NUREG/CR-7002, Revision 1

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Criteria for Development of Evacuation Time Estimate Studies

Office of Nuclear Security and Incident Response

AVAILABILITY OF REFERENCE MATERIALS IN NRC PUBLICATIONS

NRC Reference Material

As of November 1999, you may electronically access NUREG-series publications and other NRC records at the NRC's Library at www.nrc.gov/reading-rm.html. Publicly released records include, to name a few, NUREG-series publications; *Federal Register* notices; applicant, licensee, and vendor documents and correspondence; NRC correspondence and internal memoranda; bulletins and information notices; inspection and investigative reports; licensee event reports; and Commission papers and their attachments.

NRC publications in the NUREG series, NRC regulations, and Title 10, "Energy," in the *Code of Federal Regulations* may also be purchased from one of these two sources:

1. **The Superintendent of Documents**
   U.S. Government Publishing Office
   Washington, DC 20402-0001
   Internet: www.bookstore.gpo.gov
   Telephone: (202) 512-1800
   Fax: (202) 512-2104

2. **The National Technical Information Service**
   5301 Shawnee Road
   Alexandria, VA 22312-0002
   Internet: www.ntis.gov
   1-800-553-6847 or, locally, (703) 605-6000

A single copy of each NRC draft report for comment is available free, to the extent of supply, upon written request as follows:

Address: **U.S. Nuclear Regulatory Commission**
Office of Administration
Multimedia, Graphics, and Storage & Distribution Branch
Washington, DC 20555-0001
E-mail: distribution.resource@nrc.gov
Facsimile: (301) 415-2289

Some publications in the NUREG series that are posted at the NRC's Web site address www.nrc.gov/reading-rm/doc-collections/nuregs are updated periodically and may differ from the last printed version. Although references to material found on a Web site bear the date the material was accessed, the material available on the date cited may subsequently be removed from the site.

Non-NRC Reference Material

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, transactions, *Federal Register* notices, Federal and State legislation, and congressional reports. Such documents as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings may be purchased from their sponsoring organization.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at—

The NRC Technical Library
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852-2738

These standards are available in the library for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from—

American National Standards Institute
11 West 42nd Street
New York, NY 10036-8002
Internet: www.ansi.org
(212) 642-4900

Legally binding regulatory requirements are stated only in laws; NRC regulations; licenses, including technical specifications; or orders, not in NUREG-series publications. The views expressed in contractor prepared publications in this series are not necessarily those of the NRC.

The NUREG series comprises (1) technical and administrative reports and books prepared by the staff (NUREG–XXXX) or agency contractors (NUREG/CR–XXXX), (2) proceedings of conferences (NUREG/CP–XXXX), (3) reports resulting from international agreements (NUREG/IA–XXXX),(4) brochures (NUREG/BR–XXXX), and (5) compilations of legal decisions and orders of the Commission and the Atomic and Safety Licensing Boards and of Directors' decisions under Section 2.206 of the NRC's regulations (NUREG–0750).

NUREG/CR-7002, Revision 1

Criteria for Development of Evacuation Time Estimate Studies

Manuscript Completed: November 2020
Date Published: February 2021

Prepared by:
T. Smith

Office of Nuclear Security and Incident Response

ABSTRACT

The evacuation time estimate (ETE) is a calculation of the time to evacuate the plume exposure pathway emergency planning zone (EPZ). An EPZ is the area around a nuclear power plant for which planning is needed to ensure that prompt and effective actions can be taken in the event of a radiological accident. The EPZ is typically an area with a radius of about 10 miles (16 kilometers) around a large light-water reactor but may vary in extent based on the emergency planning needs for the facility type. The ETE is primarily used to inform protective action decision-making and may also be used to assist in developing traffic management plans to support an evacuation. The ETE should be developed to provide the time to evacuate 90 percent and 100 percent of the total population of the EPZ. The 90 percent ETE provides the time value that would typically be used to support protective action decisions.

This document provides guidance for the development of ETEs, including those associated with staged evacuations. The document also identifies the importance of using approved emergency response plans and existing traffic control information to reflect the expected response actions during an emergency. Guidance on the review and update of ETEs is also included. Revision 1 updates the guidance based on the study of ETEs in NUREG/CR-7269, “Enhancing Guidance for Evacuation Time Estimate Studies,” issued March 2020.

The revised guidance reflects the importance of various model parameters and identifies the measures of effectiveness useful for verifying adequate model performance. The format and guidance provided here will support consistent application of the ETE methodology and can serve as a template for the development of ETE studies. Applicants and licensees may propose an alternative method for complying with the associated portions of the emergency preparedness regulations, and the U.S. Nuclear Regulatory Commission would determine whether they have provided the basis for the findings required for the issuance or continuance of a permit or license.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The evacuation time estimate (ETE) is a calculation of the time to evacuate the plume exposure pathway emergency planning zone (EPZ), which is typically an area with a radius of about 10 miles (16 kilometers) around a nuclear power plant for large light water reactors, but may vary in extent based on the emergency planning needs for the facility type. Section IV, "Content of Emergency Plans," of Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic licensing of production and utilization facilities," requires that an analysis of the time required to evacuate be provided for various sectors and distances within the plume exposure pathway EPZ for transient and permanent residents. The ETE is primarily used to inform protective action decision-making and may also be used to assist in developing traffic management plans to support an evacuation. The ETE is used as an information tool, and therefore, no minimum evacuation time must be achieved.

The guidance in NUREG-0654/FEMA-REP-1, Revision 2, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," issued December 2019, provides additional information on the use of ETE results (NRC, 2019a). Licensees should use ETEs in the development of offsite protective action recommendations, and offsite response organizations (OROs) should use them in making offsite protective action decisions. Supplement 3 to NUREG-0654/FEMA-REP-1, Revision 1, contains guidance for using ETEs in the development of protective action strategies.

Fundamentally, evacuation processes can be described as a relationship between supply and demand. Evacuation "demand" is the number of vehicles that will access the road network during an evacuation. Evacuation "supply" is the ability of the transportation system to serve the demand placed upon it. Supply is essentially the outflow capacity of a system. This revision to NUREG/CR-7002 is based on an extensive study of the sensitivity of various ETE model supply and demand variables described in NUREG-7269, "Enhancing Guidance for Evacuation Time Estimate Studies," issued March 2020 (NRC, 2020). This revised guidance reflects the importance of various model parameters and identifies the measures of effectiveness (MOEs) determined to be useful for verifying model performance.

This guidance document details the process for developing ETEs for four population segments:

- permanent residents and transient populations
- transit dependent permanent residents
- special facility residents (e.g., those in hospitals, prisons, nursing homes)
- school populations

This document provides guidance on developing evacuation demand, preparation activities, ETE modeling and reporting results. Some of the key criteria in this document include the following:

- consideration of temporal and spatial variation in capacity and demand
- development of ETEs for the staged evacuation protective action
- emphasis on the use of existing emergency preparedness programs
- use of macroscopic, mesoscopic, and microscopic traffic simulation modeling
- consideration of shadow evacuations

- assumptions on resource availability, such as buses and ambulances
- consideration of the evacuation tail
- measures of effectiveness
- ETE updates
- ETEs for early site permit applications

Research on evacuations has shown that implementation of staged evacuations can be more beneficial to the public health and safety (NRC, 2007). This guidance document includes an approach to develop ETEs for a staged evacuation.

It is important to use the information found in approved emergency plans when developing an ETE study to ensure that the results represent the expected response from authorities. This guidance document emphasizes the use of existing emergency planning methodology when developing the ETE including the following:

- use of existing registration programs for people with disabilities and those with access and functional needs who do not reside in special facilities
- modeling of planned or approved evacuation routes
- use of approved traffic control plans in the analysis
- use of planned bus routes for analysis of the transit dependent population evacuation

The initial release of this document identified the importance of developing ETE studies using traffic control plans agreed to by the local authorities. This updated guidance provides further insight into the benefits and limitations of manual traffic control (MTC) based on a comparison to automated traffic control devices (NRC, 2020). The U.S. Nuclear Regulatory Commission (NRC) recommends that MTC be used in limited situations within an ETE study. The comparison study also found that simulating MTC as an automated traffic control device is appropriate, but that consideration should be given to the allocation of green times to be reflective of officer behavior observed in the field.

This guidance describes the benefits of using traffic simulation modeling to calculate the ETE and establishes measures of effectiveness for use in the review of this ETE element. This revision includes guidance for the use of microsimulation models. When an ETE is developed without the use of a traffic simulation model, supporting data and calculations consistent with this guidance document should be provided.

This guidance also establishes when to include a shadow evacuation in the analysis. A shadow evacuation is defined as an evacuation of people from areas outside an officially declared evacuation zone. The impact of a shadow evacuation depends on the size of the evacuating population (NRC, 2020). The shadow population is considered in the analysis when necessary to account for any effect of this population group impeding the evacuation of those under evacuation orders.

This guidance emphasizes the importance of assumptions on expected resources, such as buses and ambulances, required to support evacuation of the transit dependent population and schools, as well as people with disabilities and those with access and functional needs. The number and location of available resources directly affect the ETE, and lack of available resources has been a problem in some large-scale evacuations (NRC, 2008a).

ETEs provide information for use in the formulation of a licensee's protective action recommendation and the ORO's protective action decisions. Understanding the time needed to evacuate the public is important to ensure that the OROs implement the most appropriate protective action. For small population sites (less than 50,000 evacuees), mobilization time is a key parameter in determining the ETE. For larger sites, temporal and spatial variations in vehicle demand and network capacity drive the evacuation process. ETEs that overestimate or underestimate evacuation time are not helpful in making the best protective action decision.

Research into existing evacuations (NRC, 2005a; NRC, 2007) shows that a small percentage of the public, about 10 percent, takes a longer time to evacuate. This 10 percent is known as the "evacuation tail." Decision makers should use the 90 percent ETE values when developing procedures for the implementation of protective action decisions. The 90 percent value informs decision makers of the estimated time to evacuate the vast majority of the public, and the 100 percent ETE informs decision makers on the likely time to evacuate the entire EPZ. Therefore, the ETE study should provide the time to evacuate 90 and 100 percent of the population.

Section IV of Appendix E to 10 CFR Part 50 requires ETE updates when the EPZ permanent resident population increases such that it causes ETE values to change by 25 percent or 30 minutes, whichever is less, from the licensee's current NRC-approved or updated ETE. Additionally, in the unlikely event that the conditions of an EPZ change significantly because of natural phenomena hazards or other reasons (e.g., a bridge collapse), the NRC recommends an interim update to the ETE.

Use by Applicants and Licensees

Applicants and licensees[1] may voluntarily[2] use the guidance in this document to demonstrate compliance with the ETE analysis required by the NRC in 10 CFR Part 50, Appendix E, Section IV. Each ETE analysis report should be formatted consistently with this template and submitted to the NRC under 10 CFR 50.4, "Written communications," for review to confirm the completeness of the ETE analysis. Methods or solutions that differ from those described in this document may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative complies with the appropriate NRC regulations. Licensees may use the information in this document for actions that do not require NRC review and approval. Licensees may use the information in this document or applicable parts to resolve regulatory or inspection issues.

Use by NRC Staff

The NRC staff may use this document as a reference in its regulatory processes, such as licensing, inspection, or enforcement. However, the NRC staff does not intend to use the guidance in this document to support NRC staff actions in a manner that would constitute backfitting as that term is defined in 10 CFR 50.109, "Backfitting," and as described in NRC Management Directive 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and

[1] In this section, "licensees" refers to holders of licenses of nuclear power plants under 10 CFR Part 50 and 52 and early site permits under 10 CFR Part 52. The term "applicants" refers to applicants for licenses for nuclear power plants under 10 CFR Part 50 and 52 and all applicants for early site permits submitted under 10 CFR Part 52.

[2] In this section, "voluntarily" means that the licensee or applicant is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

Information Requests," approved September 20, 2019 (NRC, 2019b), nor does the NRC staff intend to use the guidance to affect the issue finality of an approval under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The staff also does not intend to use the guidance to support NRC staff actions in a manner that constitutes forward fitting as that term is defined and described in Management Directive 8.4. If a licensee believes that the NRC is using this document in a manner inconsistent with the discussion in this section, then the licensee may file a backfitting or forward-fitting appeal with the NRC in accordance with the process in Management Directive 8.4.

PREFACE

An enhanced understanding of the importance of various modeling parameters for evacuation simulations described in NUREG/CR-7269, “Enhancing Guidance for Evacuation Time Estimate Studies,” issued March 2020 (NRC, 2020), contributed to the update of this guidance for evacuation time estimate (ETE) development. Previous advances in ETE modeling, along with the knowledge gained through research into large scale evacuations (NRC, 2005b; NRC, 2008a), led to the original issuance of this guidance for ETE development. Additionally, NUREG/CR-6953, Volume I, “Review of NUREG-0654, Supplement 3, ‘Criteria for Protective Action Recommendations for Severe Accidents,’” (NRC, 2007), concludes that a staged evacuation protective action provides greater benefit than a standard radial keyhole evacuation.

This report provides guidance on developing staged evacuation ETEs. This guidance document offers a template for the development and updating of ETE studies. It is intended to assist users in identifying contributing factors to the ETE and provide a methodical process for development of data and performance of ETE calculations.

Section 1 introduces the ETE, describes the characteristics of the emergency planning zone (EPZ), establishes general assumptions, and identifies the evacuation scenarios to be evaluated. Section 2 provides details to consider in developing demand estimates for permanent residents and transients, transit dependent populations, special facilities, and schools, and quantifying a shadow evacuation. Section 3 describes the approach for evaluating the roadway capacity and establishes values for use in adverse weather calculations. Section 4 discusses the process for developing trip generation times and provides detail on information that should be included in an ETE study when traffic simulation modeling is used. Section 5 identifies other considerations including development of a traffic control plan, potential enhancements to the ETE, State and local review, reviews and updates of the ETE, when to include the effect of reception centers on the ETE, new reactors, and early site permits. Appendix A to this document presents an example of roadway characteristics to be provided. Appendix B contains the ETE review criteria.

