miles @ 56 mph: 9 minutes

ETE: 90 + 2 + 36 + 8 + 9 = 2:25

Rain ETE: 100 + 2 + 40 + 8 + 10 = 2:40

Snow ETE: 110 + 2 + 45 + 8 + 11 = 2:55

The estimated travel time between pickups is based on a distance of 3 miles @ 20 mph = 9 minutes (speeds are 10% and 20% lower for rain and snow, respectively). If planned properly, the pickup locations for each bus run should be clustered within the same general area. The estimated travel time to the EPZ boundary is based on a distance of 8 miles @ 56 mph = 9 minutes (average speed output by DYNEV at 2:15 good weather; 50 mph at 2:30 – rain; 47.5 mph at 2:45 - snow). It is assumed that mobilization time to first pickup is 10 minutes longer in rain and 20 minutes longer in snow. All ETE are rounded to the nearest 5 minutes.

Assuming all HH members (avg. HH size equals 2.22 persons) travel with the disabled person yields 5 x 2.22 = 11 persons per bus. From the perspective of bus capacity, fewer buses could be deployed. For example, 3 buses, each servicing about 12 HH could accommodate 2.22 x 11 = 25 people, but the additional 5 stops would add 5 x (6 + 2) = 40 minutes to the ETE. The ETE would equal 3:05 with good weather, 3:20 for rain and 3:35 for snow using 3 buses.

Ambulances

It is estimated that 11 ambulance runs will be needed to evacuate the 22 bedridden homebound persons within the EPZ.

Mobilization time and loading time is assumed to be 30 minutes to the first home. Each ambulance servicing the homebound bed-ridden population will make 2 stops with an estimated distance of 5 miles between stops and an estimated distance of 5 miles to the EPZ boundary after the final stop. It is conservatively assumed that ambulances will travel at 30 mph from household to household. Mobilization time is 5 minutes longer in rain and travel speed is 10% less in rain – 27 mph, and an additional 5 minutes longer and 10% less in snow – 24 mph All ETE are rounded to nearest 5 minutes.

The ETE are computed as follows:

a. Ambulance arrives at first household: 30 minutes
b. Loading time at first household: 30 minutes
c. Ambulance travels to second household: 5 miles @ 30 mph = 10 minutes
d. Loading time at second household: 30 minutes
e. Travel time to EPZ boundary: 5 miles @ 30 mph = 10 minutes

ETE: 30 + 30 + 10 + 30 + 10 = 1:50

Rain ETE: 35 + 30 + 11 + 30 + 11 = 1:55

Snow ETE: 40 + 30 + 13 + 30 + 13 = 2:05

The following outlines the ETE calculations if a second wave is needed:

f. Travel to host facility from EPZ boundary: 20 miles at 30 mph (27 mph in rain, 24 mph in snow) = 40 minutes (45 minutes in rain, 50 minutes in snow)
g. Unload passengers at host facility: 2 @ 15 minutes = 30 minutes. This is half the time needed to load the passengers since (1) the host facility staff can provide assistance; and (2) ambulance drivers need not move the patient inside the host facility.
h. Travel time back to EPZ: 20 miles @ 30 mph = 40 minutes (45 minutes – rain, 50

minutes – snow)

i. Loading times at the first households: 30 minutes
j. Ambulance travels to second household: 5 miles @ 30 mph = 10 minutes (11 minutes – rain, 12 minutes – snow)
k. Loading time at the second household: 30 minutes
l. Travel time to EPZ boundary: 5 miles @ 30 mph = 10 minutes (11 minutes – rain, 13 minutes – snow)

ETE: 1:50 + 40 + 30 + 40 + 30 + 10 + 30 + 10 = 5:00

Rain ETE: 1:55 + 45 + 30 + 45 + 30 + 11 + 30 + 11 = 5:15

Snow ETE: 2:05 + 50 + 30 + 50 + 30 + 12 + 30 + 12 = 5:40

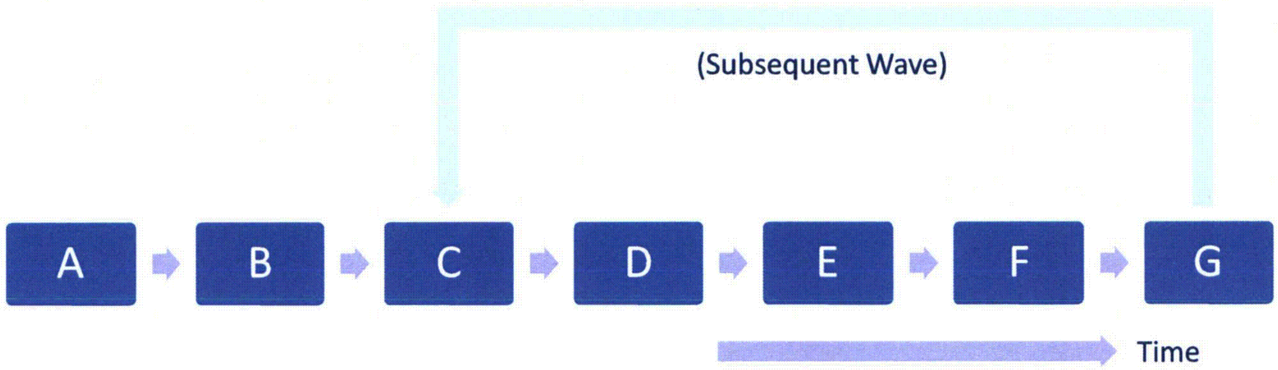
8.6 Correctional Facilities

As detailed in Table E-8, there is one correctional facility within the EPZ – Ottawa County Detention. The total inmate population at this facility is 48 persons. This facility is located in close proximity to the EPZ boundary, as shown in Figure E-8. As stated in the Ohio Radiological Emergency Plan, correctional facilities within the EPZs in Ohio have procedures in place for evacuating to host facilities. A total of 2 buses are needed to evacuate this facility, based on a capacity of 30 inmates per bus. Mobilization time is assumed to be 90 minutes (100 minutes in rain, 110 minutes in snow). It is estimated that it takes 15 minutes to load the inmates onto a bus, and that 2 buses can be loaded in parallel. Thus, total loading time is estimated at approximately 15 minutes. Using GIS software, the shortest route from the facility to the EPZ boundary, traveling away from the plant, is 3 miles. The travel time to traverse 3 miles is 6 minutes (30 mph) in good weather, 7 minutes (27 mph) in rain and 8 minutes (24 mph) in snow. All ETE are rounded to the nearest 5 minutes.

ETE: 90 + 15 + 6 = 1:50

Rain ETE: 100 + 15 + 7 = 2:00

Snow ETE: 110 + 15 + 8 = 2:15



Event	
A	Advisory to Evacuate
B	Bus Dispatched from Depot
C	Bus Arrives at Facility/Pick-up Route
D	Bus Departs for Reception Center
E	Bus Exits Region
F	Bus Arrives at Reception Center
G	Bus Available for "Second Wave" Evacuation Service
Activity	
A→B	Driver Mobilization
B→C	Travel to Facility or to Pick-up Route
C→D	Passengers Board the Bus
D→E	Bus Travels Towards Region Boundary
E→F	Bus Travels Towards Reception Center Outside the EPZ
F→G	Passengers Leave Bus; Driver Takes a Break

Figure 8-1. Chronology of Transit Evacuation Operations

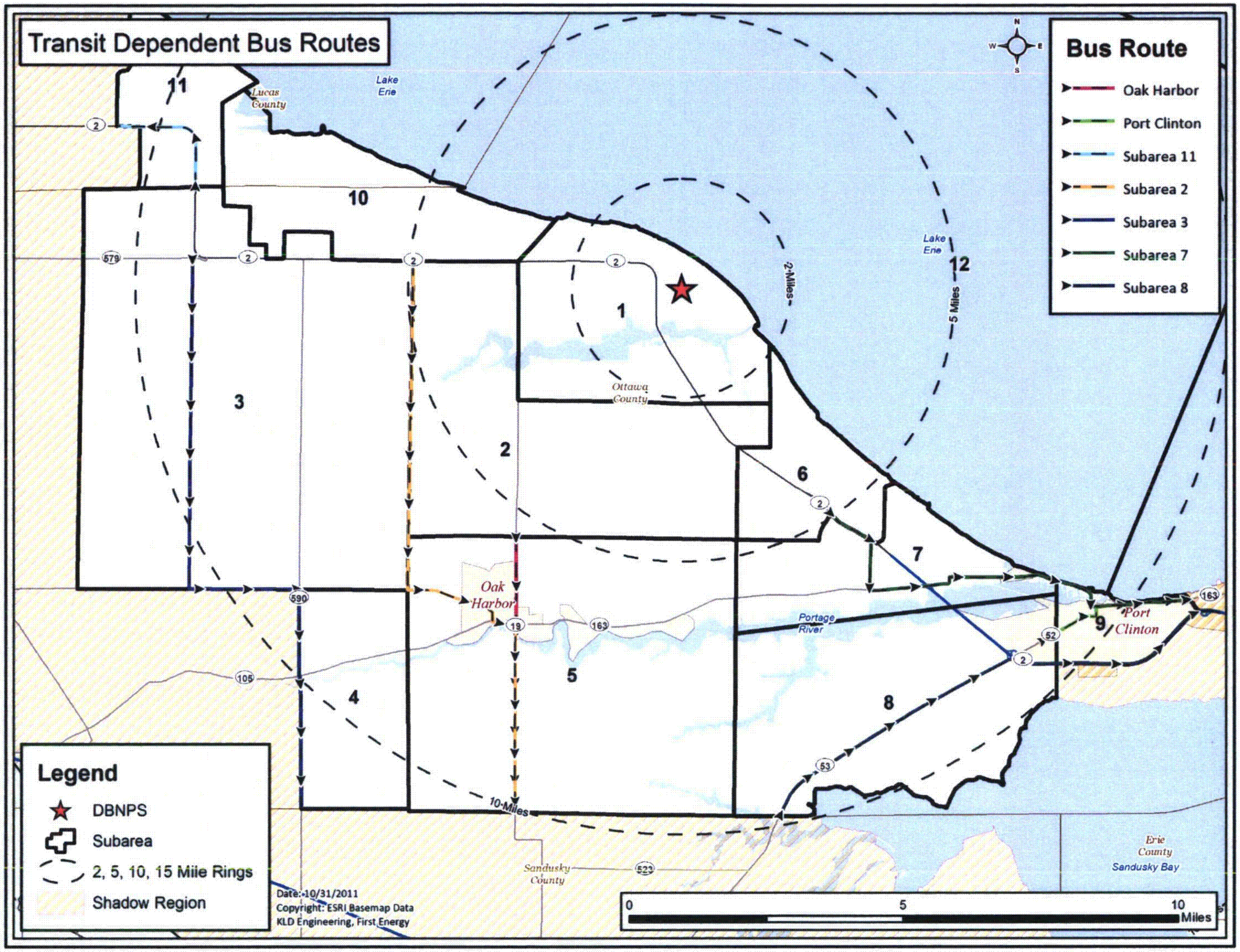


Figure 8-2. Transit-Dependent Bus Routes

Table 8-1. Transit-Dependent Population Estimates

2010 EPZ Population	Survey Average HH Size with Indicated No. of Vehicles			Estimated No. of Households	Survey Percent HH with Indicated No. of Vehicles			Survey Percent HH with Commuters	Survey Percent HH with Non-Returning Commuters	Total People Requiring Transport	Estimated Ridesharing Percentage	People Requiring Public Transit	Percent Population Requiring Public Transit
	0	1	2		0	1	2						
20,403	1.6	1.7	2.1	9,191	2.52%	26.51%	49.66%	47%	56%	853	50%	427	2.1%

Table 8-2. School Population Demand Estimates

Subarea	School Name	Enrollment	Bus Runs Required
Ottawa County Schools			
5	Oak Harbor High School	680	14
5	Oak Harbor Middle School	490	10
5	Ottawa County Christian Academy	18	1
5	R.C. Waters Elementary School	450	7
5	St. Boniface Catholic Church	32	1
9	Bataan Memorial Elementary School	390	6
9	Immaculate Conception School	110	2
9	Jefferson Elementary School	382	6
9	Port Clinton High School	584	12
9	Port Clinton Middle School	410	9
	Ottawa County Subtotals:	***3,546***	***68***
Lucas County Schools			
S.R.	Jerusalem Elementary School	631	10
	Lucas County Subtotals:	***631***	***10***
	TOTAL:	**4,177**	**78**

NOTE: Jerusalem Elementary School is in the Shadow Region. Lucas County RERP plans call for the evacuation of students at this school in the event of an emergency.