Use of the format and criteria provided here will support consistent application of ETE methodology, thereby facilitating a consistent review of initial or updated ETE studies. Licensees should use the ETE when developing procedures that support making offsite protective action recommendations and for developing those recommendations. Offsite response organizations should use the ETE when developing offsite protective action strategies and when making offsite protective action decisions.

ABBREVIATIONS AND ACRONYMS

CFR	*Code of Federal Regulations*
DOT	Department of Transportation (U.S.)
EAS	emergency alert system
EMO	evacuation management operations
DTA	dynamic traffic assignment
EPZ	emergency planning zone
ERPA	emergency response planning area
ESP	early site permit
ETE	evacuation time estimate
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
HCM	*Highway Capacity Manual*
LOS	level of service
MOE	measure of effectiveness
MTC	manual traffic control
NPP	nuclear power plant
NRC	Nuclear Regulatory Commission (U.S.)
ORO	offsite response organization
PAR	protective action recommendation
TCP	traffic control point
TRB	Transportation Research Board

1 INTRODUCTION

This section describes the emergency planning zone (EPZ) concept and the general approach used to meet the requirements for developing an evacuation time estimate (ETE). Section IV, “Content of Emergency Plans,” of Appendix E, “Emergency Planning and Preparedness for Production and Utilization Facilities,” to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, “Domestic licensing of production and utilization facilities,” requires each applicant for and holder of a nuclear power reactor license (jointly referred to as “licensees” in this report) to provide the U.S. Nuclear Regulatory Commission (NRC) with an analysis of the time required to evacuate various sectors and distances within its facility’s plume exposure pathway EPZ for transient and permanent residents. To address this requirement, licensees must develop an ETE, which is a calculation of the time required to evacuate the plume exposure pathway EPZ (NRC, 1980). The ETE is used to inform the protective action decision-making process and to assist in the development of traffic management plans to support an evacuation. The licensee should use the ETE when developing procedures that support making protective action recommendations (PARs), and offsite response organizations (OROs) should use the ETE when developing offsite protective action strategies.

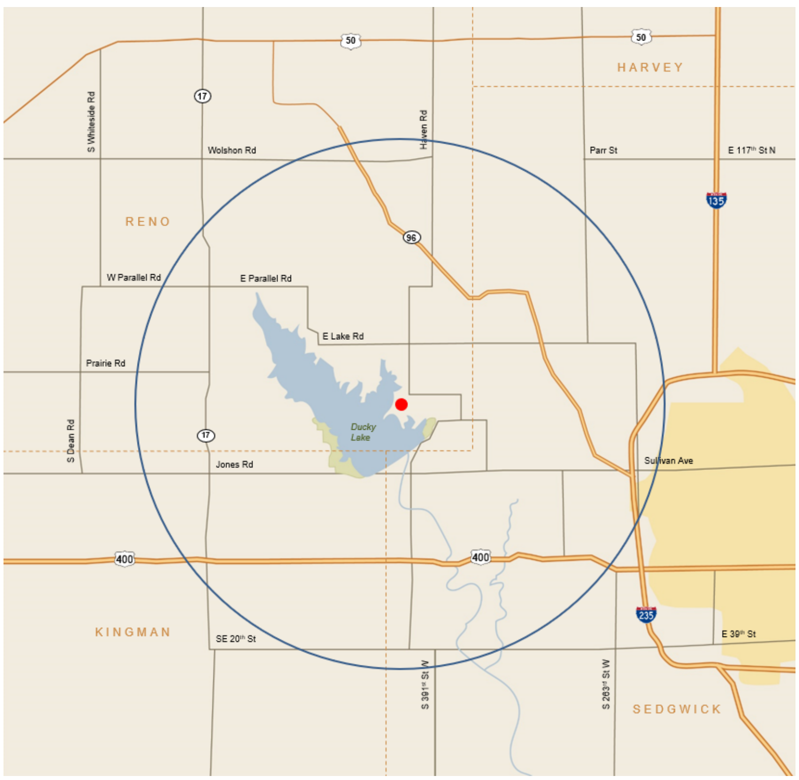


Figure 1-1 Vicinity Map

This NUREG/CR provides detailed information and guidance for use in developing or updating an ETE study. The NRC intends for the format and criteria provided here to support consistent application of ETE methodology and facilitate NRC review of initial or updated ETE studies. Each licensee should use the sections, tables, and figures presented here as appropriate for its specific EPZ.

The ETE study begins with an introduction section. The licensee should describe the EPZ, including the nuclear power plant (NPP) site location and any unique characteristics of the EPZ. This section of the study should include a map of the plume exposure pathway EPZ depicting the roadway network, population centers, political jurisdiction boundaries, and significant topographical features such as rivers, lakes, state parks, and other notable features. The licensee may provide this information on one or more maps depending on the complexity of the EPZ and the ability to clearly identify the necessary features. Figure 1-1 provides an example of a vicinity map of a hypothetical EPZ. Maps should include legends for relevant symbols, acronyms, and abbreviations.

When updating an ETE study, it is beneficial to provide an overview of changes since the development of the previous study. The licensee should include a comparison of the updated and previous ETEs when updating an existing ETE. Table 1-1 identifies information useful in comparing the ETEs.

Table 1-1 ETE Comparison

ETE Element	Previous ETE	Updated ETE
Permanent residents – Total population – Vehicle ratio		
Transit dependent population – Total population – Number of buses – Number of ambulances – Other transportation resources		
Transient population – Total population		
Special facilities – Total population – Number of buses – Other transportation resources		
Schools – Total student population – Number of buses		
Shadow evacuation percent estimated		
Special events – Attendance – Location – Duration		
Evacuation model and version		
Typical ETE – 90 percent full EPZ evacuation – 100 percent full EPZ evacuation		

Traffic simulation models that support ETE calculations are widely available. The U.S. Department of Transportation (DOT) has sponsored the "Evacuation Management Operations (EMO) Modeling Assessment: Transportation Modeling Inventory," which is available to support the selection of an appropriate model for use in evacuation analysis (DOT, 2007). The Federal Highway Administration (FHWA) has developed a toolbox for use by analysts in modeling roadway networks (FHWA, 2004a). To address the use of modeling in the analysis, this guidance document identifies measures of effectiveness (MOEs) to facilitate the review of ETE studies. ETE development should include a description of the key inputs, assumptions, outputs, and computational processes that are included in, or result from, the simulation. When a licensee develops an ETE without the use of a traffic simulation model, supporting data and calculations should be developed consistent with the approach provided here.

1.1 Approach

Evacuation analysis is based on moving the population away from the hazard in the most expedient manner practical within the constraints of the roadway network. This generally equates to a radial dispersion away from the hazard. ETEs are developed with consideration of the typical variations in capacity and demand that depend on when an event may occur, weather conditions, traffic volume, and other unique considerations of the EPZ. A well-defined approach will ensure that the licensee addresses all key elements. Care should be taken when using conservative assumptions, such as "worst-case" values, to ensure that the analysis does not result in an aggregate of all "worst-case" estimates because this is not the intent of the ETE. The licensee should describe the methods it used to address data uncertainties. This guidance includes additional considerations to reduce data uncertainty for stochastic models.

The approach should include a description of the following:

- the process used in development of the ETE
- meetings with planners, emergency managers, and local authorities, to resolve issues affecting the ETE
- information sources for roadways and traffic control systems
- information sources for demographic data
- the traffic control plans used in the analysis
- evacuation modeling used for the analysis

1.2 Assumptions

The planning basis for the ETE should include the assumptions that evacuation is ordered promptly and no early protective actions have been implemented. Use of this planning basis allows the licensee to calculate the ETE beginning with the initial notification to the public. Concurrent events that could initiate evacuations on their own, such as hurricanes, need not be assumed. For those sites where EPZs overlap, the ETE need consider only an evacuation of the NPP that is the focus of the study.

The licensee should state the general and site-specific assumptions used to support the analysis. Assumptions must have a reasonable basis and be quantified when possible. Table 1-2 lists general assumptions that are appropriate for use in the study. Additional assumptions that are specific to a section of the analysis, such as roadway capacity, should be included in the appropriate section of the ETE study.

Table 1-2 General Assumptions

1.	The ETE is measured from the time that instructions were first given to the public within the EPZ (e.g., initial emergency alert system [EAS] broadcast).
2.	Mobilization of the public begins after initial notification.
3.	Schools and special facilities receive notification at the same time as the rest of the EPZ.
4.	Evacuation time ends when the last vehicle has exited the EPZ, or when termination criteria are met (e.g., if needed for stochastic models).
5.	Background traffic is on the roadway within the EPZ when initial notification occurs and for some time after the start of the evacuation. Background traffic persists in regions beyond the EPZ.
6.	A 50 percent capacity is appropriate for buses used in the evacuation of the population dependent on public transportation.
7.	Buses used to evacuate schools and special facilities are loaded to capacity.
8.	A shadow region extends beyond the evacuation area boundary for a distance of half the radial extent of the defined evacuation area. A shadow evacuation of 20 percent of the public occurs within the shadow region.

1.3 Scenario Development

Scenarios are used to provide ETEs under varying conditions to support protective action decisions. Scenarios should represent typical variations in the traffic supply and demand variables. Typical scenario variations include different seasons, days of the week, times of day, weather conditions, roadway impacts, and special events or other circumstances. Multiple scenarios are intended to ensure that the ETE results encompass a reasonable range of potential evacuation situations for the specific site. Scenarios generally assume that residents evacuate from their home; however, the licensee should not assume that all residents are at home when they receive the initial notification. A daytime scenario should be developed for representative site-specific conditions during the workday. The evening scenarios should represent the timeframe when residents are generally at home with fewer residents dispersed within the EPZ.

Table 1-3 Evacuation Scenarios

Scenario	Season or Event	Day	Time	Weather
1	Summer	Midweek	Daytime	Normal
2	Summer	Midweek	Daytime	Adverse
3	Summer	Weekend	Daytime	Normal
4	Summer	Midweek and Weekend[1]	Evening	Normal
5	Winter	Midweek	Daytime	Normal
6	Winter	Midweek	Daytime	Adverse
7	Winter	Weekend	Daytime	Normal
8	Winter	Midweek and Weekend[1]	Evening	Normal
9	Roadway Impact	Midweek	Daytime	Normal
10	Special Events			Normal

Note 1: Recommended optional weekend scenario

The number of scenarios may vary depending on site-specific considerations, and the 10 scenarios identified in Table 1-3 are only recommendations. If prior site-specific ETE studies show the ETE to be insensitive to these scenario variations, fewer scenarios may be needed, but a minimum of 6 scenarios (not including special events) representing typical variations in vehicle demand and capacity (e.g., adverse weather or roadway impacts) should be included. Table 1-3 provides recommended optional scenarios. The report should state the reasons for not including scenarios. For each scenario used in the study, the licensee should provide a description of the scenario similar to those below.

1. **Summer Midweek Daytime (normal):** This scenario represents a typical normal weather daytime period when permanent residents are generally dispersed within the EPZ performing daily activities and major workplaces are at typical daytime levels. This scenario includes assumptions that permanent residents will evacuate from their place of residence; schools are closed and students are at summer activities; hotel and motel facilities are occupied at average summer levels; and recreational facilities are at average summer daytime levels.

2. **Summer Midweek Daytime (adverse):** This scenario represents an adverse weather daytime period when permanent residents are generally dispersed within the EPZ performing daily activities and major workplaces are at typical daytime levels. This scenario includes assumptions that permanent residents will evacuate from their place of residence; schools are closed and students are at summer activities; hotel and motel facilities are occupied at average summer levels; and recreational facilities are at average summer daytime levels.

3. **Summer Weekend Daytime (normal):** This scenario represents a typical normal weather weekend period when permanent residents are both at home and dispersed within the EPZ performing typical summer weekend activities. This scenario includes assumptions that permanent residents will evacuate from their place of residence; schools are closed and students are at home or with their families; workplaces are staffed at typical weekend levels; hotel and motel facilities are occupied at average summer weekend levels; and recreational facilities are at average summer weekend levels.

4. **Summer Midweek and Weekend Evening (normal):** This scenario represents a typical normal weather midweek and weekend evening period when permanent residents are generally at home with fewer dispersed within the EPZ performing evening activities. This scenario includes assumptions that permanent residents will evacuate from their place of residence; schools are closed and students are at home; workplaces are staffed at typical evening levels; hotel and motel facilities are occupied at average summer levels; and recreational facilities are at average summer evening levels.

5. **Winter Midweek Daytime (normal):** This scenario represents a typical normal weather weekday period during the winter when school is in session and the workforce is at a full daytime level. This scenario includes assumptions that permanent residents will evacuate from their place of residence; students will evacuate directly from the schools; workplaces are fully staffed at typical daytime levels; hotel and motel facilities are occupied at average winter levels; and recreational facilities are at winter daytime levels. The number of permanent resident vehicles may be reduced appropriately in this scenario to account for the number of students at school within the EPZ, because the buses used for evacuation of students account for the vehicle load.

6. **Winter Midweek Daytime (adverse):** This scenario represents an adverse weather weekday period during the winter when school is in session and the workforce is at a full daytime level. This scenario includes assumptions that permanent residents will evacuate from their place of residence; students will evacuate directly from the schools; workplaces are fully staffed at typical daytime levels; hotel and motel facilities are occupied at average winter levels; and recreational facilities are at winter daytime levels. The number of resident vehicles may be reduced appropriately in this scenario to account for the number of students at school within the EPZ, because the buses used for evacuation of students account for the vehicle load.

7. **Winter Weekend Daytime (normal):** This scenario reflects a typical normal weather winter weekend period when permanent residents are both at home and dispersed within the EPZ, and the workforce is at a weekend level. This scenario includes assumptions that permanent residents will evacuate from their place of residence; schools are closed and students are at home; workplaces are staffed at typical weekend levels; hotel and motel facilities are occupied at average winter weekend levels and recreational facilities are at winter weekend levels.

8. **Winter Midweek and Weekend Evening (normal)**: This scenario reflects a typical normal midweek and weekend evening period when permanent residents are home and the workforce is at a nighttime level. This scenario includes assumptions that permanent residents will evacuate from their place of residence; schools are closed and students are at home; workplaces are staffed at typical nighttime levels; hotel and motel facilities are occupied at average winter levels; and recreational facilities are at winter evening levels.

9. **Roadway Impact Midweek Daytime (normal):** This scenario represents a variety of common conditions that may impact network capacity such as minor road construction projects, and vehicle accidents. The roadway impact scenario should assume that during a summer midweek normal weather daytime scenario, one segment of one of the highest volume roadways will be out of service and unavailable to evacuees. An alternative to removing one roadway segment from use is to analyze the effect of a single outbound lane being shut down on an interstate highway. A licensee conducts this analysis to understand the impact of localized capacity reductions on the ETE. Major disruptions to the road network that would significantly impact protective action strategies should be assessed as described in Section 5.4.1, “Extreme Conditions.”

10. **Special Events (normal):** This scenario should reflect a special event activity where peak tourist populations are present within the EPZ. Assumptions made should reflect the timeframe in which the special event occurs. The estimate of population attending the event should consider both transients and permanent EPZ residents who may be in attendance to avoid double counting residents. The licensee should assume that the remaining permanent resident percentage (i.e., those not attending the event) will evacuate from their residence, workplaces will be staffed at typical levels, hotel and motel facilities are occupied at peak special event levels, and recreational facilities are at appropriate levels based on the event and time of year.

1.4 Evacuation Planning Areas

The ETE is typically developed based on the EPZ response planning areas. These areas are commonly referred to as emergency response planning areas (ERPAs), but may also be referred to as subareas, protective action areas, protective action zones, or other site-specific terms. In this document, the NRC uses the term ERPA; however, local terminology is appropriate and acceptable. ERPAs are defined as local areas within the EPZ for which emergency response information is provided. These areas are typically delineated by geographic or political boundaries to support emergency response planning and may not conform to a precise radial distance from the NPP (NRC, 1980).

Protective actions are implemented at the ERPA level. For those sites where ERPAs are large and encompass areas beyond a 2-, 5-, or 10-mile radius, the analyses, including the staged evacuation, should be based on the existing ERPAs. ERPA configurations do not need to be revised to facilitate the ETE analysis.

The licensee should develop ETEs for the complete evacuation of the following:

- radial zones as appropriate to defined ERPAs, including the complete EPZ, as shown in Table 1-5 (e.g., a 5-mile EPZ would likely contain a 0-2 mile zone and 0-5 mile zone)
- affected ERPAs necessary to support site-specific PAR logic (i.e., keyhole and staged evacuations based on wind direction as shown in Table 1-4 and Table 1-5)

1.4.1 Keyhole Evacuation

Typical analyses are performed using a keyhole evacuation as the basis. The term “keyhole evacuation” is used because the area evacuated resembles a keyhole, typically including a 360 degree area around the site with a 2-mile radius, and continuing in a downwind direction, out to 5 miles from the NPP as shown in Figure 1-2. These distances may vary depending on the EPZ size. The keyhole includes the downwind sector and adjoining sectors on each side. The calculation of the ETE for a keyhole evacuation normally includes a radial zone around the site and the affected downwind sectors; this guidance also separates these zones to support protective action decision-making for a staged evacuation as described in Section 1.4.2, “Staged Evacuation”.

Evacuation areas are developed by assuming that a plume travels in a fixed wind direction. An ETE is calculated for all of the ERPAs within the plume sector and at least the two adjoining sectors. As indicated in Table 1-4, ETEs are developed for each wind direction around the EPZ. ETEs for the transit dependent population, special facilities, and schools are developed separately.

Figure 1-3 provides an example of an EPZ and generic ERPAs. To implement an initial keyhole evacuation, the 2-mile radius around the site would be evacuated and affected downwind sectors would be evacuated to 5 miles. For instance, for a wind direction from the NNE to the SSW, the affected downwind sectors are the SSW sector and the adjacent S and SW sectors. All of the ERPAs encroached upon by these sectors would be evacuated. Development of a full suite of ETEs requires that this process be repeated for each sector rotating around the EPZ until ETEs are calculated for all wind directions and scenarios.

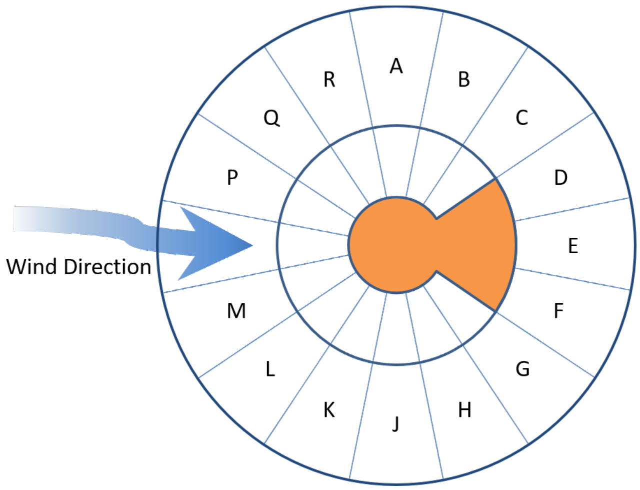


Figure 1-2 Keyhole Evacuation

In the example EPZ displayed in Figure 1-3, for a wind direction from the NNE to the SSW, the 2-mile zone includes only ERPA A, and the 5-mile downwind sectors encroach upon ERPAs B and C, which would also be evacuated. Therefore, Table 1-4 shows the affected ERPAs are A, B, and C. For the ETE study, a map identifying the ERPAs should be provided, along with a table identifying affected ERPAs for each wind direction.

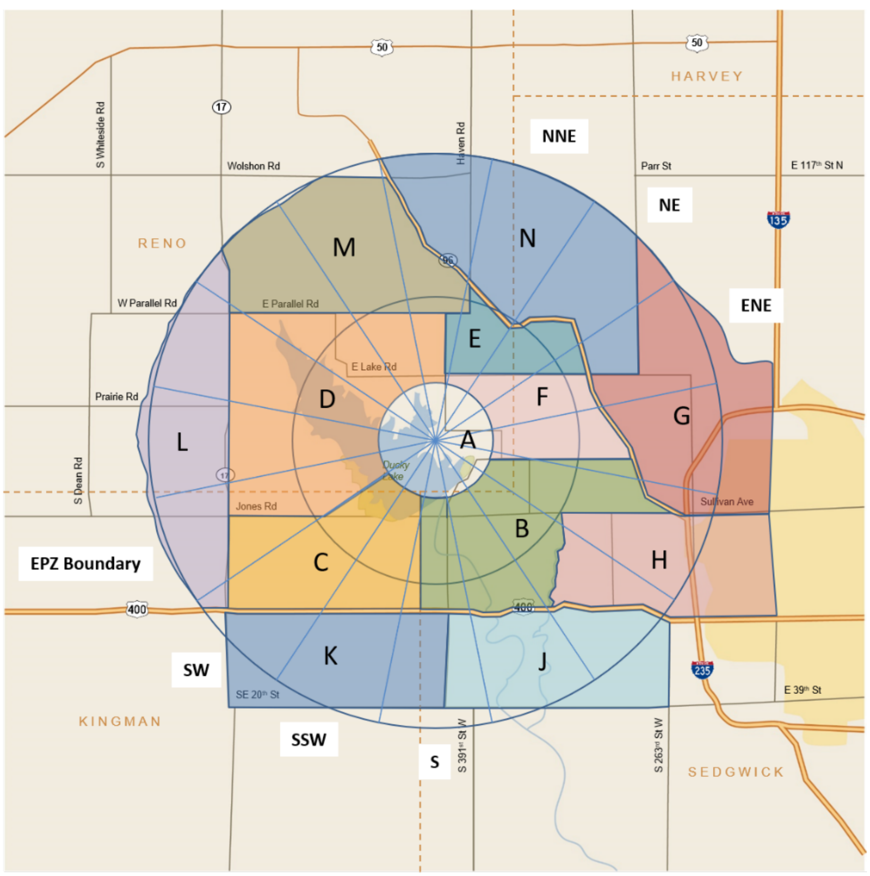


Figure 1-3 Emergency Response Planning Areas

Table 1-4 Evacuation Areas for a Keyhole Evacuation

Affected ERPAs	Area	A	B	C	D	E	F	G	H	J	K	L	M	N
Evacuate 2-mile zone and 5 miles downwind														
	Wind Direction (from)	Affected ERPAs												
		A	B	C	D	E	F	G	H	J	K	L	M	N
ABC	N	X	X	X										
ABC	NNE	X	X	X										
ACD	NE	X		X	X									
ACD	ENE	X		X	X									
AD	E	X			X									
AD	ESE	X			X									
AD	SE	X			X									
ADE	SSE	X			X	X								
ADEF	S	X			X	X	X							
ADEF	SSW	X			X	X	X							
AEF	SW	X				X	X							
AEF	WSW	X				X	X							
ABEF	W	X	X			X	X							
ABF	WNW	X	X				X							
AB	NW	X	X											
ABC	NNW	X	X	X										

1.4.2 Staged Evacuation

Research has shown that implementation of a staged keyhole evacuation can be more beneficial to the public health and safety than the normal keyhole evacuation (NRC, 2007). In a staged evacuation, one area is ordered to evacuate while adjacent areas are ordered to shelter in place until directed to evacuate. When making protective action recommendations and decisions that include a staged keyhole evacuation, it is necessary to understand the ETE for this protective action. This analysis can also be used to assess the feasibility of a staged evacuation for consideration in the PAR logic. The licensee should include in the ETE study a discussion on the approach used in the development of staged evacuation scenarios. Licensees should include a staged evacuation analysis for initial PAR strategy development as described in Section 5.6, “New Reactors.”

For each scenario, the staged evacuation analysis involves evacuating the radial zone around the site while the affected downwind zones are under a shelter-in-place order. For a 10-mile EPZ, a staged evacuation analysis typically involves evacuating the 0-2 mile zone while sheltering the 2-5 mile sector and adjoining sectors downwind. When approximately 90 percent of the 0-2 mile zone has cleared the 2 mile zone boundary, based on the ETE, the 2-5 mile zone would be loaded onto the evacuation network. The residents in the 2-5 mile zone enter the roadway network as the population within 0-2 miles is passing through the area. During the time required for the 0-2 mile zone to evacuate, the 2-5 mile zone may be assumed to be preparing to evacuate, potentially reducing the trip generation time elements for this area. The analysis combines the time to evacuate the 0-2 mile zone with the time to evacuate the 2-5 mile keyhole area. A shadow evacuation of 20 percent should be included in this analysis as described in Section 2.5.2, “Shadow Evacuation.”

The shelter time of residents within the 2-5 mile zone corresponds to the ETE for 90 percent evacuation of the 0-2 mile zone. The ETE value for the 0-2 mile 90 percent evacuation that will be used in response procedures is the estimated value obtained from the ETE document. It is not based on actual movement of vehicles during an evacuation. When developing additional ETEs for a staged evacuation, the licensee should use the format in Table 1-5.

Table 1-5 Evacuation Areas for a Staged Evacuation

Affected ERPAs	**Radial Zone**	A	B	C	D	E	F	G	H	J	K	L	M	N
A	2 mile ring	X												
A thru F	5 mile ring	X	X	X	X	X	X							
A thru N	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X
Evacuate 2 to 5 miles downwind														
Affected ERPAs	**Wind Direction (from)**	Affected ERPAs												
		A	B	C	D	E	F	G	H	J	K	L	M	N
BC	N		X	X										
BC	NNE		X	X										
CD	NE			X	X									
CD	ENE			X	X									
D	E				X									
D	ESE				X									
D	SE				X									
DE	SSE				X	X								
DEF	S				X	X	X							
DEF	SSW				X	X	X							
EF	SW					X	X							
EF	WSW					X	X							
BEF	W		X			X	X							
BF	WNW		X				X							
B	NW		X											
BC	NNW		X	X										

2 DEMAND ESTIMATION

This section details the process for estimating the number of people to be evacuated. The NRC's regulations in 10 CFR 50.47(b)(10) require that "a range of protective actions has been developed for the plume exposure pathway EPZ for emergency workers and the public." The public includes all persons located within the EPZ, including residents, transients, people with access and functional needs, and any other member of the public. Demographic data, together with information and assumptions on population groups support an estimate of the public and corresponding vehicles that will be evacuating the area. The licensee should estimate demand for the following four population segments:

1. **Permanent Residents and Transient Population**: Permanent residents include all people having a residence in the area. The transient population includes tourists, shoppers, employees, and others who visit but do not reside in the area.
2. **Transit Dependent Permanent Residents**: Permanent residents who do not have access to a vehicle or are dependent on help from outside the home to evacuate.
3. **Special Facility Residents**: Residents of nursing homes and assisted living centers, patients in hospitals, and those confined in jails, prisons, or other facilities.
4. **Schools**: All private and public educational facilities within the EPZ. Colleges and universities should be assessed on a case-by-case basis, recognizing that some students typically have access to a vehicle.

Demand estimates for these four population groups are developed separately to account for all of the public within the EPZ.