Table 8-3. School Reception Centers

School	Relocating School
Jerusalem Elementary School	Oregon Clay High School
Oak Harbor High School	Fremont Ross High School
Oak Harbor Middle School	
Ottawa County Christian Academy	
R. C. Waters Elementary School	
St. Boniface Catholic Church	
Bataan Elementary School	Sandusky High School
Immaculate Conception School	
Jefferson Elementary School	
Port Clinton High School	
Port Clinton Middle School	

Table 8-4. Special Facility Transit Demand

Area	Facility Name	Municipality	Cap-acity	Current Census	Ambu-latory	Wheel-chair Bound	Bed-ridden	Bus Runs	Wheel-chair Bus Runs	Ambulance Runs
5	Riverview Healthcare Campus	Oak Harbor	190	93	26	49	18	1	4	9
9	Edgewood Manor Nursing Home	Port Clinton	99	66	19	47	0	1	4	0
9	H.B. Magruder Hospital	Port Clinton	25	25	6	4	15	1	1	8
		TOTAL:	**314**	**184**	**51**	**100**	**33**	**3**	**9**	**17**

Table 8-5. Transportation Resources

Transportation Resource	Drivers	Buses	Vans	Wheelchair Buses	Wheelchair Vans	Ambulances
Resources Available						
Port Clinton Schools	N/A	21	-	-	-	-
Benton-Carroll-Salem Schools	N/A	30	-	-	-	-
Ottawa County Christian Academy	N/A	-	-	-	-	-
Jerusalem Elementary School	N/A	8	-	-	-	-
Riverview Healthcare Campus	N/A	-	-	1	-	-
Edgewood Manor Nursing Home	N/A	-	1	-	-	-
H.B. Magruder Hospital	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL:	**N/A**	**59**	**1**	**1**	**-**	**-**
Resources Needed						
Schools (Table 8-2):		78	-	-	-	-
Medical Facilities (Table 8-4):		3	-	9	-	17
Transit-Dependent Population (Table 8-10):		14	-	-	-	-
Homebound Special Needs (Section 8.5):		2	-	-	17	11
Correctional Facilities (Section 8.6):		2	-	-	-	-
TOTAL TRANSPORTATION NEEDS:		**99**	**-**	**9**	**17**	**28**

Table 8-6. Bus Route Descriptions

Bus Route Number	Description	Nodes Traversed from Route Start to EPZ Boundary
2	Ottawa County Christian Academy	225, 226, 227, 228, 231, 256, 258, 260, 261, 264, 473, 265, 266, 267, 268, 269
5	Oak Harbor High School	226, 227, 228, 231, 256, 258, 260, 261, 264, 473, 265, 266, 267, 268, 269
6	Oak Harbor Middle School	416, 263, 260, 261, 264, 473, 265, 266, 267, 268, 269
7	R. C. Waters Elementary School	417, 263, 260, 261, 264, 473, 265, 266, 267, 268, 269
8	Jefferson Elementary School	308, 311, 312, 315, 326, 327, 328, 329, 330, 331, 334, 335, 98, 97, 99, 94, 95
9	Port Clinton High School	307, 306, 308, 311, 312, 315, 326, 327, 328, 329, 330, 331, 334, 335, 98, 97, 99, 94, 95
10	Bataan Elementary School	302, 301, 300, 298, 106, 25, 24, 103, 102, 101, 100, 96, 94, 95
11	Port Clinton Middle School	308, 311, 312, 315, 326, 327, 328, 329, 330, 331, 334, 335, 98, 97, 99, 94, 95
12	St. Boniface Catholic Church	5, 263, 260, 261, 264, 473, 265, 266, 267, 268
14	SR-2 EB	154, 149, 148, 147, 146, 145, 143, 142, 137, 141, 136, 134, 132, 131, 130, 128, 119, 117, 116, 126, 118, 115, 123, 114, 113, 120, 112, 111, 110, 105, 104, 103, 102, 101, 100, 96, 94
15	SR-2 WB	94, 96, 100, 101, 102, 103, 104, 105, 110, 111, 112, 120, 113, 114, 123, 115, 118, 126, 116, 117, 119, 128, 130, 131, 132, 134, 136, 141, 137, 142, 143, 145, 146, 147, 148, 149, 154
16	SR-163 WB	262, 260, 258, 256, 231, 228, 227, 226, 225, 224, 223, 181, 222, 221, 208
17	SR-105 WB	230, 232, 233, 234, 235, 255, 254, 182, 253, 252, 251, 250, 249, 248, 247, 246, 450, 451, 199
20	Transit-Dependent - Port Clinton	106, 298, 300, 318, 317, 314, 313, 316, 312, 315, 326, 327, 328, 329, 330, 331, 334, 335
21	Transit-Dependent - Oak Harbor	421, 420, 419, 416, 263, 260, 261, 264, 473, 265, 266, 267, 268
22	Transit-Dependent - Subarea 2	241, 240, 456, 239, 238, 237, 236, 223, 224, 225, 226, 227, 228, 231, 256, 258, 260, 261, 264, 473, 265, 266, 267, 268
23	Transit-Dependent - Graytown	243, 245, 222, 181, 182, 183, 184, 487, 185
24	Transit-Dependent - Subarea 7	111, 405, 404, 109, 403, 402, 401, 400, 399, 398, 324, 323, 322, 321, 320, 319, 316, 312, 315, 326, 327, 328, 329, 330, 331, 334, 335
25	Transit-Dependent - Subarea 8	17, 18, 19, 20, 21, 22, 23, 24, 103, 102, 101, 100, 96, 94
26	Transit-Dependent - Subarea 11	146, 147, 148, 149, 154

Table 8-7. School Evacuation Time Estimates - Good Weather

School	Driver Mobilization Time	Loading Time (min)	Dist. To EPZ Bdry (mi.)	Average Speed[2] (mph)	Travel Time to EPZ Bdry (min.)	ETE (hr:min)	Dist. EPZ bdry to H.S. (mi.)	Travel Time from EPZ Bdry to H.S. (min)	ETE to H.S. (hr:min)
Ottawa County Schools									
Bataan Memorial Elementary School	90	15	5.7	35	10	**1:55**	13.1	23	**2:20**
Immaculate Conception School	90	15	5.7	35	10	**1:55**	13.1	23	**2:20**
Jefferson Elementary School	90	15	2.7	35	5	**1:50**	13.1	23	**2:15**
Oak Harbor High School	90	15	4.4	35	8	**1:55**	7.8	14	**2:10**
Oak Harbor Middle School	90	15	3.9	35	7	**1:55**	7.8	14	**2:10**
Ottawa County Christian Academy	90	15	4.9	35	9	**1:55**	7.8	14	**2:10**
Port Clinton High School	90	15	3	32	6	**1:55**	13.1	23	**2:15**
Port Clinton Middle School	90	15	2.7	35	5	**1:50**	13.1	23	**2:15**
R.C. Waters Elementary School	90	15	3.7	35	7	**1:55**	7.8	14	**2:10**
St. Boniface Catholic Church	90	15	3.8	35	7	**1:55**	7.8	14	**2:10**
Lucas County Schools									
Jerusalem Elementary School[2]	90	15	0	35	0	**1:45**	6.8	12	**2:00**
					Maximum for EPZ:	**1:55**		**Maximum:**	**2:20**
					Average for EPZ:	**1:55**		**Average:**	**2:10**

1 Buses traveled along state routes to host facilities. The state speed limit for a state route in Ohio is 35mph.
2 Jerusalem Elementary School is located outside the EPZ.

Table 8-8. School Evacuation Time Estimates – Rain

School	Driver Mobilization Time	Loading Time (min)	Dist. To EPZ Bdry (mi.)	Average Speed[1] (mph)	Travel Time to EPZ Bdry (min.)	ETE (hr:min)	Dist. EPZ bdry to H.S. (mi.)	Travel Time from EPZ Bdry to H.S. (min)	ETE to H.S. (hr:min)
Ottawa County Schools									
Bataan Memorial Elementary School	100	20	5.7	35	10	**2:10**	13.1	23	**2:35**
Immaculate Conception School	100	20	5.7	32.8	11	**2:15**	13.1	23	**2:35**
Jefferson Elementary School	100	20	2.7	32.8	5	**2:05**	13.1	23	**2:30**
Oak Harbor High School	100	20	4.4	35	8	**2:10**	7.8	14	**2:25**
Oak Harbor Middle School	100	20	3.9	35	7	**2:10**	7.8	14	**2:25**
Ottawa County Christian Academy	100	20	4.9	35	9	**2:10**	7.8	14	**2:25**
Port Clinton High School	100	20	3	29.8	7	**2:10**	13.1	23	**2:30**
Port Clinton Middle School	100	20	2.7	32.8	5	**2:05**	13.1	23	**2:30**
R.C. Waters Elementary School	100	20	3.7	35	7	**2:10**	7.8	14	**2:25**
St. Boniface Catholic Church	100	20	3.8	35	7	**2:10**	7.8	14	**2:25**
Lucas County Schools									
Jerusalem Elementary School[2]	100	20	0	35	0	**2:00**	6.8	12	**2:15**
					Maximum for EPZ:	**2:15**		**Maximum:**	**2:35**
					Average for EPZ:	**2:10**		**Average:**	**2:25**

1 Buses traveled along state routes to host facilities. The state speed limit for a state route in Ohio is 35mph.
2 Jerusalem Elementary School is located outside the EPZ.

Table 8-9. School Evacuation Time Estimates – Snow

School	Driver Mobilization Time	Loading Time (min)	Dist. To EPZ Bdry (mi.)	Average Speed[1] (mph)	Travel Time to EPZ Bdry (min.)	ETE (hr:min)	Dist. EPZ bdry to H.S. (mi.)	Travel Time from EPZ Bdry to H.S. (min)	ETE to H.S. (hr:min)
Ottawa County Schools									
Bataan Memorial Elementary School	110	25	5.7	35	10	**2:25**	13.1	23	**2:50**
Immaculate Conception School	110	25	5.7	29	12	**2:30**	13.1	23	**2:50**
Jefferson Elementary School	110	25	2.7	29	6	**2:25**	13.1	23	**2:45**
Oak Harbor High School	110	25	4.4	35	8	**2:25**	7.8	14	**2:40**
Oak Harbor Middle School	110	25	3.9	35	7	**2:25**	7.8	14	**2:40**
Ottawa County Christian Academy	110	25	4.9	35	9	**2:25**	7.8	14	**2:40**
Port Clinton High School	110	25	3	26.4	7	**2:25**	13.1	23	**2:45**
Port Clinton Middle School	110	25	2.7	29	6	**2:25**	13.1	23	**2:45**
R.C. Waters Elementary School	110	25	3.7	35	7	**2:25**	7.8	14	**2:40**
St. Boniface Catholic Church	110	25	3.8	35	7	**2:25**	7.8	14	**2:40**
Lucas County Schools									
Jerusalem Elementary School[2]	110	25	0	35	0	**2:15**	6.8	12	**2:30**
					Maximum for EPZ:	**2:30**		**Maximum:**	**2:50**
					Average for EPZ:	**2:25**		**Average:**	**2:40**

1 Buses traveled along state routes to host facilities. The state speed limit for a state route in Ohio is 35mph.
2 Jerusalem Elementary School is located outside the EPZ.