2.1 <u>Permanent Residents and Transient Population</u>

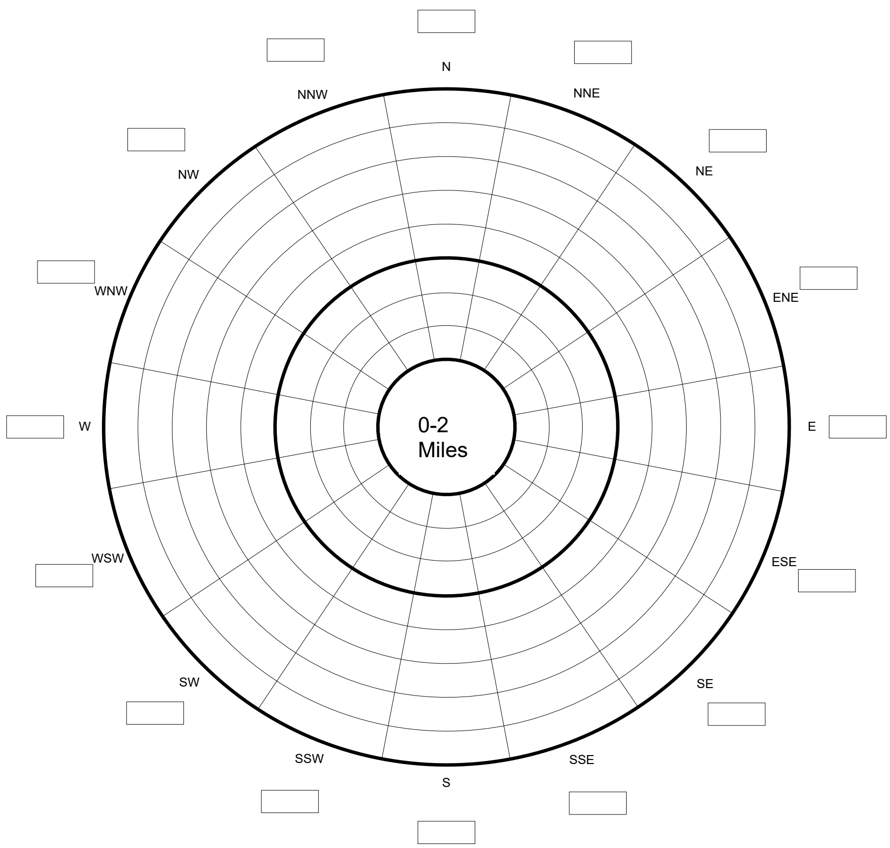
The licensee should use U.S. Census Bureau data adjusted as necessary for growth to estimate the number of permanent residents. The ETE study should include the availability date of the census data. Along with census data, local data may be used for population estimates. The population values used in the ETE should be developed for the year the ETE is prepared. The licensee should divide the permanent resident population group into the following two subgroups:

1. residents having available private transportation
2. transit dependent residents (dependent on others for transportation)

The distribution of permanent resident and transient populations should be provided in a format similar to Figure 2-1 with total populations provided for each sector. The rings and sectors of this figure may be extended to show the shadow populations. For smaller EPZs, it may be appropriate to use increments of less than 1 mile.

2.1.1 Permanent Residents with Vehicles

The ETE study should include an estimate of persons per vehicle. An estimate of 1 to 3 people per vehicle is typical. The licensee should use values within this range for the permanent population unless site-specific information supports the use of lower or higher values.



Population Miles	Subtotal by Ring	Cumulative Population
0-2		
2-3		
3-4		
4-5		
5-6		
6-7		
7-8		
8-9		
9-10		
10-EPZ Boundary		

Figure 2-1 Population by Sector

2.1.2 Transient Population

The transient population includes people temporarily visiting the area, such as tourists, shoppers, or employees, who do not reside within the EPZ. The licensee should develop a list of facilities that attract transient populations and note peak and average attendance for these facilities. The use of average attendance values, by season, is generally acceptable. For example, the summer average weekday population for beach areas would be used for summer weekday scenarios, and average weekend population would be used for weekend scenarios.

The transient population should be itemized and totaled as appropriate for each scenario. For example, motel capacities may be full for evening scenarios, but empty during daytime scenarios when tourists are visiting parks or other areas. The licensee should provide the

distribution of the transient population in a format similar to Figure 2-1. Care should be taken not to double count transient populations. To avoid double counting transients and permanent residents, the licensee should indicate the percentage of permanent residents of the EPZ assumed to be at parks, shopping, or other locations. The number of people per vehicle should be identified. For transient employees, this value is typically around 1 to 1.5 persons per vehicle. A value of 1.5 to 2.5 persons per vehicle is typical for general transients, but this may vary by type of activity or location. The licensee should provide a basis for using higher vehicle occupancy rates. Major employers, defined as those with 200 or more employees working a single shift, should be listed and include the number of people per vehicle.

2.2 Transit Dependent Permanent Residents

The licensee should estimate the time to evacuate those residents that do not have access to a vehicle. The licensee should consider and identify special services that may be needed to support the evacuation of these residents (NRC, 1980). Surveys are helpful in identifying the site-specific demographics of this population group, including the number of individuals and specialized transport needs. This population group may include the following:

- households with no vehicles available during the evacuation
- residents unable to self-evacuate (e.g., elderly who do not drive at night or do not drive distances of more than a few miles)
- residents dependent on specialized transportation such as wheelchair vans or ambulances

The licensee should review State and local emergency plans to identify if plans are in place to provide transportation to transit dependent residents during an evacuation. Where local plans exist, the licensee should use them in developing the ETE. Data from local and county emergency planning registration programs should be used as a first order planning tool to support the demand estimate but should not be used as the only source of data.

Previous research (NRC, 2008b) and data reviewed on existing ETEs indicate a range of about 3 to 10 percent of EPZ permanent resident populations may be transit dependent. A portion of the population will rideshare during an evacuation, leaving the area with friends, neighbors, or relatives, and it is acceptable to assume that up to 50 percent of residents without vehicles will rideshare. The NRC bases this value on results of a national telephone survey of EPZ residents (NRC, 2008b), which indicated that more than 50 percent of residents would offer a ride to individuals waiting for transportation. Empirical data obtained from the widely studied Mississauga, Canada evacuation in 1979 also supports a value of 50 percent (IES, 1981). If a higher value is used, then the licensee should provide a basis for that value. Assuming that 50 percent of transit dependent persons rideshare suggests that 1.5 percent to 5 percent of the EPZ permanent resident population may require transportation. A basis should be provided for use of values lower than 1.5 percent.

The capacity of municipal buses is based on adults, and the capacity of school buses is based on children. Considering that residents are evacuating with their belongings, including clothing, medicines, and pets, a reasonable estimate for buses is 50 percent of the stated seating capacity (NRC, 2008a) with no credit taken for standing room capacity. The licensee should identify the capacities assumed for buses and other transportation and, if an estimate higher than 50 percent capacity is used, provide a basis for that estimate. Licensees should take care not to double count resources when calculating transportation needs for populations dependent on public transport and the transportation needs for special facility residents.

A subset of transit dependent residents includes people with disabilities and those with access and functional needs that live independent of a special facility. A telephone survey of residents living within EPZs found that 6 percent of respondents said they, or someone in their household, would need assistance to evacuate (NRC, 2008b). The licensee should separately develop and quantify information on households with residents dependent on specialized transportation such as wheelchair vans or ambulances.

The licensee should summarize the total number of vehicles (e.g., buses, ambulances, specialized transport vehicles) assumed available to support the evacuation of transit dependent residents, as well as people with disabilities and those with access and functional needs not residing in special facilities. This will support the determination of how many evacuation runs may be needed.

2.3 Special Facility Residents

Special facility include, but are not limited to, hospitals, nursing homes, jails, and prisons. Special facility residents depend on facility personnel for transportation in an emergency. Special facility personnel are counted in the special facility population group. The licensee should describe the process for obtaining special facility data. This typically includes contacting each facility. The ETE study should include a list of special facilities, including the type of facility, location, and population, using the average number of residents typically at the facility. There may be unique situations where, after extensive efforts to obtain data on facilities, information is not available and assumptions must be used. In such instances, assumptions must be documented and have a basis. For instance, considering similar facilities, such as nursing homes, an estimated capacity might be based on beds per square foot of the facility and should be comparable to that of other nursing homes in the area.

The licensee should clearly indicate when a single bus run will not evacuate a facility and additional bus runs are needed. Resources needed to evacuate special facilities typically include buses, vans, ambulances, automobiles, drivers and specially trained staff. Specially trained staff may include medical support or security support for prisons, jails, and other correctional facilities. The number and capacity of all vehicles needed to support the evacuation should be provided. Care should be taken not to double count resources when calculating transportation needs for populations dependent on public transport and the transportation needs for special facilities.

2.4 Schools

State and local emergency response plans may include early protective actions for evacuation of schools prior to the general public. However, the development of ETEs should consider that school evacuations begin with the same initial notification provided to the general public. Schools present a unique issue with the expectation that some students may be picked up by parents, relatives, or friends, which may reduce the student population requiring bus transportation. The licensee should provide a list of schools, including name, location, student population, transportation resources required to support the evacuation, and the source of the school population values.

In many areas, high school students drive to school, and these students would be expected to evacuate in their personal vehicles. Busing for high school students may be reduced to reflect the number of students who drive, as estimated by school staff. For elementary and middle schools, transportation resources should be based on 100 percent school capacity. The

licensee should discuss the assumptions for evacuation of school staff. When evacuation cannot be accomplished with a single trip, the need for return trips should be clearly indicated.

2.5 Other Demand Estimate Considerations

As described below, the licensee should also consider demand estimates for peak populations during special events within the EPZ, for shadow evacuations of the population outside of the evacuation area, and for the background and pass-through traffic within the EPZ.

2.5.1 Special Events

Special events occur within most EPZs and can attract large numbers of transients to the EPZ for short periods of time, creating a temporary surge in demand. Special events might include Fourth of July celebrations, parades, sporting events, or any number of activities that bring large populations into the EPZ. These events frequently define the peak tourist population that is to be included in the study (NRC, 1980). All special events that draw a large group of transients should be listed in the ETE with the estimated population, duration, and season of the event. However, the licensee needs to analyze only one special event that encompasses the peak tourist population as described below.

The total attendance for an event may be helpful in developing the ETE but may not need to be considered as the demand estimation used. For instance, a weekend festival that draws 100,000 people over the duration of the event may not need to be assessed as an evacuation of 100,000 people. The average hourly or daily attendance may provide a better evacuation number than the total population of the festival. For events where the attendees arrive and depart at relatively the same time, such as a sporting event, the total values are appropriate for use. To avoid double counting transients and permanent residents, the licensee should indicate the percentage of permanent residents of the EPZ assumed to be at special events.

2.5.2 Shadow Evacuation

A shadow evacuation occurs when people outside of any officially declared evacuation zone evacuate without having been instructed to do so. Shadow evacuations are considered in developing the demand estimation because the additional traffic generated has the potential to impede an evacuation, particularly near the boundary of the evacuation area. A shadow evacuation of 20 percent of the permanent resident population, based on U.S. Census Bureau data, should be assumed to occur in areas outside of the evacuation area being assessed. The 20 percent value is static to support a standardized assessment and represents a reasonable estimate for evaluating the impact of a shadow evacuation (NRC, 2020). The shadow region of interest should extend beyond the evacuation area boundary out to at least half the radial distance of the evacuation area as illustrated in Figure 2-2. The shadow region of interest also depends on the evacuation area under consideration. An example of the shadow region for a keyhole evacuation is shown in Figure 2-3.

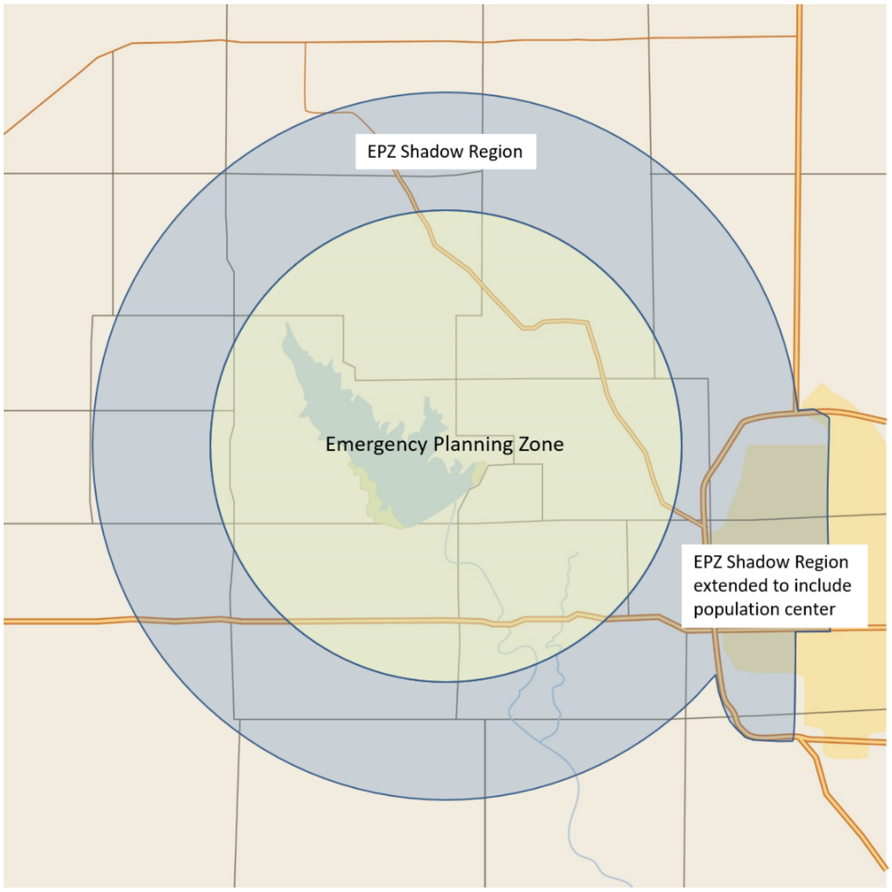


Figure 2-2 Shadow Region for EPZ

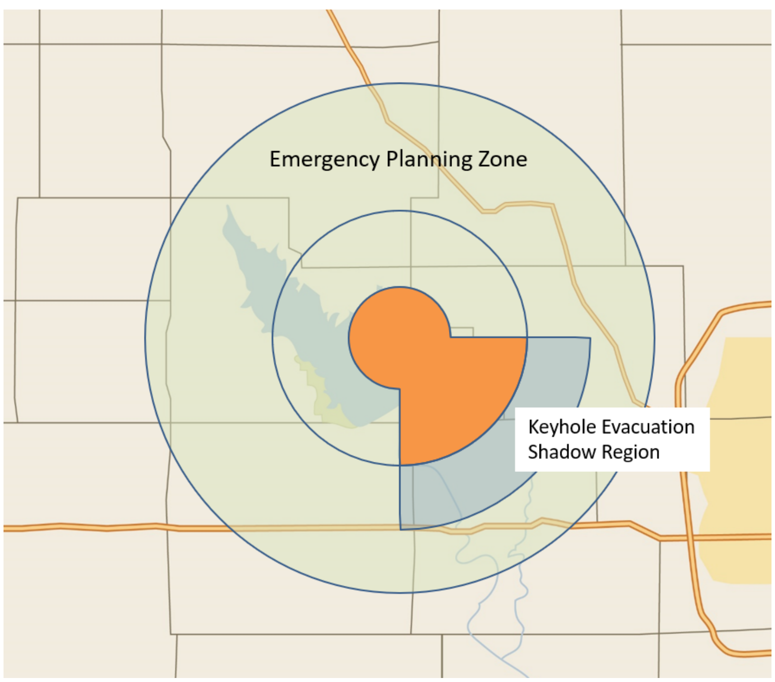


Figure 2-3 Shadow Region for Keyhole Evacuation

A shadow evacuation would likely occur in a graded manner with the potential for a 20 percent shadow to occur from the areas that are closer to the declared evacuation area, decreasing with distance away from the affected area. Research shows that the shadow evacuation participation rate has minimal impact on the evacuation of those closest to the NPP and that a 20 percent shadow is a reasonable number to assume (NRC, 2020). Research also shows that for small population sites, the ETE is insensitive to a shadow evacuation (NRC, 2020). ETE studies do not need to model a shadow evacuation if the number of evacuees is less than 50,000 and 20 percent of the shadow population is less than half of the evacuating population. The number of evacuees is based on the combined permanent resident and transient populations within the entire EPZ such that the combined population would be less than 50,000 evacuees averaged across all scenarios or less than a maximum of 50,000 among all scenarios for the entire EPZ. For EPZs with more than 50,000 evacuees, the shadow region may need to be extended to include the influence of major population centers, as shown in Figure 2.2. Section 4.5, "Model Boundaries," provides guidance for establishing model boundaries in the vicinity of a major population center.

The licensee should provide population estimates for the shadow evacuation in the shadow region beyond the EPZ by sector. The loading of the shadow population onto the roadway network should be applied consistent with the trip generation time developed for the permanent resident population. It is not necessary to include a shadow population for transient or special facility populations.

2.5.3 Background and Pass-Through Traffic

Background and pass-through traffic contribute to the demand estimation. Background traffic is defined as vehicles on the roadway when the initial notification occurs and consists of both residents and transients within the EPZ. The licensee needs to consider that these individuals may be on the roadway within the EPZ at the beginning of an emergency, and the ETE should include time for activities needed to return home, when appropriate, and then evacuate. The licensee should assume that background traffic will take reasonable trips between origin and destination nodes throughout the model but should not assume that background traffic will only follow evacuation routes traveling to the same destination nodes as evacuees.

Pass-through traffic includes vehicles that enter the EPZ roadway network and "pass through" prior to the establishment of access control points. In some EPZs, this may account for a significant volume of vehicles. In the ETE study, the volume of vehicles should be representative of the average daytime traffic within the EPZ. Values may be reduced for nighttime scenarios. The licensee may assume that pass-through traffic will stop entering the EPZ about 2 hours after initial notification when access control points have been established.

Background traffic within the EPZ can be considered to comprise mostly EPZ residents who will subsequently evacuate. The licensee should reduce background traffic generated within the EPZ from the initial value to zero during the time interval between initial notification and the time when an equivalent number of evacuee vehicles have been loaded onto the network. For example, if background traffic is assumed to be 10 percent of the total number of EPZ vehicles, then the background traffic generation rate would be reduced from a steady 10 percent contribution down to 0 percent during the time from initial notification until approximately 10 percent of the evacuee vehicles have been loaded onto the network. Alternatively, the licensee can reduce background traffic within the EPZ from its initial value to zero over a 2-hour period following initial notification; this may be more appropriate for sites with EPZ populations greater than 50,000 residents. Background traffic outside the evacuation area may be assumed to be

constant, unless specific conditions would dictate otherwise (e.g., traffic control redirects background traffic away from the evacuation route). The licensee should describe its approach to modeling background and pass-through traffic.

2.6 Summary of Demand Estimation

The demand estimation will provide the total number of people and vehicles to be evacuated for each of the population groups including permanent residents with vehicles, transit dependent permanent residents (those who require specialized vehicle transportation and those who require only bus transportation), transients, special facilities, schools, shadow population, and background and pass-through demand. The ETE study should include a summary table that identifies the total populations used in the analysis for each scenario and a separate summary table that identifies the total number of vehicles by population group for each scenario. These values should represent the input values used in the traffic simulation modeling.

3 ROADWAY CAPACITY

This section identifies the methods and data used in the assessment of roadway capacities. The capacity of a roadway is defined as the maximum rate at which vehicles can be expected to traverse a section of roadway during a given time period under prevailing roadway, traffic, and control conditions. Roadway capacity influences evacuation travel time particularly as traffic demand approaches or exceeds capacity. For this reason, a detailed capacity analysis is important. The modeling of roadway capacity in traffic simulation tools varies by level of abstraction. Macroscopic traffic simulation tools require an estimated value based on capacity associated with each roadway segment. This base capacity can be modified using a capacity reduction factor to account for congested conditions or adverse weather. For microscopic simulation tools, capacity is the result of the interaction among vehicles, characteristics of the roadway, and driving behavior.

The licensee can perform capacity analyses through the application of processes and equations established in the U. S. Department of Transportation's *Highway Capacity Manual* (HCM) (TRB, 2010) and augmented as appropriate for consideration of saturated flow conditions. As roadways become saturated, the HCM methodologies are not as well developed, and the analysis is best performed using traffic simulation models, which employ numerical techniques to predict performance of traffic behavior. The licensee should discuss the method used to assess roadway capacity.

3.1 Roadway Characteristics

Roadway characteristics are needed for proper depiction of the evacuation transportation network. Roadways should be categorized by functional class to identify the types of roadways used in the analysis. Local or regional terminology may be used for the roadway classes, and the following classes should be identified if present:

- freeways or interstates
- freeway ramps
- major arterials
- minor arterials
- collectors
- local roadways

Field surveys of the key routes within the EPZ should be performed, as necessary, to validate existing mapping and obtain roadway characteristics and information for use in the analyses. The following information should be obtained as needed to support the modeling:

- number of lanes and lane width
- left turns in lane group
- right turns in lane group
- roundabouts or rotary intersections
- toll gates and associated lane channelization
- intersection queuing capacities
- posted speed limits
- roadway segments with significant capacity reductions
- grade changes of more than about 4 percent

The ETE study should include a legible map of the roadway system that identifies node numbers and segments used to develop the ETE. Depending on the complexity of the EPZ and the number of nodes and segments, the map may be presented in quadrants or other sectors for clarity. The licensee may provide an electronic version of the map to allow enlargement as needed to support a detailed review of the nodes and segments of the roadway network. Appendix A provides examples.

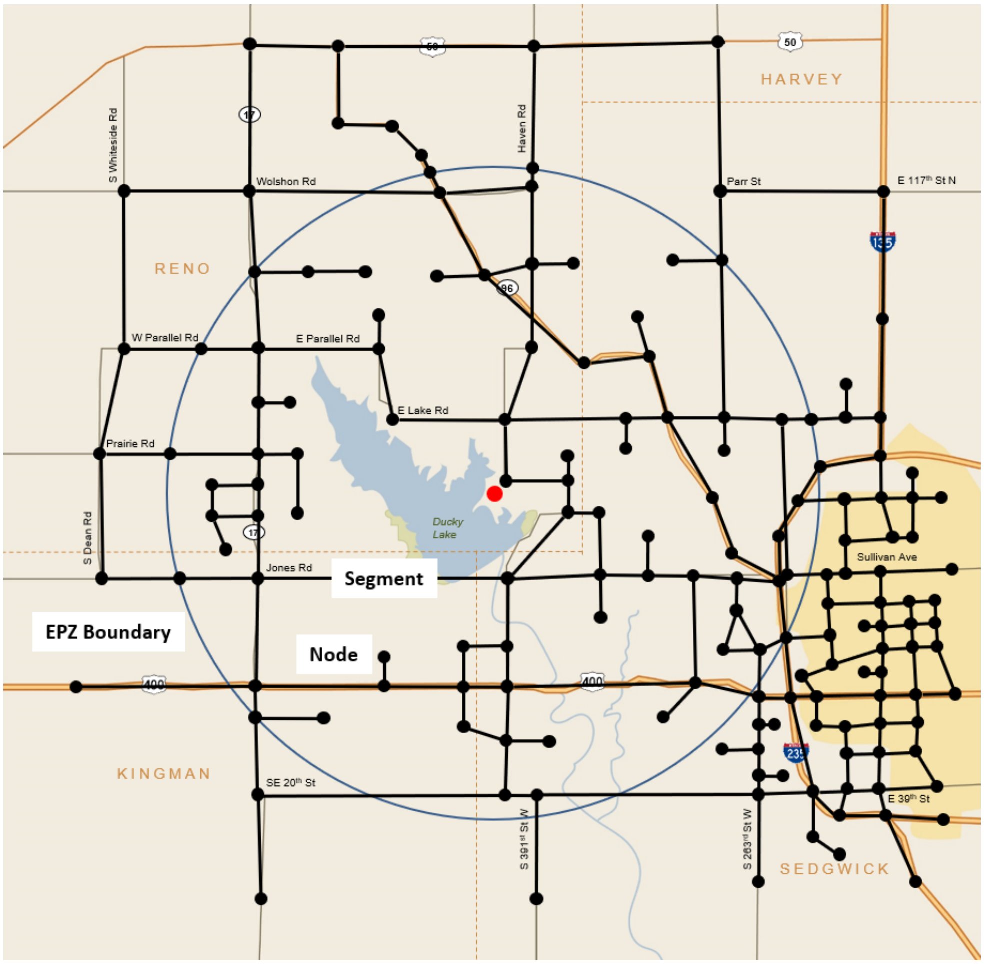


Figure 3-1 Roadway Network Identifying Nodes and Links

3.2 Model Approach

Traffic simulation models are categorized as microscopic, mesoscopic, and macroscopic, all of which may be appropriate for use in calculating evacuation times. As the descriptions of the model types indicate, they reflect different fidelities in both the inputs and outputs. Macroscopic models employ deterministic relationships of speed, capacity, and density of the traffic stream, such as those contained in the HCM. The vehicle simulations in macroscopic models are grouped and are governed by the average speed on a link, rather than based on individual vehicles. Microscopic models simulate the movement of individual vehicles based on car-following and lane-changing theories and provide the ability to model signalized intersections and associated queuing in detail. However, to produce realistic results using a microscopic model, a significant amount of field data and accurate representation of driver behavior

characteristics are needed. Mesoscopic models implement properties of both microscopic and macroscopic by analyzing small, homogenous groups of vehicles. Mesoscopic models facilitate analyses that are more detailed than macroscopic and less detailed than microscopic. The FHWA published a multivolume Traffic Analysis Toolbox providing guidance on appropriate application of traffic simulation models.

Microscopic simulation models are useful and powerful tools with many advanced capabilities that yield detailed results. However, they can also require substantial effort to develop. Because of the additional effort to code the microscopic model, select and adjust site-specific input parameters, and validate the performance against field conditions to ensure reasonable baseline results, the use of microscopic models is challenging when developing complex ETE studies in a timely manner. The FHWA study, "Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation," compares the level of effort required to model regions of various sizes with microscopic traffic simulation (FHWA, 2014). Microscopic simulation may be appropriate for models of smaller populations or analysis areas, or to perform detailed analyses along specific routes.

3.2.1 Macroscopic Model Capacity

The processes outlined in the HCM for two lane highways, multilane highways, and freeways are used to determine the capacity of roadway segments by accounting for lane width, lateral clearance, heavy vehicles, and other vehicles, through the use of adjustment factors (TRB, 2010). However, many of the computational approaches used in the HCM break down as the roadway capacity is exceeded. Because this is a prominent condition during evacuations, traffic simulation modeling is used to assess traffic behavior. These models can better assess saturated flow when evacuation time becomes more dependent on the ratio of demand to capacity (v/c ratio) under the conditions and characteristics of the roadway network and the interactions between individual vehicles on the roadway.

The licensee should describe in detail the approach it used to calculate the roadway capacity for the transportation network and should discuss important factors that are expressly used in the modeling, particularly those associated with the control or interruption of flow within the network. The licensee should consider an approach that provides a detailed analysis of key routes, such as evacuation routes. Routes that are not designated evacuation routes must also be evaluated, but field estimates in lieu of field measurements may be appropriate for these roadways. In the capacity analysis, the licensee should expressly state where field information is used in the ETE calculation and how the licensee acquired that information.