Table 8-10. Summary of Transit-Dependent Bus Routes

Route	No. of Buses	Route Description	Length (mi.)
20	4	Transit-Dependent - Port Clinton	2.98
21	3	Transit-Dependent - Oak Harbor	5.04
22	1	Transit-Dependent - Subarea 2	11.72
23	1	Transit-Dependent - Graytown	12.04
24	2	Transit-Dependent - Subarea 7	8.02
25	2	Transit-Dependent - Subarea 8	9.37
26	1	Transit-Dependent - Subarea 11	2.42
TOTAL	**14**		

Table 8-11. Transit-Dependent Evacuation Time Estimates - Good Weather

Route Number	Bus Number	One-Wave						Two-Wave						
		Mobilization	Length (miles)	Speed (mph)	Route Travel Time	Pickup Time	ETE	Length (miles)	Travel Time to Rec. Ctr	Unload	Driver Rest	Route Travel Time	Pickup Time	ETE
20	1	90	2.98	15.8	11.32	30	2:15	13.88	18.51	5	10	25.44	30	3:45
	2	110	2.98	21.8	8.20	30	2:30	13.88	18.51	5	10	25.44	30	4:00
	3	130	2.98	24	7.45	30	2:50	13.88	18.51	5	10	25.44	30	4:20
	4	150	2.98	23.8	7.51	30	3:10	13.88	18.51	5	10	25.44	30	4:40
21	1	90	5.04	44	6.87	30	2:10	7.80	10.40	5	10	17.37	30	3:20
	2	110	5.04	41.8	7.23	30	2:30	7.80	10.40	5	10	17.37	30	3:45
	3	130	5.04	43.1	7.02	30	2:50	7.80	10.40	5	10	17.37	30	4:00
22	1	90	11.72	46.5	15.12	30	2:20	7.80	10.40	5	10	24.81	30	3:40
23	1	90	12.04	56.5	12.79	30	2:15	10.77	14.36	5	10	26.67	30	3:40
24	1	90	8.02	30.6	15.73	30	2:20	13.88	18.51	5	10	31.07	30	3:55
	2	110	8.02	35.9	13.40	30	2:35	13.88	18.51	5	10	31.07	30	4:10
25	1	90	9.37	62.8	8.95	30	2:10	13.88	18.51	5	10	27.40	30	3:40
	2	110	9.37	62.8	8.95	30	2:30	13.88	18.51	5	10	27.40	30	4:00
26	1	90	2.42	55.2	2.63	30	2:05	4.84	6.45	5	10	9.12	30	3:05
						Maximum ETE:	3:10						**Maximum ETE:**	4:40
						Average ETE:	2:27						**Average ETE:**	3:51

Table 8-12. Transit-Dependent Evacuation Time Estimates – Rain

Route Number	Bus Number	One-Wave: Mobilization	One-Wave: Length (miles)	One-Wave: Speed (mph)	One-Wave: Route Travel Time	One-Wave: Pickup Time	One-Wave: ETE	Two-Wave: Length (miles)	Two-Wave: Travel Time to Rec. Ctr	Two-Wave: Unload	Two-Wave: Driver Rest	Two-Wave: Route Travel Time	Two-Wave: Pickup Time	Two-Wave: ETE
20	1	100	2.98	16.6	10.77	40	**2:35**	13.88	20.82	5	10	28.30	40	**4:15**
	2	120	2.98	22.2	8.05	40	**2:50**	13.88	20.82	5	10	28.30	40	**4:35**
	3	140	2.98	22.1	8.09	40	**3:10**	13.88	20.82	5	10	28.30	40	**4:55**
	4	160	2.98	22.9	7.81	40	**3:30**	13.88	20.82	5	10	28.30	40	**5:15**
21	1	100	5.04	39.5	7.66	40	**2:30**	7.80	11.70	5	10	19.34	40	**3:55**
	2	120	5.04	39.3	7.69	40	**2:50**	7.80	11.70	5	10	19.34	40	**4:15**
	3	140	5.04	39.3	7.69	40	**3:10**	7.80	11.70	5	10	19.34	40	**4:35**
22	1	100	11.72	39.5	17.80	40	**2:40**	7.80	11.70	5	10	27.57	40	**4:15**
23	1	100	12.04	48.7	14.83	40	**2:35**	10.77	16.16	5	10	29.81	40	**4:20**
24	1	100	8.02	28	17.19	40	**2:40**	13.88	20.82	5	10	34.53	40	**4:30**
	2	120	8.02	33.5	14.36	40	**2:55**	13.88	20.82	5	10	34.53	40	**4:45**
25	1	100	9.37	55.7	10.09	40	**2:35**	13.88	20.82	5	10	30.70	40	**4:20**
	2	120	9.37	54.7	10.28	40	**2:55**	13.88	20.82	5	10	30.70	40	**4:40**
26	1	100	2.42	48.1	3.02	40	**2:25**	4.84	7.26	5	10	10.20	40	**3:40**
						Maximum ETE:	**3:30**						**Maximum ETE:**	**5:15**
						Average ETE:	**2:48**						**Average ETE:**	**4:26**

Table 8-13. Transit-Dependent Evacuation Time Estimates – Snow

Route Number	Bus Number	One-Wave						Two-Wave						
		Mobilization	Length (miles)	Speed (mph)	Route Travel Time	Pickup Time	ETE	Length (miles)	Travel Time to Rec. Ctr	Unload	Driver Rest	Route Travel Time	Pickup Time	ETE
20	1	110	2.98	16.2	11.04	50	**2:55**	13.88	23.79	5	10	31.96	50	**4:55**
	2	130	2.98	18.5	9.66	50	**3:10**	13.88	23.79	5	10	31.96	50	**5:15**
	3	150	2.98	19	9.41	50	**3:30**	13.88	23.79	5	10	31.96	50	**5:35**
	4	170	2.98	19.7	9.08	50	**3:50**	13.88	23.79	5	10	31.96	50	**5:50**
21	1	110	5.04	34.8	8.69	50	**2:50**	7.80	13.37	5	10	21.99	50	**4:30**
	2	130	5.04	35	8.64	50	**3:10**	7.80	13.37	5	10	21.99	50	**4:50**
	3	150	5.04	35.1	8.62	50	**3:30**	7.80	13.37	5	10	21.99	50	**5:10**
22	1	110	11.72	37.1	18.95	50	**3:00**	7.80	13.37	5	10	31.31	50	**4:50**
23	1	110	12.04	44.5	16.23	50	**3:00**	10.77	18.46	5	10	33.93	50	**4:55**
24	1	110	8.02	25.5	18.87	50	**3:00**	13.88	23.79	5	10	39.22	50	**5:10**
	2	130	8.02	29.6	16.26	50	**3:20**	13.88	23.79	5	10	39.22	50	**5:25**
25	1	110	9.37	50	11.24	50	**2:55**	13.88	23.79	5	10	34.97	50	**5:00**
	2	130	9.37	50.1	11.22	50	**3:15**	13.88	23.79	5	10	34.97	50	**5:15**
26	1	110	2.42	43.9	3.31	50	**2:45**	4.84	8.30	5	10	11.63	50	**4:10**
						Maximum ETE:	**3:50**						**Maximum ETE:**	**5:50**
						Average ETE:	**3:09**						**Average ETE:**	**5:03**

9 TRAFFIC MANAGEMENT STRATEGY

This section discusses the suggested traffic control and management strategy that is designed to expedite the movement of evacuating traffic. The resources required to implement this strategy include:

- Personnel with the capabilities of performing the planned control functions of traffic guides (preferably, not necessarily, law enforcement officers).
- Traffic Control Devices to assist these personnel in the performance of their tasks. These devices should comply with the guidance of the Manual of Uniform Traffic Control Devices (MUTCD) published by the Federal Highway Administration (FHWA) of the U.S.D.O.T. All state and most county transportation agencies have access to the MUTCD which is available on-line: http://mutcd.fhwa.dot.gov. This site provides access to the official PDF version.
- A plan that defines all locations, provides necessary details and is documented in a format that is readily understood by those assigned to perform traffic control.

The functions to be performed in the field are:

1. Facilitate evacuating traffic movements that safely expedite travel out of the EPZ.
2. Discourage traffic movements that move evacuating vehicles in a direction which takes them significantly closer to the power plant, or which interferes with the efficient flow of other evacuees.

We employ the terms "facilitate" and "discourage" rather than "enforce" and "prohibit" to indicate the need for flexibility in performing the traffic control function. There are always legitimate reasons for a driver to prefer a direction other than that indicated. For example:

- A driver may be traveling home from work or from another location, to join other family members prior to evacuating.
- An evacuating driver may be travelling to pick up a relative, or other evacuees.
- The driver may be an emergency worker en route to perform an important activity.

The implementation of a plan must also be flexible enough for the application of sound judgment by the traffic guide.

The traffic management plan is the outcome of the following process:

1. The existing Traffic Control Points (TCPs) and Access Control Points (ACPs) identified by the offsite agencies in their existing emergency plans serve as the basis of the traffic management plan, as per NUREG/CR-7002.
2. Computer analysis of the evacuation traffic flow environment.

   This analysis identifies the best routing and those critical intersections that experience pronounced congestion. Any critical intersections that are not identified in the existing offsite plans are suggested as additional TCPs and ACPs
3. A field survey of the highway network within 15 miles of the power plant. The schematics describing traffic and access control at suggested additional TCPs and ACPs, which are presented in Appendix G, are based on data collected during field surveys, upon large scale maps, and on overhead photos.
4. Consultation with emergency management and law enforcement personnel.

   Trained personnel who are experienced in controlling traffic and are aware of the likely evacuation traffic patterns and have reviewed the control tactics at the suggested additional TCPs and ACPs.
5. Prioritization of TCPs and ACPs.

   Application of traffic and access control at some TCPs and ACPs will have a more pronounced influence on expediting traffic movements than at other TCPs and ACPs. For example, TCPs controlling traffic originating from areas in close proximity to the power plant could have a more beneficial effect on minimizing potential exposure to radioactivity than those TCPs located far from the power plant. These priorities should be assigned by state/county emergency management representatives and by law enforcement personnel.

The control tactics identified in the schematics in Appendix G have been reviewed by the state and county emergency planners, and local and state police. Specifically the number and locations of the suggested TCPs and ACPs have been reviewed in detail, and the indicated resource requirements have been reconciled with current assets.

The use of Intelligent Transportation Systems (ITS) technologies can reduce manpower and equipment needs, while still facilitating the evacuation process. Dynamic Message Signs (DMS) can be placed within the EPZ to provide information to travelers regarding traffic conditions, route selection, and reception center information. DMS can also be placed outside of the EPZ to warn motorists to avoid using routes that may conflict with the flow of evacuees away from the power plant. Highway Advisory Radio (HAR) can be used to broadcast information to evacuees en route through their vehicle stereo systems. Automated Traveler Information Systems (ATIS) can also be used to provide evacuees with information. Internet websites can provide traffic and evacuation route information before the evacuee begins his trip, while on board navigation systems (GPS units), cell phones, and pagers can be used to provide information en route. These are only several examples of how ITS technologies can benefit the evacuation process. Consideration should be given that ITS technologies be used to facilitate the evacuation process, and any additional signage placed should consider evacuation needs.

The ETE analysis treated all intersections that are existing TCP locations in the offsite agency plans as being controlled by actuated signals.

Chapters 2N and 5G, and Part 6 of the 2009 MUTCD are particularly relevant and should be reviewed during emergency response training.

The ETE calculations reflect the assumption that all "external-external" travel along highways located outside of the EPZ continue throughout the evacuation. No ACP's will be established for the external traffic roadways because they are outside the EPZ.

All transit vehicles and other responders entering the EPZ to support the evacuation are assumed to be unhindered by personnel manning ACPs and TCPs.

Study Assumptions 5 and 6 in Section 2.3 discuss ACP and TCP staffing schedules and operations.

10 EVACUATION ROUTES

Evacuation routes are comprised of two distinct components:

- Routing from a Subarea being evacuated to the boundary of the Evacuation Region and thence out of the Emergency Planning Zone (EPZ).
- Routing of transit-dependent evacuees from the EPZ boundary to reception centers.

Evacuees will select routes within the EPZ in such a way as to minimize their exposure to risk. This expectation is met by the DYNEV II model routing traffic away from the location of the plant, to the extent practicable. The DTRAD model satisfies this behavior by routing traffic so as to balance traffic demand relative to the available highway capacity to the extent possible. See Appendices B through D for further discussion.

The routing of transit-dependent evacuees from the EPZ boundary to reception centers or host facilities is designed to minimize the amount of travel outside the EPZ, from the points where these routes cross the EPZ boundary.

Figure 10-1 presents a map showing the reception centers for evacuees. The major evacuation routes for the EPZ are presented in Figure 10-2 and Figure 10-3.

The county radiological emergency plans identify reception centers and "care centers". It is assumed that all school evacuees will be taken to the appropriate relocating school and subsequently picked up by parents or guardians. Transit-dependent evacuees are transported to the nearest reception center for each county. This study does not consider the transport of evacuees from reception centers to care centers, if the counties do make the decision to relocate evacuees.

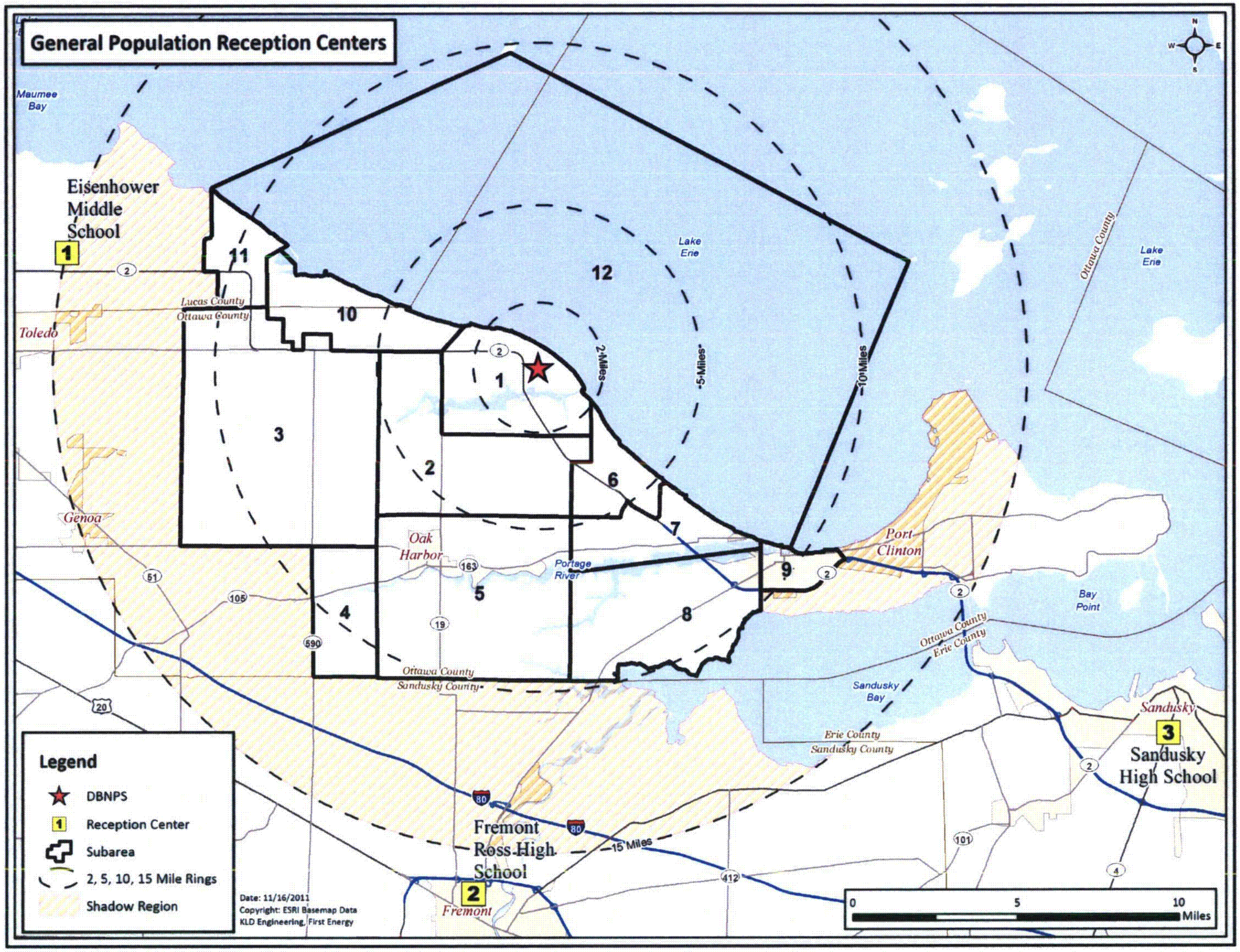


Figure 10-1. General Population Reception Centers

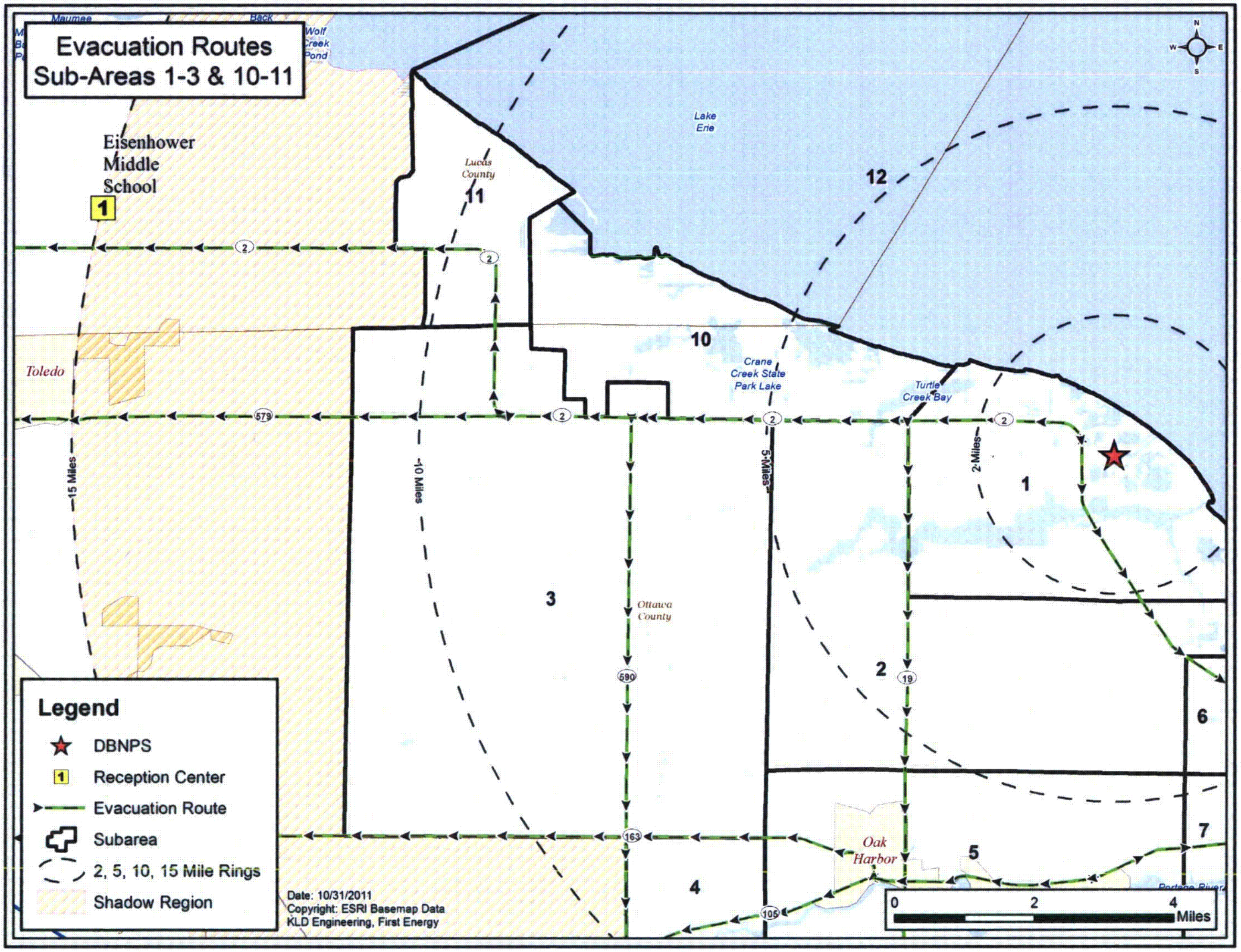


Figure 10-2. Evacuation Route Map of the Northwestern Quadrant of the EPZ (Subareas 1-3 & 10-11)

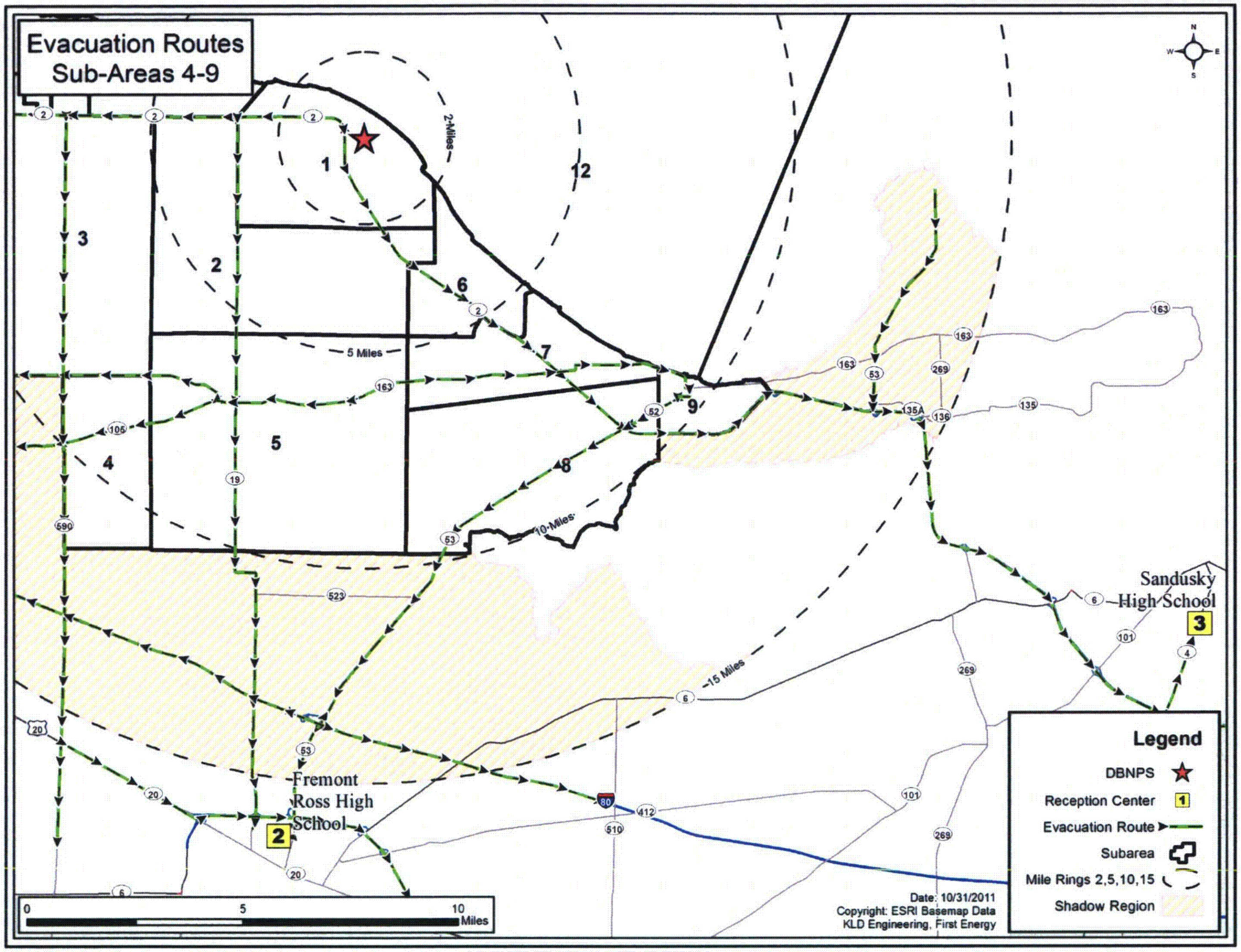


Figure 10-3. Evacuation Route Map for the Southeastern Quadrant of the EPZ (Subareas 4-9)

11 SURVEILLANCE OF EVACUATION OPERATIONS

There is a need for surveillance of traffic operations during the evacuation. There is also a need to clear any blockage of roadways arising from accidents or vehicle disablement. Surveillance can take several forms.

1. Traffic control personnel, located at Traffic Control and Access Control points, provide fixed-point surveillance.
2. Ground patrols may be undertaken along well-defined paths to ensure coverage of those highways that serve as major evacuation routes.
3. Aerial surveillance of evacuation operations may also be conducted using helicopter or fixed-wing aircraft, if available.
4. Cell phone calls (where cellular coverage exists) from evacuees can provide direct field reports of road blockages.

These concurrent surveillance procedures provide coverage of the entire EPZ as well as the area around its periphery. It is the responsibility of the Counties to support an emergency response system that can receive messages from the field and be in a position to respond to any reported problems in a timely manner. This coverage should quickly identify, and expedite the response to any blockage caused by a disabled vehicle.

<u>Tow Vehicles</u>

In a congested traffic environment, any vehicle disablement is likely to arise due to a low-speed collision, a vehicle mechanical failure or the exhaustion of its fuel supply. In any case, the disabled vehicle can be pushed onto the shoulder, thereby restoring traffic flow. Past experience in other emergencies indicates that evacuees who are leaving an area often perform activities such as pushing a disabled vehicle to the side of the road without prompting.

While the need for tow vehicles is expected to be low under the circumstances described above, it is still prudent to be prepared for such a need. Consideration should be given that tow trucks with a supply of gasoline be deployed at strategic locations within, or just outside, the EPZ. These locations should be selected so that:

- They provide access to key, heavily loaded, evacuation routes.
- Responding tow trucks would most likely travel counter-flow relative to evacuating traffic.

Consideration should also be given for the state and local emergency management agencies to encourage gas stations to remain open during the evacuation.

12 CONFIRMATION TIME

It is necessary to confirm that the evacuation process is effective in the sense that the public is complying with the Advisory to Evacuate. The EPZ county radiological emergency plans do not discuss a procedure for confirming evacuation. Should procedures not already exist, we suggest an alternative or complementary approach.