3.2.2 Microscopic Model Capacity

Microscopic models simulate the movement of individual vehicles based on car-following and lane-changing theories and provide the ability to model signalized intersections and associated queuing in detail. To produce realistic results using a microscopic model, a significant amount of field data and accurate representation of driver behavior characteristics are needed. Traffic analysts characterize segment capacity with average headway and average speed even though in reality the maximum flow rate is likely to be constantly changing. Volume III of the FHWA Traffic Analysis Toolbox provides a methodology for development and application of microscopic simulation models (FHWA, 2019). If the licensee uses microscopic simulations, then the licensee should describe its approach to modeling and calibrating the driver behavior models.

3.2.3 Route Choice

Route decisions can be modeled using either static or dynamic traffic assignment (DTA). In static traffic assignment, an analyst defines the routes the vehicles will follow. Dynamic traffic assignment implements time-dependent origin and destination (O-D) trips that are assigned based on traffic conditions. Balancing traffic volumes on the multiple evacuation routes requires expert judgment regarding driver decisions at each intersection within the analysis area. For this reason, static models should have a basis for the route decisions. Static route choice may be impractical to implement in models with a significant number of possible route decisions, and DTA may be more appropriate in most cases. In general, the route choice applied in the simulation model should match expected evacuation routes and volumes. The licensee should describe its method of route selection and calibration of DTA algorithms used in the analysis.

3.3 Intersection Control

The efficiency of roadway networks is frequently constrained by intersection capacity, which is influenced by intersection control. Important characteristics of intersections include the number of approach lanes for through traffic, left and right turn lanes, and effective green time, which is the time used by vehicles to enter the intersection at the saturation flow rate. The ETE study should discuss how intersection characteristics are represented in the evacuation model. A list should be provided that includes the total number of intersections modeled with unsignalized control (e.g., stop signs), signalization, or traffic control personnel who physically direct traffic.

When developing the ETE, the licensee should contact local agencies to understand whether special signal timing plans exist for emergency conditions. If these emergency condition timing plans exist, and are current, this information should be used in the analysis. The licensee should describe in detail the approach to modeling intersections. In particular, this description should include the signal cycle timing, green time allocation to the constituent approaches, and other control variables such as whether signals work within a coordinated corridor or are coordinated across the network.

A key objective of traffic modeling is to best represent the expected traffic flow under evacuation conditions. The analysis approach should not attempt to optimize traffic flow through intersections. All signalized intersections should be included in the traffic simulation modeling; however, it is not practical or necessary to obtain individual traffic signalization timing for every intersection, because signal timing often changes throughout the day depending on traffic flow. Traffic simulation modeling should consider the following types of intersections:

- unsignalized
- fixed time signals
- actuated signals
- manned traffic controlled intersections

Unsignalized intersections, such as those featuring stop or yield control, must be included. Fixed time signals provide a constant effective green time through the intersection for the primary and secondary roadways, and these timing durations may vary by time of day. The licensee may assume that all fixed time signals within a jurisdiction operate under similar timing conditions. Representative signal timing will need to be developed and may be determined by obtaining signal timing during the field survey of a representative set of signals or may be obtained from discussions with local transportation engineers. It is important that the fixed timing signal locations and timing be included in the analysis because it is likely that these will

continue to operate as fixed timing signals unless augmented by traffic control personnel. The ETE study should include a description of the approach used to determine the fixed signal timing.

Actuated signals are more complex as they allocate green time based on the level of demand at each intersection approach, and the signal timing varies depending on approach volumes. One method for modeling actuated signals is to allocate green time based on the level of demand flow between the primary and secondary cross streets to simulate saturated conditions in each direction. This method can effectively address the actuated signal conditions. The licensee should document its approach to modeling actuated signal control. The ETE study should also discuss any nonstandard intersection designs or intersection control assumptions modeled that do not represent field conditions.

Manned traffic controlled intersections are those locations where traffic control personnel will be stationed during the evacuation to support traffic movement through the intersection. One method for modeling manned traffic controlled intersections is to treat these as actuated signals and adjust the signal timing to reflect more efficient operations. The licensee may assume that traffic control personnel will attempt to move traffic through the intersection in a way similar to that of an actuated signal by reducing the lost time of through traffic and turning traffic. Other types of traffic control points (TCPs), such as access control points specific to reentry into the EPZ or to limit crossing into the EPZ (or a specific ERPA) to avoid looting and other crimes (sometimes referred to as “Lockdown TCPs” or “Security TCPs”), are typically manned later when National Guard or other resources become available. These types of access control points do not need to be explicitly modeled as part of the ETE. See Section 2.5.3, “Background and Pass-Through Traffic” for assumptions on access control points.

In general, the licensee may assume that manned traffic-controlled intersections operate as efficiently as signalized intersections. The use of officers to direct traffic during an evacuation represents a decision to employ resources that may be required for other purposes during an emergency. Where MTC is assumed, green time allocation along the primary direction may be extended on the order of 200 seconds and should be randomized to capture variability in cycle length. The licensee may assume that MTC will not be used at the tail end of the evacuation (final 10 percent of evacuees).

If the licensee uses simulation models that adjust the signal cycle length within a single model run, then the ETE study should discuss the process to adjust the cycle timing. The licensee should clearly state if signal timing is adjusted within the model for all intersections, for actuated signals, and for intersections manned by response personnel to direct traffic.

3.4 Adverse Weather

The adverse weather condition is intended to represent weather conditions that are probable within the region. The licensee need not evaluate those adverse weather conditions that may occur at frequencies of 100 years or longer. The reduction factors in Table 3-1 may be used for the adverse weather conditions. Impacts of adverse weather can vary based on the region and familiarity of the drivers with the weather condition; therefore, the factors in Table 3-1 are guidance and may be adjusted based on local conditions.

Table 3-1 Weather Capacity Factors

Weather Condition	Roadway Capacity	Speed
Normal	100%	100%
Adverse – Rain/Light Snow	90%	90%
Adverse – Heavy Snow	75%	85%
Adverse – Fog	90%	85%

The values in Table 3-1 for rain and snow are derived from Chapter 10 of the HCM, Exhibit 10-15 (TRB, 2010) and the Federal Highway Administration study, "Identifying and Assessing Key Weather-Related Parameters and Their Impacts on Traffic Operations Using Simulation" (FHWA, 2004b).

The licensee should also consider the effect of adverse weather on mobilization. For heavy snow scenarios, snow removal equipment may be necessary to clear access roads for the evacuation. The time for snow removal crews to mobilize and clear snow should be considered in the trip generation time developed for the site. Frequently, municipal snow removal equipment is operating during snowfall to maintain access; thus, this may not have much impact on time elements. The trip generation time may need to include the time taken by residents to clear their driveways of snow.

For microsimulation, the capacity and speed reductions of Table 3-1 do not apply directly to the models. The ETE study should discuss the calibration of software-specific models to account for driver behavior in adverse weather. The FHWA Traffic Analysis Tools program developed a module titled "Traffic Analysis Toolbox Volume XI: Weather and Traffic Analysis, Modeling and Simulation," to guide traffic engineers and transportation operations managers in analyzing and modeling weather impacts on highway traffic movement (FHWA, 2010a). The module includes a summary of the effects of adverse weather that have been observed on traffic stream parameters (e.g., roadway capacity, volume, free-flow speed, and speed at capacity). Free-flow speed reductions between 2 to 9 percent for rain and 2 to 36 percent for snow have been observed. Similarly, reductions in roadway capacity of approximately 4 to 30 percent and 3 to 27 percent have been observed in rain and snow, respectively. In addition, effects at the intersection level were quantified as impacts to saturation flow, saturation headway, and lost startup time (i.e., time taken by the first few vehicles to react to the start of a green phase and to accelerate from a stopped position) as shown in Table 3-2 (FHWA, 2010a).

Table 3-2 Inclement Weather Impacts on Traffic Flow

Typical Impacts	Weather Event	
	Rain	Snow
Capacity	-4 ~ -30%	-3 ~ -27%
Volume	-20%	-6 ~ -26%
Speed at Capacity	-8 ~ -14%	-5 ~ -19%
Saturation Flow	-2 ~ -6%	-4 ~ -21%
Lost Startup Time	+7.6 ~ 31.5%	+18.5 ~ 65.2%
Saturation Headway	+2.5 ~ 13.2%	+4.4 ~ 30.9%
Free-Flow Speed	-2 ~ -9%	-3 ~ 36%

The FHWA study, “Microscopic Analysis of Traffic Flow in Inclement Weather – Part 2,” quantified the impacts of icy roadway conditions on driver car-following behavior (FHWA, 2010b). If included in the ETE analysis, icy conditions should be evaluated as an adverse weather scenario provided that the impact on traffic conditions is within the values listed in Tables 3-1 and 3-2. If the licensee assumes that ice will impact traffic flow more than the values listed in Tables 3-1 and 3-2, then icy conditions should be evaluated as an extreme condition as described in Section 5.4.1, “Extreme Conditions.”

4 DEVELOPMENT OF EVACUATION TIMES

This section describes how evacuation preparation activities are developed and quantified and how to present the ETE modeling methods and data to facilitate review (i.e., the inputs and outputs of traffic simulation models). The ETE supports protective action recommendations (PARs) and decisions and reflects the response of the public to evacuation orders. It is therefore important to understand that ETEs that overestimate or underestimate the evacuation time are not helpful in making the best protective action decision. This approach differs from traditional traffic analyses, which are often conservative. During evacuations, a small percentage of the population takes longer to evacuate; analyses often refer to these people as the "evacuation tail." The evacuation tail generally consists of the last 10 percent of evacuees. Planning is in place to evacuate 100 percent of the public; however, PARs and decisions should be based on the 90 percent ETE values. For this reason, the licensee develops ETEs for evacuation of 90 and 100 percent of the EPZ population. The 90 percent value informs decision makers of the estimated time to evacuate the vast majority of the public, and the 100 percent ETE informs decision makers on the likely time to fully evacuate the EPZ.

The licensee will use the ETE when developing procedures that support making offsite PARs, and OROs should use the ETEs when developing offsite protective action strategies. The level of data required to develop an ETE study necessitates that the analyst interact directly with State and local agencies and facilities such as hospitals, and schools, to obtain current and relevant information needed to support the calculations.

4.1 Traffic Simulation Models

Traffic simulation modeling is usually conducted to develop the ETE for the general public population group, and analysts that perform this modeling should understand traffic simulation applications. A variety of models and commercial services are available to support a simulation analysis. The DOT-sponsored "Evacuation Management Operations (EMO) Modeling Assessment: Transportation Modeling Inventory" is also available to support selection of an appropriate model for use in evacuation analysis (DOT, 2007). The FHWA toolbox for use in modeling roadway networks is also helpful in the development of traffic simulation (FHWA, 2004a). The FHWA modeling toolbox is intended to support transportation planning and is not specific to evacuations; therefore, appropriate adjustments are necessary.

The DOT and FHWA sources discuss microscopic, mesoscopic, and macroscopic models, any of which may be appropriate for use. As the number of commercially available models and professional services to develop ETEs increases, it is important that only models that have been demonstrated for use in the development of ETEs or in assessing transportation networks be used in the development of ETEs. The ETE study should provide general information about the model, including prior use in the development of ETE studies for NPPs or other applicable commercial or government applications. The analyst also needs to understand the analysis tools and the sensitivities of input parameters. If the licensee develops an ETE without the aid of a traffic simulation model, such as for a sparsely populated site, then the analytical approach should be consistent with this section, and the study should include the detailed information requested, as applicable.

The use of traffic simulation modeling in the development of ETEs provides the ability to assess evacuation of EPZs in great detail. Because models produce results using embedded algorithms and input data, it has become more difficult to review the analysis. In "The

Sensitivity of Evacuation Time Estimates to Changes in Input Parameters for the I-DYNEV Computer Code" (NRC, 1988b), the NRC identified several parameters as sensitive, meaning that when these parameters were adjusted, the resulting ETE was noticeably affected. The study underscores the importance of the model input values. Sensitive parameters identified in that NRC study include the following:

- number of vehicles—evacuation times increase approximately linear to the increase in population
- roadway capacity—changes in roadway capacity affect the evacuation time in a linear manner
- trip generation time—evacuation times are sensitive to the trip generation time. When delays due to congestion are minimal, evacuation times will increase in a linear manner with trip generation time

In NUREG/CR-7269, "Enhancing Guidance for Evacuation Time Estimate Studies," (NRC, 2020), the NRC examined in detail the sensitivity and importance of various modeling parameters for three representative site models typifying small (fewer than 50,000 evacuees), medium (50,000 to 200,000 evacuees), and large (greater than 200,000 evacuees) EPZ populations. The representative site models are also characterized by features of the transportation network that can influence evacuation dynamics because of differences in capacity between rural, coastal, and urban locations. The methodology for the development of the three representative models and the analyses of the outputs produced insights, observations, and conclusions that support the following:

- an enhanced understanding of the impact of shadow evacuations
- an understanding of the impact of model extent on ETEs and potential travel conditions beyond the EPZ
- a quantified understanding of the utility of manual traffic control
- a quantified understanding of select parameters of importance

The key findings from this study reinforce the fundamental relationship between supply and demand in transportation systems and provide an understanding of how parameters affecting network performance can vary in both time and space. Additionally, this study informed the use of microscopic simulation models and the importance of various model outputs to facilitate review of model performance (NRC, 2020).

For EPZs where the population density is low and there is minor congestion, the travel time element of the evacuation may be brief, and the total ETE may be very close to the trip generation time (NRC, 1988b; NRC, 2020). For sites with higher population density where there is congestion and travel is slowed during the evacuation, the travel time may be influenced more by the ratio of demand to capacity (v/c ratio) than by the trip generation time (NRC, 2020).

Traffic simulation modeling is an improved approach over simplistic comparisons of demand to capacity for the complex analyses required for an ETE, and it is necessary to develop these models in a transparent manner. For this reason, the NRC has identified measures of effectiveness (MOEs) useful for evaluating ETE traffic simulation model output (NRC, 2020). Volume VI, "Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness," of the FHWA Traffic Analysis Toolbox (FHWA, 2007) contains additional guidance for the definition, interpretation, and computation of MOEs for traffic operations.