The procedure we suggest employs a stratified random sample and a telephone survey. The size of the sample is dependent on the expected number of households that do not comply with the Advisory to Evacuate. It is reasonable to assume, for the purpose of estimating sample size that at least 80 percent of the population within the EPZ will comply with the Advisory to Evacuate. On this basis, an analysis could be undertaken (see Table 12-1) to yield an estimated sample size of approximately 300.

The confirmation process should start at about 2 hours and 30 minutes after the Advisory to Evacuate, which is when 90 percent of evacuees have completed their mobilization activities (see Figure 5-4). At this time, virtually all evacuees will have departed on their respective trips and the local telephone system will be largely free of traffic.

As indicated in Table 12-1, approximately 7½ person hours are needed to complete the telephone survey. If six people are assigned to this task, each dialing a different set of telephone exchanges (e.g., each person can be assigned a different set of Subareas), then the confirmation process will extend over a time frame of about 75 minutes. Thus, the confirmation should be completed before the mobilization is completed. Of course, fewer people would be needed for this survey if the Evacuation Region were only a portion of the EPZ. Use of modern automated computer controlled dialing equipment can significantly reduce the manpower requirements and the time required to undertake this type of confirmation survey.

If this method is indeed used by the offsite agencies, a list of telephone numbers within the EPZ should be kept in the Emergency Operations Center (EOC) at all times. Such a list could be purchased from vendors and should be periodically updated. The 2 hour and 30 minute start time will enable telephone operators to arrive at their workplace, obtain a call list and prepare to make the necessary phone calls.

Should the number of telephone responses (i.e., people still at home) exceed 20 percent, then the telephone survey should be repeated after an hour's interval until the confirmation process is completed.

Other techniques should also be considered. After traffic volumes decline, the personnel manning TCPs can be redeployed to travel through residential areas to observe evacuation activities and to encourage any laggards to begin their evacuation trips.

Table 12-1. Estimated Number of Telephone Calls Required for Confirmation of Evacuation

Problem Definition

Estimate number of phone calls, n, needed to ascertain the proportion, F of households that have not evacuated.

Reference: Burstein, H., Attribute Sampling, McGraw Hill, 1971

Given:

- No. of households plus other facilities, N, within the EPZ (est.) = 9,250
- Est. proportion, F, of households that will not evacuate = 0.20
- Allowable error margin, e: 0.05
- Confidence level, α: 0.95 (implies A = 1.96)

Applying Table 10 of cited reference,

$$p = F + e = 0.25; \;\; q = 1 - p = 0.75$$

$$n = \frac{A^2 pq + e}{e^2} = 308$$

Finite population correction:

$$n_F = \frac{nN}{n + N - 1} = 298$$

Thus, some 300 telephone calls will confirm that approximately 20 percent of the population has not evacuated. If only 10 percent of the population does not comply with the Advisory to Evacuate, then the required sample size, n_F = 211.

Est. Person Hours to complete 300 telephone calls

Assume:

- Time to dial using touch tone (random selection of listed numbers): 30 seconds
- Time for 6 rings (no answer): 36 seconds
- Time for 4 rings plus short conversation: 60 sec.
- Interval between calls: 20 sec.

Person Hours:

$$\frac{300[30 + 0.8(36) + 0.2(60) + 20]}{3600} = 7.6$$

APPENDIX A

Glossary of Traffic Engineering Terms

A. GLOSSARY OF TRAFFIC ENGINEERING TERMS

Table A-1. Glossary of Traffic Engineering Terms

Term	Definition
Analysis Network	A graphical representation of the geometric topology of a physical roadway system, which is comprised of directional links and nodes.
Link	A network link represents a specific, one-directional section of roadway. A link has both physical (length, number of lanes, topology, etc.) and operational (turn movement percentages, service rate, free-flow speed) characteristics.
Measures of Effectiveness	Statistics describing traffic operations on a roadway network.
Node	A network node generally represents an intersection of network links. A node may have control characteristics, i.e., the allocation of service time to each approach link.
Origin	A location attached to a network link, within the EPZ or Shadow Region, where trips are generated at specified rates in vehicles per hour (vph). These trips enter the roadway system to travel to their respective destinations.
Prevailing Roadway and Traffic Conditions	Relates to the physical features of the roadway, the nature (e.g., composition) of traffic on the roadway and the ambient conditions (weather, visibility, pavement conditions, etc.).
Service Rate	Maximum rate at which vehicles, executing a specific turn maneuver, can be discharged from a section of roadway at the prevailing conditions, expressed in vehicles per second (vps) or vehicles per hour (vph).
Service Volume	Maximum number of vehicles which can pass over a section of roadway in one direction during a specified time period with operating conditions at a specified Level of Service (The Service Volume at the upper bound of Level of Service, E, equals Capacity). Service Volume is usually expressed as vehicles per hour (vph).
Signal Cycle Length	The total elapsed time to display all signal indications, in sequence. The cycle length is expressed in seconds.
Signal Interval	A single combination of signal indications. The interval duration is expressed in seconds. A signal phase is comprised of a sequence of signal intervals, usually green, yellow, red.

Term	Definition
Signal Phase	A set of signal indications (and intervals) which services a particular combination of traffic movements on selected approaches to the intersection. The phase duration is expressed in seconds.
Traffic (Trip) Assignment	A process of assigning traffic to paths of travel in such a way as to satisfy all trip objectives (i.e., the desire of each vehicle to travel from a specified origin in the network to a specified destination) and to optimize some stated objective or combination of objectives. In general, the objective is stated in terms of minimizing a generalized "cost". For example, "cost" may be expressed in terms of travel time.
Traffic Density	The number of vehicles that occupy one lane of a roadway section of specified length at a point in time, expressed as vehicles per mile (vpm).
Traffic (Trip) Distribution	A process for determining the destinations of all traffic generated at the origins. The result often takes the form of a Trip Table, which is a matrix of origin-destination traffic volumes.
Traffic Simulation	A computer model designed to replicate the real-world operation of vehicles on a roadway network, so as to provide statistics describing traffic performance. These statistics are called Measures of Effectiveness.
Traffic Volume	The number of vehicles that pass over a section of roadway in one direction, expressed in vehicles per hour (vph). Where applicable, traffic volume may be stratified by turn movement.
Travel Mode	Distinguishes between private auto, bus, rail, pedestrian and air travel modes.
Trip Table or Origin-Destination Matrix	A rectangular matrix or table, whose entries contain the number of trips generated at each specified origin, during a specified time period, that are attracted to (and travel toward) each of its specified destinations. These values are expressed in vehicles per hour (vph) or in vehicles.
Turning Capacity	The capacity associated with that component of the traffic stream which executes a specified turn maneuver from an approach at an intersection.

APPENDIX B

DTRAD: Dynamic Traffic Assignment and Distribution Model

B. DYNAMIC TRAFFIC ASSIGNMENT AND DISTRIBUTION MODEL

This section describes the integrated dynamic trip assignment and distribution model named DTRAD (Dynamic Traffic Assignment and Distribution) that is expressly designed for use in analyzing evacuation scenarios. DTRAD employs logit-based path-choice principles and is one of the models of the DYNEV II System. The DTRAD module implements path-based *Dynamic Traffic Assignment* (DTA) so that time dependent Origin-Destination (OD) trips are "assigned" to routes over the network based on prevailing traffic conditions.

To apply DYNEV II, the analyst must specify the highway network, link capacity information, the time-varying volume of traffic generated at all origin centroids and, optionally, a set of accessible candidate destination nodes on the periphery of the EPZ for selected origins. DTRAD calculates the optimal dynamic trip distribution and the optimal dynamic trip assignment (i.e., routing) of the traffic generated at each origin node traveling to its set of candidate destination nodes, so as to minimize evacuee travel "cost".

Overview of Integrated Distribution and Assignment Model

The underlying premise is that the selection of destinations and routes is intrinsically coupled in an evacuation scenario. That is, people in vehicles seek to travel out of an area of potential risk as rapidly as possible by selecting the "best" routes. The model is designed to identify these "best" routes in a manner that realistically distributes vehicles from origins to destinations and routes them over the highway network, in a consistent and optimal manner, reflecting evacuee behavior.

For each origin, a set of "candidate destination nodes" is selected by the software logic and by the analyst to reflect the desire by evacuees to travel away from the power plant and to access major highways. The specific destination nodes within this set that are selected by travelers and the selection of the connecting paths of travel, are both determined by DTRAD. This determination is made by a logit-based path choice model in DTRAD, so as to minimize the trip "cost", as discussed later.

The traffic loading on the network and the consequent operational traffic environment of the network (density, speed, throughput on each link) vary over time as the evacuation takes place. The DTRAD model, which is interfaced with the DYNEV simulation model, executes a succession of "sessions" wherein it computes the optimal routing and selection of destination nodes for the conditions that exist at that time.

Interfacing the DYNEV Simulation Model with DTRAD

The DYNEV II system reflects NRC guidance that evacuees will seek to travel in a general direction away from the location of the hazardous event. An algorithm was developed to support the DTRAD model in dynamically varying the Trip Table (O-D matrix) over time from one DTRAD session to the next. Another algorithm executes a "mapping" from the specified "geometric" network (link-node analysis network) that represents the physical highway system, to a "path" network that represents the vehicle [turn] movements. DTRAD computations are performed on the "path" network: DYNEV simulation model, on the "geometric" network.

DTRAD Description

DTRAD is the DTA module for the DYNEV II System.

When the road network under study is large, multiple routing options are usually available between trip origins and destinations. The problem of loading traffic demands and propagating them over the network links is called Network Loading and is addressed by DYNEV II using macroscopic traffic simulation modeling. Traffic assignment deals with computing the distribution of the traffic over the road network for given O-D demands and is a model of the route choice of the drivers. Travel demand changes significantly over time, and the road network may have time dependent characteristics, e.g., time-varying signal timing or reduced road capacity because of lane closure, or traffic congestion. To consider these time dependencies, DTA procedures are required.

The DTRAD DTA module represents the dynamic route choice behavior of drivers, using the specification of dynamic origin-destination matrices as flow input. Drivers choose their routes through the network based on the travel cost they experience (as determined by the simulation model). This allows traffic to be distributed over the network according to the time-dependent conditions. The modeling principles of D-TRAD include:

- It is assumed that drivers not only select the best route (i.e., lowest cost path) but some also select less attractive routes. The algorithm implemented by DTRAD archives several "efficient" routes for each O-D pair from which the drivers choose.
- The choice of one route out of a set of possible routes is an outcome of "discrete choice modeling". Given a set of routes and their generalized costs, the percentages of drivers that choose each route is computed. The most prevalent model for discrete choice modeling is the logit model. DTRAD uses a variant of Path-Size-Logit model (PSL). PSL overcomes the drawback of the traditional multinomial logit model by incorporating an additional deterministic path size correction term to address path overlapping in the random utility expression.
- DTRAD executes the TA algorithm on an abstract network representation called "the path network" which is built from the actual physical link-node analysis network. This execution continues until a stable situation is reached: the volumes and travel times on the edges of the path network do not change significantly from one iteration to the next. The criteria for this convergence are defined by the user.
- Travel "cost" plays a crucial role in route choice. In DTRAD, path cost is a linear summation of the generalized cost of each link that comprises the path. The generalized cost, c, for a link, a, is expressed as

  $$c_a = \alpha t_a + \beta l_a + \gamma s_a,$$

  where c_a is the generalized cost for link a, and α, β, and γ are cost coefficients for link travel time, distance, and supplemental cost, respectively. Distance and supplemental costs are defined as invariant properties of the network model, while travel time is a dynamic property dictated by prevailing traffic conditions. The DYNEV simulation model computes travel times on all edges in the network and DTRAD uses that information to constantly update the costs of paths. The route choice decision model in the next simulation iteration uses these updated values to adjust the route choice behavior. This way, traffic demands are dynamically re-assigned based on time dependent conditions. The interaction between the DTRAD traffic assignment and DYNEV II simulation models is depicted in Figure B-1. Each round of interaction is called a Traffic Assignment Session (TA session). A TA session is composed of multiple iterations, marked as loop B in the figure.

- The supplemental cost is based on the "survival distribution" (a variation of the exponential distribution). The Inverse Survival Function is a "cost" term in DTRAD to represent potential risk of travel toward the plant:

  $s_a = -\beta \ln(p), \ 0 \leq p \leq l; \ \beta > 0$

  $p = \frac{d_n}{d_0}$

  d_n = Distance of node, n, from the plant
  d_0 = Distance from the plant where there is zero risk
  β = Scaling factor

The value of d_o = 15 miles, the outer distance of the shadow region. Note that the supplemental cost, s_a, of link, a, is (high, low), if its downstream node, n, is (near, far from) the power plant.

Network Equilibrium

In 1952, John Wardrop wrote:

> *Under equilibrium conditions traffic arranges itself in congested networks in such a way that no individual trip-maker can reduce his path costs by switching routes.*

The above statement describes the "User Equilibrium" definition, also called the "Selfish Driver Equilibrium". It is a hypothesis that represents a [hopeful] condition that evolves over time as drivers search out alternative routes to identify those routes that minimize their respective "costs". It has been found that this "equilibrium" objective to minimize costs is largely realized by most drivers who take the same trip over the same network at the same time (i.e., commuters). Effectively, such drivers "learn" which routes are best for them over time. Thus, the traffic environment "settles down" to a near-equilibrium state.

Clearly, since an emergency evacuation is a sudden, unique event, it does not constitute a long-term learning experience which can achieve an equilibrium state. Consequently, DTRAD was not designed as an equilibrium solution, but to represent drivers in a new and unfamiliar situation, who respond in a flexible manner to real-time information (either broadcast or observed) in such a way as to minimize their respective costs of travel.

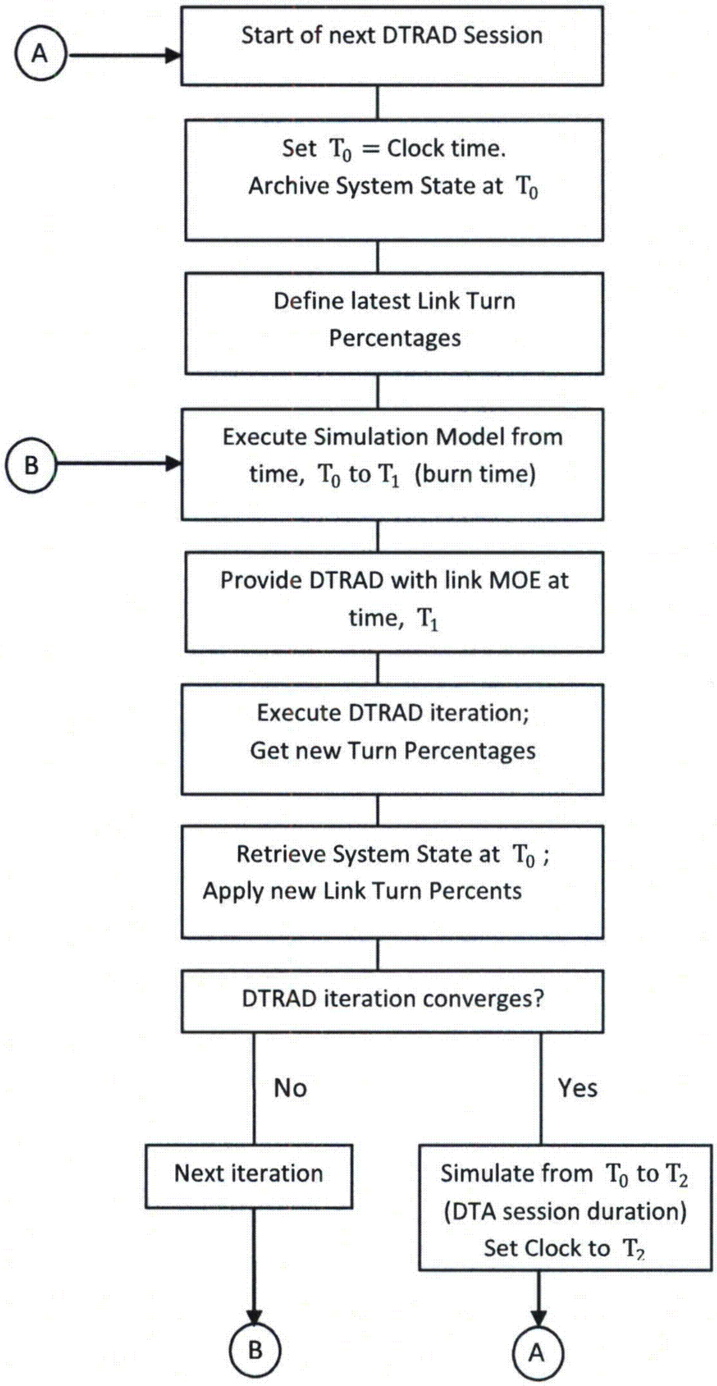


Figure B-1. Flow Diagram of Simulation-DTRAD Interface

APPENDIX C

DYNEV Traffic Simulation Model

C. DYNEV TRAFFIC SIMULATION MODEL

The DYNEV traffic simulation model is a *macroscopic* model that describes the operations of traffic flow in terms of aggregate variables: vehicles, flow rate, mean speed, volume, density, queue length, *on each link*, for each turn movement, during each Time Interval (simulation time step). The model generates trips from "sources" and from Entry Links and introduces them onto the analysis network at rates specified by the analyst based on the mobilization time distributions. The model simulates the movements of all vehicles on all network links over time until the network is empty. At intervals, the model outputs Measures of Effectiveness (MOE) such as those listed in Table C-1.

Model Features Include:

- Explicit consideration is taken of the variation in density over the time step; an iterative procedure is employed to calculate an average density over the simulation time step for the purpose of computing a mean speed for moving vehicles.
- Multiple turn movements can be serviced on one link; a separate algorithm is used to estimate the number of (fractional) lanes assigned to the vehicles performing each turn movement, based, in part, on the turn percents provided by the DTRAD model.
- At any point in time, traffic flow on a link is subdivided into two classifications: queued and moving vehicles. The number of vehicles in each classification is computed. Vehicle spillback, stratified by turn movement for each network link, is explicitly considered and quantified. The propagation of stopping waves from link to link is computed within each time step of the simulation. There is no "vertical stacking" of queues on a link.
- Any link can accommodate "source flow" from zones via side streets and parking facilities that are not explicitly represented. This flow represents the evacuating trips that are generated at the source.
- The relation between the number of vehicles occupying the link and its storage capacity is monitored every time step for every link and for every turn movement. If the available storage capacity on a link is exceeded by the demand for service, then the simulator applies a "metering" rate to the entering traffic from both the upstream feeders and source node to ensure that the available storage capacity is not exceeded.
- A "path network" that represents the specified traffic movements from each network link is constructed by the model; this path network is utilized by the DTRAD model.
- A two-way interface with DTRAD: (1) provides link travel times; (2) receives data that translates into link turn percentages.
- Provides MOE to animation software, EVAN
- Calculates ETE statistics

All traffic simulation models are data-intensive. Table C-2 outlines the necessary input data elements.

To provide an efficient framework for defining these specifications, the physical highway environment is represented as a network. The unidirectional links of the network represent roadway sections: rural, multi-lane, urban streets or freeways. The nodes of the network generally represent intersections or points along a section where a geometric property changes (e.g., a lane drop, change in grade or free flow speed).

Figure C-1 is an example of a small network representation. The freeway is defined by the sequence of links, (20,21), (21,22), and (22,23). Links (8001, 19) and (3, 8011) are Entry and Exit links, respectively. An arterial extends from node 3 to node 19 and is partially subsumed within a grid network. Note that links (21,22) and (17,19) are grade-separated.

Table C-1. Selected Measures of Effectiveness Output by DYNEV II

Measure	Units	Applies To
Vehicles Discharged	Vehicles	Link, Network, Exit Link
Speed	Miles/Hours (mph)	Link, Network
Density	Vehicles/Mile/Lane	Link
Level of Service	LOS	Link
Content	Vehicles	Network
Travel Time	Vehicle-hours	Network
Evacuated Vehicles	Vehicles	Network, Exit Link
Trip Travel Time	Vehicle-minutes/trip	Network
Capacity Utilization	Percent	Exit Link
Attraction	Percent of total evacuating vehicles	Exit Link
Max Queue	Vehicles	Node, Approach
Time of Max Queue	Hours:minutes	Node, Approach
Route Statistics	Length (mi); Mean Speed (mph); Travel Time (min)	Route
Mean Travel Time	Minutes	Evacuation Trips; Network

Table C-2. Input Requirements for the DYNEV II Model

HIGHWAY NETWORK

- Links defined by upstream and downstream node numbers
- Link lengths
- Number of lanes (up to 6) and channelization
- Turn bays (1 to 3 lanes)
- Destination (exit) nodes
- Network topology defined in terms of downstream nodes for each receiving link
- Node Coordinates (X,Y)
- Nuclear Power Plant Coordinates (X,Y)

GENERATED TRAFFIC VOLUMES

- On all entry links and source nodes (origins), by Time Period

TRAFFIC CONTROL SPECIFICATIONS

- Traffic signals: link-specific, turn movement specific
- Signal control treated as fixed time or actuated
- Location of traffic control points (these are represented as actuated signals)
- Stop and Yield signs
- Right-turn-on-red (RTOR)
- Route diversion specifications
- Turn restrictions
- Lane control (e.g., lane closure, movement-specific)

DRIVER'S AND OPERATIONAL CHARACTERISTICS

- Driver's (vehicle-specific) response mechanisms: free-flow speed, discharge headway
- Bus route designation.

DYNAMIC TRAFFIC ASSIGNMENT

- Candidate destination nodes for each origin (optional)
- Duration of DTA sessions
- Duration of simulation "burn time"
- Desired number of destination nodes per origin

INCIDENTS

- Identify and Schedule of closed lanes
- Identify and Schedule of closed links

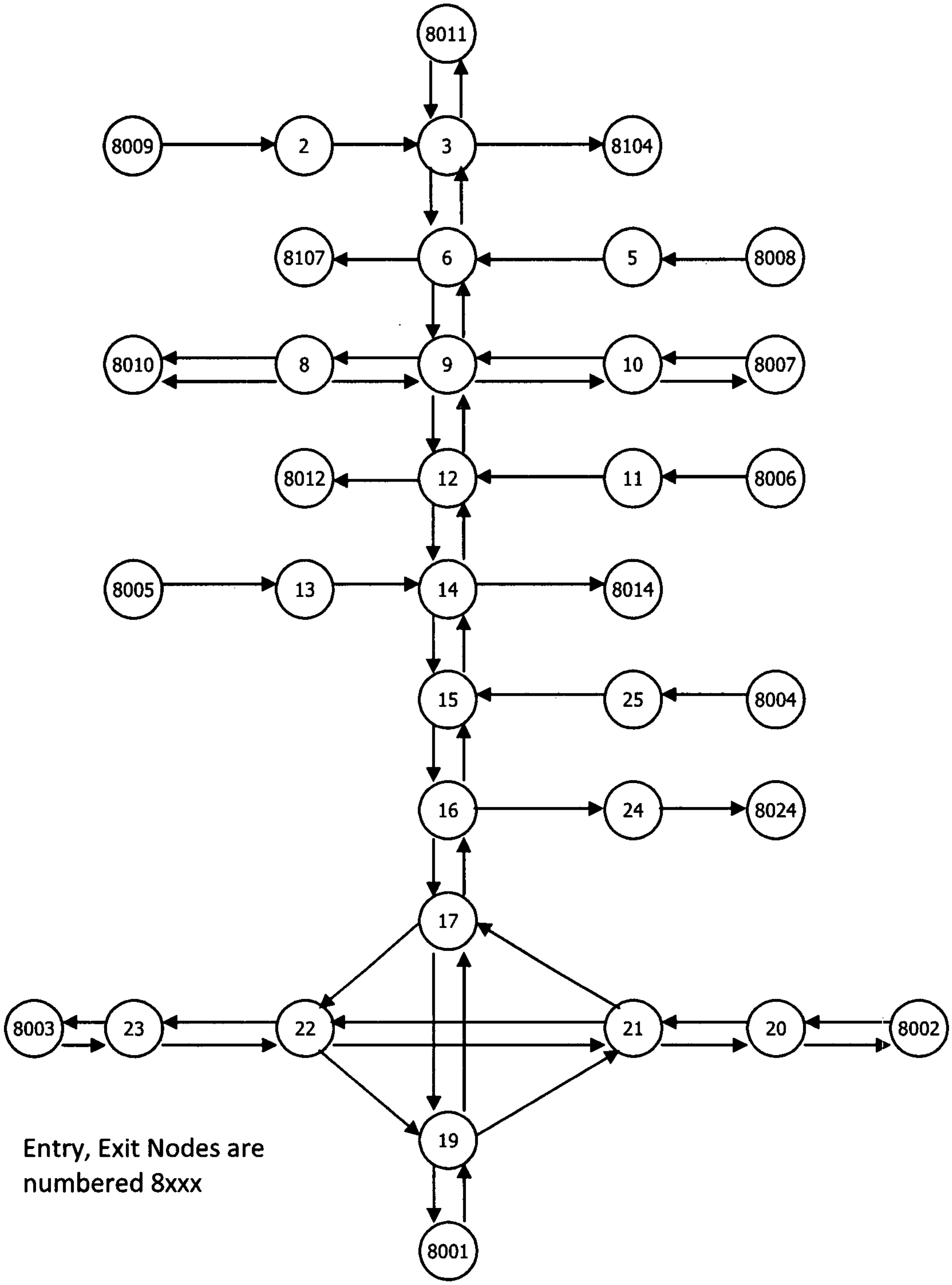


Figure C-1. Representative Analysis Network

METHODOLOGY

The Fundamental Diagram

It is necessary to define the fundamental diagram describing flow-density and speed-density relationships. Rather than "settling for" a triangular representation, a more realistic representation that includes a "capacity drop", $(1 - R)Q_{max}$, at the critical density when flow conditions enter the forced flow regime, is developed and calibrated for each link. This representation, shown in Figure C-2, asserts a constant free speed up to a density, k_f, and then a linear reduction in speed in the range, $k_f \leq k \leq k_c = 45$ vpm, the density at capacity. In the flow-density plane, a quadratic relationship is prescribed in the range, $k_c < k \leq k_s = 95$ vpm which roughly represents the "stop-and-go" condition of severe congestion. The value of flow rate, Q_s, corresponding to k_s, is approximated at $0.7\,RQ_{max}$. A linear relationship between k_s and k_j completes the diagram shown in Figure C-2. Table C-3 is a glossary of terms.