4.2 Traffic Simulation Model Input

The licensee should provide traffic simulation model assumptions and input parameters to support the analysis, including a set of model inputs containing at least the following:

- roadway capacity values or driver behavior models
- free-flow speeds
- total vehicles entering the network
- vehicle occupancy (persons per vehicle)
- time based vehicle loading curves
- placement and number of origin nodes
- directional preference
- destination nodes and capacities

The rate of loading at origin nodes can have a significant impact on the ETE. The licensee should be careful not to load too many vehicles from a single origin node. The ETE study should describe the method for determining the number of origin nodes within the model. Chapter 3, "Model Development," of NUREG/CR-7269 provides examples of model input data (NRC, 2020). Because different models may have different definitions for similar variables, the study should include a glossary to support the review. The licensee should also provide a figure that shows the origins, destinations, nodes, links, and evacuation routes as shown in Figure A-1 of Appendix A.

4.3 Trip Generation Time

Preparation activities, including the time to receive the notification and time to prepare to evacuate, are developed as elements of the trip generation time, sometimes referred to as "mobilization time." The trip generation time is then integrated into the calculation of the ETE. The licensee uses the trip generation time to develop the vehicle loading curves. NUREG/CR-6863, "Development of Evacuation Time Estimate Studies for Nuclear Power Plants," (NRC, 2005a) describes the development of trip generation times and includes the following steps:

- identifying the sequence of events
- obtaining data for each event
- developing time distributions for analysis
- summing the distributions
- calculating trip generation times

Each population group has different considerations for trip generation times. Surveys of residents within the EPZ are commonly used to collect some of the data needed to develop the time distributions. When a licensee relies on surveys, the licensee should describe the survey method (e.g., telephone, interview, online poll, etc.), number of participants, and statistical relevance. Trip generation times based on a sample survey of residents are subject to statistical uncertainty. Additionally, temporary conditions within the EPZ (e.g., frequent natural hazards, public health emergencies) may lead to skewed survey results. To minimize the uncertainty in the trip generation time, updates to the ETE may use new and previous sample data for the various population groups and situations that influence the trip generation time. Trip generation times and evacuation logistics should be developed based on assumed normal activities and operations. The data used to develop trip generation times should be summarized

in the ETE study. The licensee should describe the methods used to minimize uncertainty in the development of trip generation times.

Trip generation time becomes an increasingly important component of the ETE as the evacuation demand decreases (NRC, 2020). The ETEs for the transit dependent residents, special facility residents, and schools are each developed separately from those for the general public. The logistics of the trip generation times for these groups can be complex and may affect the ETE more than the actual travel time out of the EPZ.

4.3.1 Permanent Residents and Transient Population

It is important to provide sufficient detail on the logistics of evacuation elements used to develop time values. For example, the permanent resident trip generation time for an event during a normal working day may include the following elements, each of which will have a distribution of times (Urbanik, 2000):

- notification of the public—the period of time to notify the public
- prepare to leave work or other activity—the time between receipt of notification and when individuals actually leave the workplace, stores, restaurants, or other locations
- travel to home—the time it takes to reach home after leaving work or other activity
- prepare to leave for the evacuation—the time to pack and prepare the home prior to leaving, including such activities as removal of snow from driveways, if appropriate

The licensee can assume that permanent residents evacuate from their home but should not assume that permanent residents are home at all times. The notification element of the trip generation time for the transient population should consider areas where notification of persons may be difficult including campgrounds, hunting or fishing areas, parks, or beaches. As visitors to the EPZ, this population group will have a “prepare to leave work or other activity” element in which individuals may return to hotels before evacuating. Where special events that draw large numbers of transients use transportation resources such as park-and-ride services, the licensee should discuss the logistics of such activities. The trip generation time for the transient population is integrated with that of the general public to support the loading of the transportation network.

4.3.2 Transit Dependent Permanent Residents

Transit dependent residents include ambulatory people who are mobile and nonambulatory people who need assistance. Typically, the local or county emergency management agencies will have emergency plans for evacuation that include the use of public buses along existing bus routes or along special routes for evacuation of the ambulatory transit dependent population. The licensee should use existing plans and bus routes in the ETE analysis when available. If new plans are developed with the ETE, responsible authorities should agree to these new plans. The ETE study should describe the means of evacuating these residents and the number of buses needed to support the demand estimation as previously determined. The licensee should identify the time estimated for transit dependent residents to prepare and then travel to bus pickup points as well as the expected method of travel to the pickup points. Development of the ETE should include confirmation of the type and number of resources available and whether resources are available locally or need to be mobilized from outside the EPZ. The intent is not to physically verify each vehicle but to confirm that commitments are established to provide all of the resources needed. When buses are used, the time needed for residents to prepare and get to the bus stop should be included in the trip generation time.

The trip generation time should address the availability of buses. Municipal buses are generally used throughout the day and may not be immediately available to support an evacuation. Buses may need to complete their normal routes before being available. The licensee should evaluate logistical details such as the time to obtain buses, brief drivers, and initiate the bus route. The ETE study should provide the number of bus stops and the time needed to load passengers to support the bases of the time estimates, as well as a map of bus routes.

The local or county emergency management agencies may also have emergency plans for evacuation of the nonambulatory residents. The evacuation of these residents will require the use of ambulances, wheelchair vans, or other specialized vehicles. The ETE study should identify the location of these resources. The trip generation time should include time to mobilize ambulances or special vehicles, time to drive to the homes of the nonambulatory residents, and loading time.

In calculating the travel time to exit the EPZ, vehicle speeds should be consistent with traffic speeds for the actual route used and should not be based on the average roadway speed for the full EPZ. When there are not enough vehicles to conduct the evacuation in a single trip, the following additional information should be provided:

- location of the destination point
- travel time to the congregate care center or other special facility, as appropriate
- time to unload
- travel time back through the EPZ to pick up additional residents
- travel time to exit the EPZ

The above steps are repeated as necessary until all of the transit dependent residents have been evacuated. In the multiple-trip scenario, the travel speeds may be limited by evacuation traffic and traffic control on portions of the route for both inbound and outbound vehicles.

4.3.3 Special Facilities

The evacuation logistics for special facilities require developing information to establish the time for mobilization of resources, loading of special facility residents, and travel out of the EPZ. Specially trained staff, such as medical support or security support for prisons, jails, and other correctional facilities, may need to be contacted and mobilized along with vehicles and drivers. The licensee should discuss the logistics for mobilizing specially trained staff when appropriate. The ETE study should include information on evacuation logistics for the following:

- time needed to contact the drivers
- time for drivers to arrive at the transit depot
- time for briefing, receipt of radios, fueling of buses, and other actions as applicable
- inbound travel time from the depot to the special facilities

The inbound speeds of vehicles to support the evacuation should consider that traffic control may be in place that may slow inbound traffic. The licensee should establish the time for loading of special facility residents, which may depend on the size of the facility. The ETE study should provide the following information:

- Time for loading of residents. For facilities with a small population, this activity may be performed relatively quickly. For facilities with a larger population that may require the

loading of many vehicles, the details of vehicle queuing and loading should be discussed. The analysis should consider the time to cycle vehicles to the facility entrance to load residents.

- For special facilities, the licensee should identify the number of wheelchair and bedbound individuals and discuss the logistics of evacuating these residents.

The outbound speeds should be developed with consideration of the prevailing traffic conditions at the time and should be obtained from the model output for the specific routes, when available. Information on evacuation of special facilities should be provided in a comprehensive format similar to Table 4-1.

Table 4-1 Special Facilities ETE

Facility	Population	Number/ Type of Vehicles	Mobilization Time	Loading Time	Distance to EPZ Boundary	Travel Time to EPZ Boundary[1]	ETE

Note 1: When return trips are needed, include "Travel Time to Destination."

When the evacuation involves special facilities that require return trips, the destination of the buses must be known to develop the ETE. For special facilities, this may be a hospital, prison, or other facility outside of the EPZ rather than a congregate care center. The ETE study should identify whether a reception center is used in the evacuation and if special facility residents are expected to pass through the reception center before being transported to their final destination. The time elements for subsequent trips should include the following:

- time to travel to the unloading point
- time to unload
- time to travel back to the facility
- time to load the second group
- time to travel out of the EPZ

4.3.4 Schools

The evacuation logistics for schools also require developing information to establish the time for mobilization of resources, loading of students, and travel out of the EPZ. Information on evacuation logistics should be provided for the following:

- time needed to contact the drivers
- time for drivers to arrive at the transit depot
- time for briefing, receipt of radios, fueling of buses, etc., as applicable
- inbound travel time from the depot to the schools

The inbound speeds of buses to support the evacuation should consider that traffic control may be in place that may slow inbound traffic. The ETE study should provide information for the following:

- Time for loading students. For schools with a small population (i.e., a few hundred students), this activity may be performed relatively quickly. For schools with a larger population that may require the loading of many buses, the details of bus queuing and

loading should be discussed. Typically, this would include schools requiring more than 20 buses to arrive and load students at the same time.

The outbound speeds should be developed with consideration of the prevailing traffic conditions at the time and should be obtained from the model output for the specific routes, when available. Information on evacuation of schools should be provided in a comprehensive format similar to Table 4-2.

Table 4-2 Schools ETE

School Name	Population	Number of Buses	Mobilization Time	Loading Time	Distance to EPZ Boundary	Travel Time to EPZ Boundary[1]	ETE

Note 1: When return trips are needed, include "Travel Time to Destination."

When evacuation involves return trips, the destination of the buses must be known to develop the ETE. The ETE study should identify whether a reception center is used in the evacuation and if students are expected to pass through the reception center before being evacuated to their final destination. The time elements for subsequent trips should include the following:

- time to travel to the unloading point
- time to unload
- time to travel back to the schools
- time to load the second group
- time to travel out of the EPZ

4.4 Stochastic Model Runs

Traffic simulation models that use stochastic methods achieve average results based on a number of simulation runs performed with different random number seeds. For each random seed, the model selects a value from the embedded distributions and executes the calculation. Different seed numbers produce different results, and results are presented as an average of the number of runs. In most cases, 10 runs will generate a large enough sample size to produce reasonable results without requiring excessive computational resources or time (FHWA 2004c, 2019); however, such recommendations do not consider the size of the EPZ networks modeled, the exact stochastic variation within the network, or constraints such as time or computational resource limitations (NRC, 2020).

Fewer simulation runs may be acceptable based on the performance of the model and the acceptable tolerance in ETE calculations. Assuming the 90 percent ETE as the most important metric, a statistical calculation can be performed to determine the number of runs needed for each ETE analysis to achieve average results at the 95 percent confidence level:

$$N = \left(\frac{Z \cdot \sigma}{E}\right)^2$$

where:

N is the number of simulation runs required (rounded up)
Z is the Z-score (or T-score with $N - 1$ degrees of freedom) for a two-sided error of 2.5 percent (5 percent total)

σ is the standard deviation of the 90 percent ETE from an initial sample of 10 runs
E is the acceptable error when estimating the mean

The objective of this statistical analysis is to determine if fewer than 10 runs will produce an average result that falls within the confidence interval of the unknown true mean. Assuming a normal distribution and confidence interval of 95th percentile, then Z = 1.96. The acceptable error, E, should be assumed to be equal to 5 minutes when the average 90 percent ETE is less than 180 minutes, or 10 minutes when the average 90 percent ETE is greater than 180 minutes. Volume III of the FHWA Traffic Analysis Toolbox (FHWA, 2019) contains other acceptable methods for computing the minimum number of runs.

A typical ETE study may produce 300-600 unique ETEs depending on the number of scenarios, the size of the EPZ, and the evacuation strategies simulated. Performing 10 stochastic runs for each result would significantly increase the computational resources and time required to develop an ETE study, particularly for very large and complex models. Research shows that the variation of random seeds did not significantly affect the ETEs in three representative models of small, medium and large population sites (NRC, 2020). Because stochastic parameters introduce variability within a limited range, changing random seeds would not be expected to demonstrate any appreciable effects at a large scale (NRC, 2020). Additionally, the variability in ETEs introduced by the use of different scenarios can reasonably be expected to exceed the variability introduced by different random seeds. As such, when computational resources and time are limited, it is acceptable to use one run of a single random seed to produce an ETE. In this case, the licensee should include a sensitivity study and report the variability in the 90 percent and 100 percent ETE using 10 different random seeds for a single scenario: evacuation of the entire EPZ during summer, midweek, daytime, normal weather conditions.

4.5 Model Boundaries

Traffic simulation models are sensitive to initial and boundary conditions. Boundary conditions are important because certain traffic conditions that can propagate upstream could influence traffic within the study area and impact the ETE. In general, the model boundary should extend at least 1 mile beyond the evacuation area under consideration. The shadow region, if included, is typically large enough to capture these downstream influences on traffic exiting the evacuation area.

For travel along minor evacuation routes and for EPZs with less than 50,000 evacuees, ETEs are typically less sensitive to downstream conditions (NRC, 2020). However, in some cases—particularly for EPZs with large populations and limited evacuation routes—it may be necessary to extend the model boundary in localized areas along major evacuation routes to include additional features such as sudden capacity reductions or major population centers as shown in Figure 4-1. For the purpose of ETE studies, major population centers should be considered when the population in the localized area of interest (typically a large city) exceeds 4 times the number of EPZ evacuees. For example, if the number of EPZ evacuees is 75,000, a population center of 300,000 people or more would contribute a significant number of shadow evacuees and additional background traffic. Such features should be included in the model if they exist near the model boundary such that evacuees traveling along a major evacuation route would encounter an abrupt change in traffic conditions, typically within one additional mile of travel. For this reason, the model boundary may need to be extended approximately one mile in the vicinity of the feature of interest as shown in Figure 4-1. The licensee should give practical consideration to the model extent and the level of effort needed to develop reasonable ETEs.