The fundamental diagram is applied to moving traffic on every link. The specified calibration values for each link are: (1) Free speed, v_f ; (2) Capacity, Q_{max} ; (3) Critical density, $k_c = 45$ vpm ; (4) Capacity Drop Factor, R = 0.9 ; (5) Jam density, k_j . Then, $v_c = \frac{Q_{max}}{k_c}$, $k_f = k_c - \frac{(V_f - V_c)\,k_c^2}{Q_{max}}$. Setting $\bar{k} = k - k_c$, then $Q = RQ_{max} - \frac{RQ_{max}}{8333}\,\bar{k}^2$ for $0 \leq \bar{k} \leq \bar{k}_s = 50$. It can be shown that $Q = \left(0.98 - 0.0056\,\bar{k}\right) RQ_{max}$ for $\bar{k}_s \leq \bar{k} \leq \bar{k}_j$, where $\bar{k}_s = 50$ and $\bar{k}_j = 175$.

The Simulation Model

The simulation model solves a sequence of "unit problems". Each unit problem computes the movement of traffic on a link, for each specified turn movement, over a specified time interval (TI) which serves as the simulation time step for all links. Figure C-3 is a representation of the unit problem in the time-distance plane. Table C-3 is a glossary of terms that are referenced in the following description of the unit problem procedure.

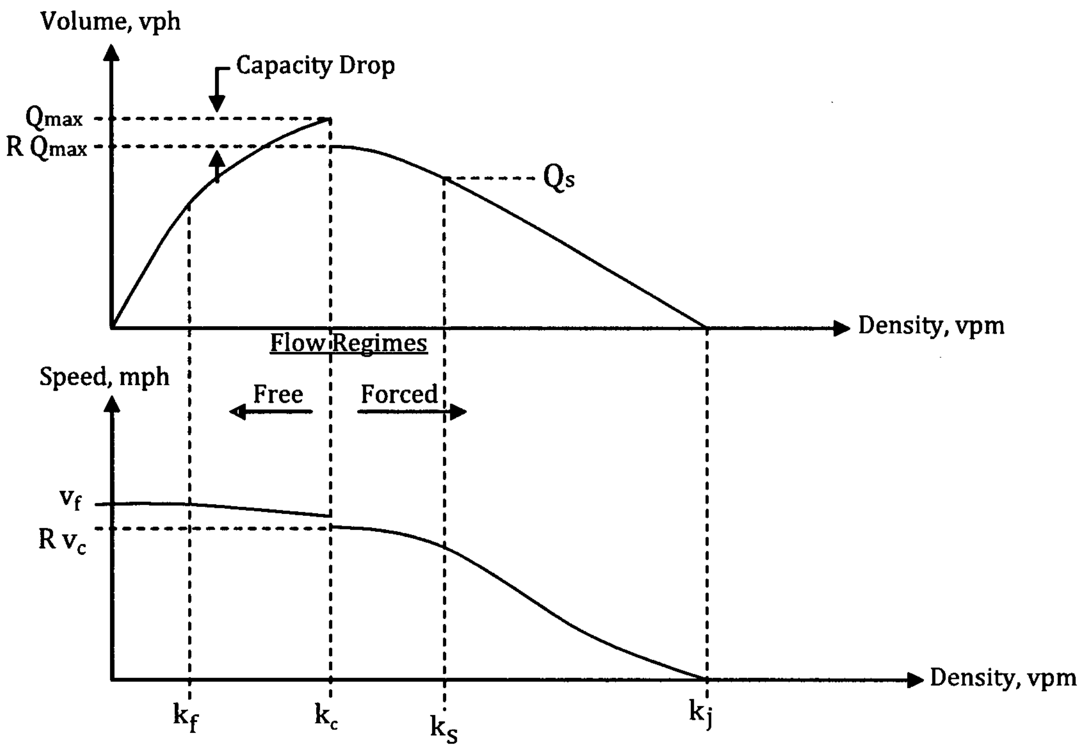


Figure C-2. Fundamental Diagrams

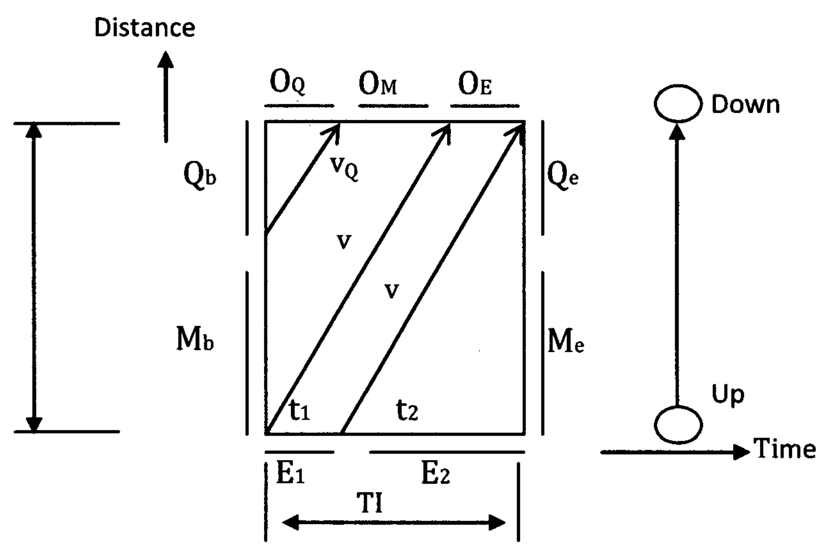


Figure C-3. A UNIT Problem Configuration with $t_1 > 0$

Table C-3. Glossary

Cap	The maximum number of vehicles, of a particular movement, that can discharge from a link within a time interval.
E	The number of vehicles, of a particular movement, that enter the link over the time interval. The portion, E_{TI}, can reach the stop-bar within the TI.
G/C	The green time: cycle time ratio that services the vehicles of a particular turn movement on a link.
h	The mean queue discharge headway, seconds.
k	Density in vehicles per lane per mile.
$\bar{k}$	The average density of <u>moving</u> vehicles of a particular movement over a TI, on a link.
L	The length of the link in feet.
L_b , L_e	The queue length in feet of a particular movement, at the [beginning, end] of a time interval.
LN	The number of lanes, expressed as a floating point number, allocated to service a particular movement on a link.
L_v	The mean effective length of a queued vehicle including the vehicle spacing, feet.
M	Metering factor (Multiplier): 1.
M_b , M_e	The number of moving vehicles on the link, of a particular movement, that are moving at the [beginning, end] of the time interval. These vehicles are assumed to be of equal spacing, over the length of link upstream of the queue.
O	The total number of vehicles of a particular movement that are discharged from a link over a time interval.
O_Q , O_M , O_E	The components of the vehicles of a particular movement that are discharged from a link within a time interval: vehicles that were Queued at the beginning of the TI; vehicles that were Moving within the link at the beginning of the TI; vehicles that Entered the link during the TI.
P_x	The percentage, expressed as a fraction, of the total flow on the link that executes a particular turn movement, x.

Q_b , Q_e — The number of queued vehicles on the link, of a particular turn movement, at the [beginning, end] of the time interval.

Q_{max} — The maximum flow rate that can be serviced by a link for a particular movement in the absence of a control device. It is specified by the analyst as an estimate of link capacity, based upon a field survey, with reference to the HCM.

R — The factor that is applied to the capacity of a link to represent the "capacity drop" when the flow condition moves into the forced flow regime. The lower capacity at that point is equal to RQ_{max} .

RCap — The remaining capacity available to service vehicles of a particular movement after that queue has been completely serviced, within a time interval, expressed as vehicles.

S_x — Service rate for movement x, vehicles per hour (vph).

t_1 — Vehicles of a particular turn movement that enter a link over the first t_1 seconds of a time interval, can reach the stop-bar (in the absence of a queue down-stream) within the same time interval.

TI — The time interval, in seconds, which is used as the simulation time step.

v — The mean speed of travel, in feet per second (fps) or miles per hour (mph), of moving vehicles on the link.

v_Q — The mean speed of the last vehicle in a queue that discharges from the link within the TI. This speed differs from the mean speed of moving vehicles, v.

W — The width of the intersection in feet. This is the difference between the link length which extends from stop-bar to stop-bar and the block length.

The formulation and the associated logic presented below are designed to solve the unit problem for each sweep over the network (discussed below), for each turn movement serviced on each link that comprises the evacuation network, and for each TI over the duration of the evacuation.

Given $= Q_b, M_b, L, TI, E_0, LN, G/C, h, L_v, R_0, L_c, E, M$
Compute $= O, Q_e, M_e$
Define $O = O_Q + O_M + O_E$; $E = E_1 + E_2$

1. For the first sweep, s = 1, of this TI, get initial estimates of mean density, k_0, the R – factor, R_0 and entering traffic, E_0, using the values computed for the final sweep of the prior TI. For each subsequent sweep, $s > 1$, calculate $E = \sum_i P_i \; O_i + S$ where P_i, O_i are the relevant turn percentages from feeder link, i, and its total outflow (possibly metered) over this TI; S is the total source flow (possibly metered) during the current TI.
   Set iteration counter, n = 0, $k = k_0$, and $E = E_0$.

2. Calculate $v(k)$ such that $k \leq 130$ using the analytical representations of the fundamental diagram.
   Calculate $Cap = \frac{Q_{max}(TI)}{3600} \left(G/C\right) LN$, in vehicles, this value may be reduced due to metering
   Set $R = 1.0$ if $G/C < 1$ or if $k \leq k_c$; Set $R = 0.9$ only if $G/C = 1$ and $k > k_c$
   Calculate queue length, $L_b = Q_b \frac{L_v}{LN}$

3. Calculate $t_1 = TI - \frac{L}{V}$. If $t_1 < 0$, set $t_1 = E_1 = O_E = 0$; Else, $E_1 = E \frac{t_1}{TI}$.

4. Then $E_2 = E - E_1$; $t_2 = TI - t_1$

5. If $Q_b \geq Cap$, then
   $O_Q = Cap, O_M = O_E = 0$
   If $t_1 > 0$, then
   $Q_e' = Q_b + M_b + E_1 - Cap$
   Else
   $Q_e' = Q_b - Cap$
   End if
   Calculate Q_e and M_e using Algorithm A (below)

6. Else $(Q_b < Cap)$
   $O_Q = Q_b$, $RCap = Cap - O_Q$

7. If $M_b \leq RCap$, then

8. If $t_1 > 0$, $O_M = M_b$, $O_E = \min\left(RCap - M_b, \frac{t_1\,Cap}{TI}\right) \geq 0$

$Q'_e = E_1 - O_E$

If $Q'_e > 0$, then

Calculate Q_e, M_e with Algorithm A

Else

$Q_e = 0$, $M_e = E_2$

End if

Else $(t_1 = 0)$

$O_M = \left(\frac{v(TI) - L_b}{L - L_b}\right) M_b$ and $O_E = 0$

$M_e = M_b - O_M + E$; $Q_e = 0$

End if

9. Else $(M_b > RCap)$

$O_E = 0$

If $t_1 > 0$, then

$O_M = RCap$, $Q'_e = M_b - O_M + E_1$

Calculate Q_e and M_e using Algorithm A

10. Else $(t_1 = 0)$

$M_d = \left[\left(\frac{v(TI) - L_b}{L - L_b}\right) M_b\right]$

If $M_d > RCap$, then

$O_M = RCap$

$Q'_e = M_d - O_M$

Apply Algorithm A to calculate Q_e and M_e

Else

$O_M = M_d$

$M_e = M_b - O_M + E$ and $Q_e = 0$

End if

End if

End if

End if

11. Calculate a new estimate of average density, $\bar{k}_n = \frac{1}{4}[k_b + 2\,k_m + k_e]$,

where k_b = density at the beginning of the TI

k_e = density at the end of the TI

k_m = density at the mid-point of the TI

All values of density apply only to the <u>moving</u> vehicles.

If $|\bar{k}_n - \bar{k}_{n-1}| > \epsilon$ and $n < N$

where N = max number of iterations, and ϵ is a convergence criterion, then

12. set $n = n + 1$, and return to step 2 to perform iteration, n, using $k = \bar{k}_n$.
End if

Computation of unit problem is now complete. Check for excessive inflow causing spillback.

13. If $Q_e + M_e > \frac{(L-W)\,LN}{L_v}$, then

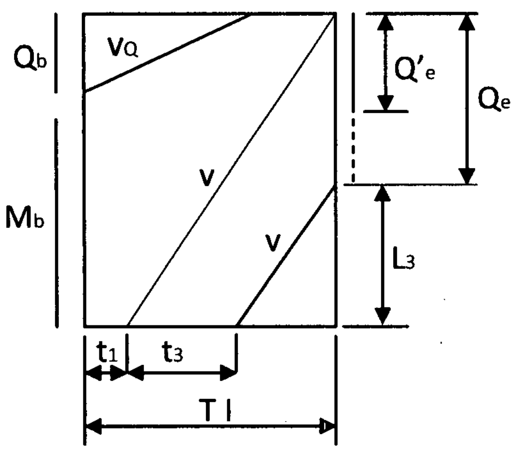
The number of excess vehicles that cause spillback is: $SB = Q_e + M_e - \frac{(L-W)\cdot LN}{L_v}$, where W is the width of the upstream intersection. To prevent spillback, meter the outflow from the feeder approaches and from the source flow, S, during this TI by the amount, SB. That is, set

$$M = 1 - \frac{SB}{(E + S)} \geq 0 \text{, where M is the metering factor (over all movements).}$$

This metering factor is assigned appropriately to all feeder links and to the source flow, to be applied during the next network sweep, discussed later.

Algorithm A

This analysis addresses the flow environment over a TI during which moving vehicles can join a standing or discharging queue. For the case shown, $Q_b \leq Cap$, with $t_1 > 0$ and a queue of length, Q'_e, formed by that portion of M_b and E that reaches the stop-bar within the TI, but could not discharge due to inadequate capacity. That is, $Q_b + M_b + E_1 > Cap$. This queue length, $Q'_e = Q_b + M_b + E_1 - Cap$ can be extended to Q_e by traffic entering the approach during the current TI, traveling at speed, v, and reaching the rear of the queue within the TI. A portion of the entering vehicles, $E_3 = E\,\frac{t_3}{TI}$, will likely join the queue. This analysis calculates t_3, Q_e and M_e for the input values of L, TI, v, E, t, L_v, LN, Q'_e .



When $t_1 > 0$ and $Q_b \leq Cap$:

Define: $L'_e = Q'_e\,\frac{L_v}{LN}$. From the sketch, $L_3 = v(TI - t_1 - t_3) = L - (Q'_e + E_3)\frac{L_v}{LN}$.

Substituting $E_3 = \frac{t_3}{TI}\,E$ yields: $-vt_3 + \frac{t_3}{TI}\,E\,\frac{L_v}{LN} = L - v(TI - t_1) - L'_e$. Recognizing that the first two terms on the right hand side cancel, solve for t_3 to obtain:

$$t_3 = \frac{L'_e}{\left[v - \frac{E}{TI}\frac{L_v}{LN}\right]} \qquad \text{such that} \quad 0 \le t_3 \le TI - t_1$$

If the denominator, $\left[v - \frac{E}{TI}\frac{L_v}{LN}\right] \le 0$, set $t_3 = TI - t_1$.

$$\text{Then, } Q_e = Q'_e + E\,\frac{t_3}{TI}\ , \qquad M_e = E\left(1 - \frac{t_1 + t_3}{TI}\right)$$

The complete Algorithm A considers all flow scenarios; space limitation precludes its inclusion, here.

Lane Assignment

The "unit problem" is solved for each turn movement on each link. Therefore it is necessary to calculate a value, LN_x, of allocated lanes for each movement, x. If in fact all lanes are specified by, say, arrows painted on the pavement, either as full lanes or as lanes within a turn bay, then the problem is fully defined. If however there remain unchannelized lanes on a link, then an analysis is undertaken to subdivide the number of these physical lanes into turn movement specific virtual lanes, LN_x.

IMPLEMENTATION

Computational Procedure

The computational procedure for this model is shown in the form of a flow diagram as Figure C-4. As discussed earlier, the simulation model processes traffic flow for each link independently over the TI that the analyst specifies; it is usually 60 seconds or longer. The first step is to execute an algorithm to define the sequence in which the network links are processed so that as many links as possible are processed <u>after</u> their feeder links are processed, within the same network sweep. Since a general network will have many closed loops, it is not possible to guarantee that every link processed will have all of its feeder links processed earlier.

The processing then continues as a succession of time steps of duration, TI, until the simulation is completed. Within each time step, the processing performs a series of "sweeps" over all network links; this is necessary to ensure that the traffic flow is synchronous over the entire network. Specifically, the sweep ensures continuity of flow among all the network links; in the context of this model, this means that the values of E, M, and S are all defined for each link such that they represent the synchronous movement of traffic from each link to all of its outbound links. These sweeps also serve to compute the metering rates that control spillback.

Within each sweep, processing solves the "unit problem" for each turn movement on each link. With the turn movement percentages for each link provided by the DTRAD model, an algorithm allocates the number of lanes to each movement serviced on each link. The timing at a signal, if any, applied at the downstream end of the link, is expressed as a G/C ratio. The signal timing needed to define this ratio is an input requirement for the model. The model also has the capability of representing, with macroscopic fidelity, the actions of actuated signals responding to the time-varying competing demands on the approaches to the intersection.

The solution of the unit problem yields the values of the number of vehicles, O, that discharge from the link over the time interval and the number of vehicles that remain on the link at the end of the time interval as stratified by queued and moving vehicles: Q_e and M_e. The procedure considers each movement separately (multi-piping). After all network links are processed for a given network sweep, the updated consistent values of entering flows, E; metering rates, M; and source flows, S are defined so as to satisfy the "no spillback" condition. The procedure then performs the unit problem solutions for all network links during the following sweep.

Experience has shown that the system converges (i.e., the values of E, M and S "settle down" for all network links) in just two sweeps if the network is entirely undersaturated or in four sweeps in the presence of extensive congestion with link spillback. (The initial sweep over each link uses the final values of E and M, of the prior TI). At the completion of the final sweep for a TI, the procedure computes and stores all measures of effectiveness for each link and turn movement for output purposes. It then prepares for the following time interval by defining the values of Q_b and M_b for the start of the next TI as being those values of Q_e and M_e at the end of the prior TI. In this manner, the simulation model processes the traffic flow over time until the end of the run. Note that there is no space-discretization other than the specification of network links.

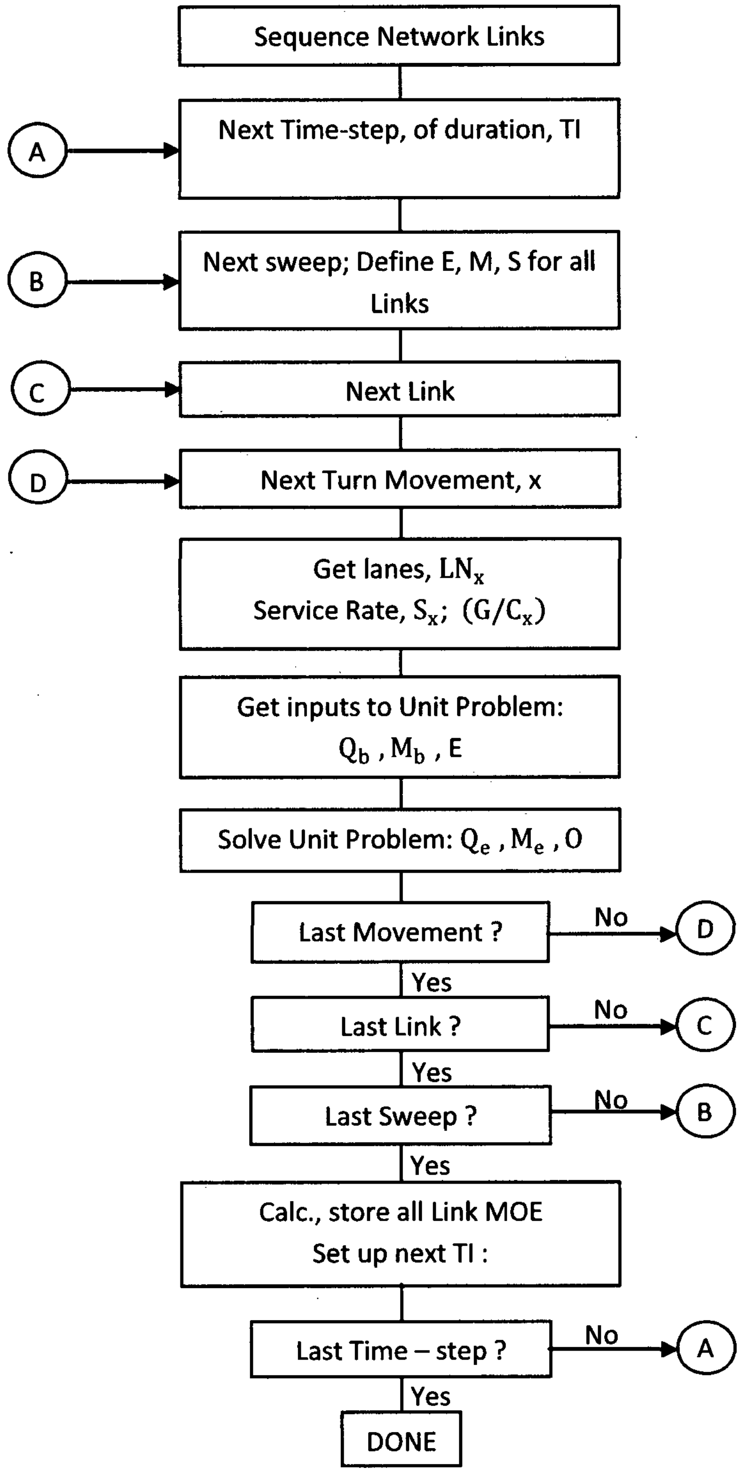


Figure C-4. Flow of Simulation Processing (See Glossary: Table C-3)

Interfacing with Dynamic Traffic Assignment (DTRAD)

The **DYNEV II** system reflects NRC guidance that evacuees will seek to travel in a general direction away from the location of the hazardous event. Thus, an algorithm was developed to identify an appropriate set of destination nodes for each origin based on its location and on the expected direction of travel. This algorithm also supports the DTRAD model in dynamically varying the Trip Table (O-D matrix) over time from one DTRAD session to the next.

Figure B-1 depicts the interaction of the simulation model with the DTRAD model in the **DYNEV II** system. As indicated, **DYNEV II** performs a succession of DTRAD "sessions"; each such session computes the turn link percentages for each link, that remain constant for the session duration, $[T_0, T_2]$, specified by the analyst. The end product is the assignment of traffic volumes from each origin to paths connecting it with its destinations in such a way as to minimize the network-wide cost function. The output of the DTRAD model is a set of updated link turn percentages which represent this assignment of traffic.

As indicated in Figure B-1, the simulation model supports the DTRAD session by providing it with operational link MOE that are needed by the path choice model and included in the DTRAD cost function. These MOE represent the operational state of the network at a time, $T_1 \leq T_2$, which lies within the session duration, $[T_0, T_2]$. This "burn time", $T_1 - T_0$, is selected by the analyst. For each DTRAD iteration, the simulation model computes the change in network operations over this burn time using the latest set of link turn percentages computed by the DTRAD model. Upon convergence of the DTRAD iterative procedure, the simulation model accepts the latest turn percentages provided by the DTA model, returns to the origin time, T_0, and executes until it arrives at the end of the DTRAD session duration at time, T_2. At this time the next DTA session is launched and the whole process repeats until the end of the **DYNEV II** run.

Additional details are presented in Appendix B.