The ETE study should describe the method for establishing the traffic model boundaries. The ETE study should also identify significant capacity reductions or population centers included in the model that may influence the ETE and that are located just beyond the prescribed evacuation area or shadow region.

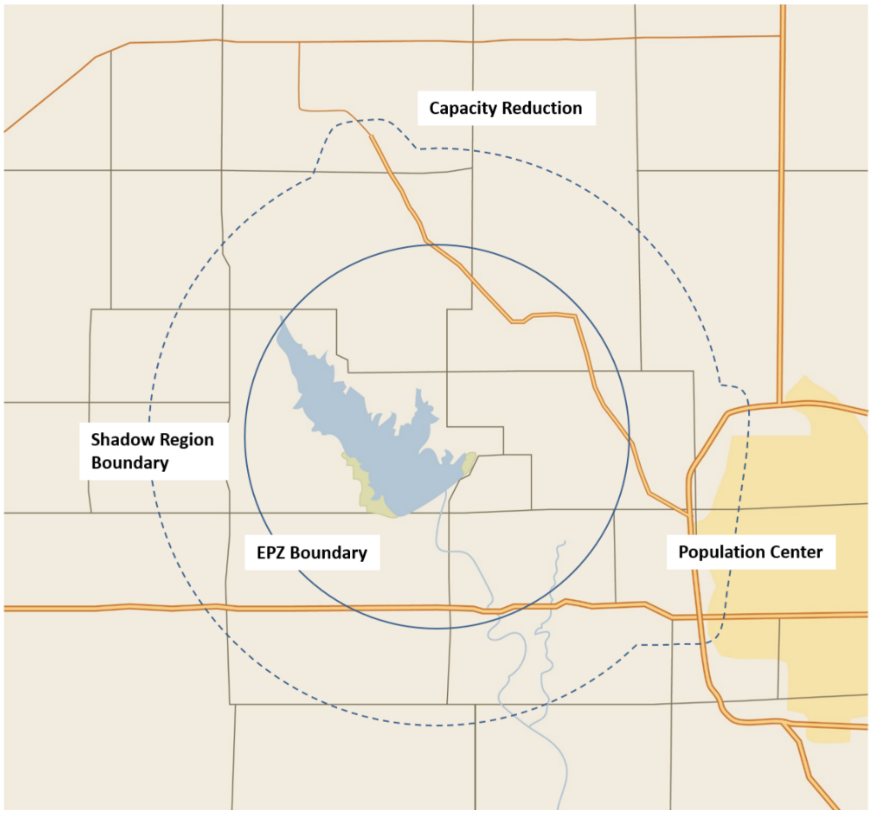


Figure 4-1 Simulation Model Boundary Conditions

4.6 Traffic Simulation Model Output

The licensee should include a discussion of whether the traffic simulation model used in the analysis must be in equilibrium before calculation of the ETE. Equilibrium is established by running a model until the number of vehicles entering the roadway network is equal to the number of vehicles exiting the network. Model output provides the MOEs for the ETE study. Examples of MOEs include traffic-based performance measures such as average travel times, total number of vehicles exiting the system, and queue lengths at various times during the evacuation. At a minimum, the following output should be provided in a table or graphical format (such as a heat map) for the evacuation of the whole EPZ:

- evacuee average travel distance and time
- evacuee average delay time
- number of vehicles arriving at each destination node
- total and percent of vehicles not exiting the network
- a plot that provides both the mobilization curve and evacuation curve identifying the cumulative percentage of evacuees who have mobilized and exited the EPZ
- average speed for each major evacuation route that exits the EPZ

Additional or alternative MOEs may be provided for sites where other performance measures might provide a better view of the traffic conditions and resulting ETEs. Section 3.8, "Base Model Data Collection and Analysis," of NUREG/CR-7269 (NRC, 2020), provides examples of useful MOEs to assess model performance, including average values for representative small, medium, and large population site models.

The licensee should include mobilization curves in plots of evacuation curves to lend insight into the evacuation process. Traffic models may sometimes remove vehicles from the network for a variety of reasons. The ETE study should limit the number of "lost" vehicles to less than about 5 percent. This may vary by scenario and it is acceptable if some conditions experience more lost vehicles provided that the average among scenarios is less than about 5 percent.

For sites where the roadway network and population distribution characteristics are distinctly different and essentially disconnected within the EPZ, it may be beneficial to separate the MOEs for distinct regions within the model. For example, an EPZ bisected by a river may have very distinct population density and transportation networks on either side.

To describe the operational conditions of the roadway network, the level of service (LOS), as defined in the HCM, provides a quality measure. The LOS represents the range of traffic operational characteristics, which are designated as "A" for free-flow operating conditions through "F" for forced-flow or congested operating conditions. The LOS is used to describe the levels of congestion at selected time intervals during an evacuation. The ETE study should provide color-coded graphics identifying areas where congestion exists (e.g., LOS "E" and LOS "F" conditions). These graphics should be provided for various times for a full EPZ evacuation scenario.

4.7 Evacuation Time Estimates for the General Public

The ETE should include the time to evacuate 90 percent and 100 percent of the total permanent resident and transient population of the affected ERPAs and should include an analysis of the staged evacuation protective action. The ETEs for the transit dependent population, special facilities, and schools are developed separately, and only the time to evacuate 100 percent of these population groups is needed.

When developing the 100 percent ETE value for the general public, the licensee should include all members of the general public within the affected ERPAs. Any reductions in trip generation times and truncating of trip generation time values must be explained in detail. Truncation is the reduction in trip generation time values to limit the effect of a very small number of residents who take an excessive amount of time to prepare to evacuate. Existing telephone surveys eliciting data on the expected time needed to prepare to evacuate show that a small number of residents may take considerably longer to evacuate. This extra time can extend an ETE disproportionately with respect to the remaining population. When the licensee has such data, it may adjust or truncate times if it provides a valid basis for doing so.

Stochastic models also present a challenge in determining the 100 percent ETE because not all vehicles may exit the network or the last few vehicles exiting the EPZ may take a disproportionately long time. For computation of the 100 percent ETE, if the evacuation of the final few vehicles in the evacuation tail would create an excessively long ETE because of the randomness of the simulation (e.g., fewer than 10 vehicles remain in the network, but only 1 or 2 vehicles exit every 15 minutes), then the licensee may establish termination criteria for declaring when the 100 percent evacuation is complete before the last vehicle exits. The ETE

study should describe any termination criteria used for determining the ETE if the ETE termination is not based on the time the last vehicle exits the evacuation zone. Additionally, the ETE study should include the number of vehicles not exiting the network.

Traffic simulation model results need to be presented in such a way that they are readily understood and interpreted by decision makers and reviewers of the study. The 90 and 100 percent ETEs should be developed for the following:

- radial zones as appropriate to defined ERPAs, including the complete EPZ, as shown in Table 4-3 (e.g., a 5-mile EPZ would likely contain a 0-2 mile zone and 0-5 mile zone)
- affected ERPAs necessary to support site-specific PAR logic (i.e., staged and keyhole evacuations based on wind direction as shown in Table 4-3 and Table 4-4)

ETE studies should include ETEs based on site-specific PAR logic. The ETE study should provide separate ETE tables for the 90 percent and for the 100 percent evacuation times for the full set of scenarios evaluated. These tables should include the special event ETE, which is based on the demand estimation developed earlier. Scenarios used only to support the development of traffic control planning are not included in these tables but should be documented within the report. The licensee should provide separate ETEs for just the 100 percent evacuation for the transit dependent population, special facilities, and schools.

For staged evacuation scenarios, these tables should follow the format presented in Table 4-3. The ETE tables should show the time needed to complete a staged evacuation for the zones under consideration. For example, this analysis might involve evacuating the 0-2 mile zone while the 2-5 mile zone is under a shelter-in-place order. When about 90 percent of the population from the 0-2 mile zone have exited the 2-mile boundary (according to the 90 percent ETE), the population of the 2-5 mile zone begins to evacuate. During the time required for the population in the 0-2 mile zone to evacuate, the population in the 2-5 mile zone may be assumed to be preparing to evacuate, which may reduce the mobilization time for this area. The residents in the ERPAs beyond 5 miles should be modeled to react as does the population in the 2-5 mile zone (i.e., begin evacuation after the 90 percent ETE has expired for the 0-2 mile zone). Historically, licensees developed keyhole evacuation ETEs for evacuation of the 2-mile zone and 5 miles downwind but not as a staged evacuation. When ETEs are developed for a keyhole evacuation, the format in Table 4-4 is appropriate and 90 and 100 percent values should be provided.

4.8 Resource Assumptions in ETE Studies

Studies of ETEs are not evacuation plans. The ETE is based on an assumed number of available passenger vehicles, buses, ambulances, specialized transport, and other vehicles needed to facilitate an evacuation, along with an assumed number of drivers and other specially trained personnel. In an emergency, the time needed to evacuate will depend on the prevailing conditions and the resources actually available. While this guidance provides a method to ensure realistic estimates of those resources, the ETE does not represent a commitment to maintain those resources. However, the assumed number of vehicles and drivers contained in ETE studies, and the conditions under which those resources were applied to develop an ETE, provides information useful to emergency planners and local authorities for resource planning and for understanding the utility of those available resources during the evacuation process.

Table 4-3 ETEs for a Staged Evacuation

100 Percent Evacuation of Affected Areas											
Affected ERPAs	Scenario	Summer				Winter				Roadway Impact	Special Event
		Midweek Daytime		Weekend Daytime	Midweek Weekend Evening	Midweek Daytime		Weekend Daytime	Midweek Weekend Evening	Midweek Daytime	
	Number	1	2	3	4	5	6	7	8	9	10
	Weather	Normal	Adverse	Normal	Normal	Normal	Adverse	Normal	Normal	Normal	
	2-mile zone										
	5-mile zone										
	10-mile zone										
Evacuate 2 to 5 miles downwind											
N											
NNE											
NE											
ENE											
E											
ESE											
SE											
SSE											
S											
SSW											
SW											
WSW											
W											
WNW											
NW											
NNW											

Table 4-4 ETEs for a Keyhole Evacuation

100 Percent Evacuation of Affected Areas											
Affected ERPAs	Scenario	Summer				Winter				Roadway Impact	Special Event
		Midweek Daytime		Weekend Daytime	Midweek Weekend Evening	Midweek Daytime		Weekend Daytime	Midweek Weekend Evening	Midweek Daytime	
	Number	1	2	3	4	5	6	7	8	9	10
	Weather	Normal	Adverse	Normal	Normal	Normal	Adverse	Normal	Normal	Normal	
Evacuate 2 mile zone and 5 miles downwind											
N											
NNE											
NE											
ENE											
E											
ESE											
SE											
SSE											
S											
SSW											
SW											
WSW											
W											
WNW											
NW											
NNW											

5 OTHER CONSIDERATIONS

The preceding sections describe the methodology and approach to calculating the ETE. In addition to the calculation of an ETE, the licensee should address other considerations in the ETE study. These considerations are described below and should be included as appropriate.

5.1 Development of Traffic Control Plans

Traffic simulation modeling in support of the ETE analysis can be used in the development of traffic control plans to support an evacuation. An ETE study provides an opportunity to model the EPZ with variations of traffic control to best effect the evacuation with the resources available. When a new traffic control plan shows improvement in evacuation times, responsible authorities should approve the new plan if it is to be used in the ETE analysis. The ETE study should include a discussion of adjustments or additions to the traffic control plan.

5.2 Enhancements in Evacuation Time

The ETE analysis is a tool that can be used to identify recommendations for enhancements to evacuation strategies. When evaluating potential enhancements that may reduce evacuation times, the licensee may limit the evaluation to those roadways or sections of the EPZ that have the greatest impact on the ETE. This evaluation may include intersections and roadway segments where significant congestion occurs for some period of time. The NRC does not expect every intersection or roadway segment to be evaluated. The licensee should describe the process used to select the intersections or roadway segments for evaluation.

The study of ETEs in NUREG/CR-7269 gives insight into the impact that traffic model supply and demand parameters have on the ETE for sites with small, medium, and large populations and may serve as a starting point for examining site-specific sensitivities (NRC, 2020). The licensee should address potential enhancements with a discussion of the results of each evaluation. The results should include the reduction in evacuation time observed in the modeling output or the expected reduction in evacuation time for suggested enhancements. Examples include the following:

- Identify opportunities to increase intersection throughput, such as turn restrictions.
- Identify opportunities for reducing the trip generation time.
- Identify opportunities for reducing the evacuation tail.

The use of manual traffic control (MTC) at intersections, in particular, could benefit from an ETE analysis. Research shows that the use of officers in the field to control traffic should be limited to key locations where it is believed that MTC would be useful and can be readily implemented (NRC, 2020). Extensive use of manned traffic control at intersections does not appear to have advantage over automated traffic control (NRC, 2020). Research also shows that MTC may result in long queues, which in urban regions with closely spaced intersections may result in localized gridlock and longer ETE times (NRC, 2020). However, MTC does have utility for loading a network rather than controlling the flow of traffic through intersections. As such, it may be important to include a representation of MTC at locations where large groups of vehicles would be joining the network (e.g., sporting events, church parking lots, major employers). The results of the identified potential enhancements should be presented to the local authorities for their consideration.

5.3 State and Local Review

The licensee needs to interact with State and local agencies to obtain local and regional data, understand the operations and resources of the emergency response capabilities, and understand the traffic management system. The ETE should list those agencies that the licensee contacted and briefly describe the extent of interaction with these agencies as related to the development of the ETE. Any issues that may affect the ETE should be discussed and resolved. This will ensure that appropriate agencies, such as those providing traffic control or resources to support the evacuation, are aware of the ETE strategies, issues, and assumptions.

5.4 Reviews and Updates

Emergency planners depend on an accurate ETE analysis to support evacuation decisions. Therefore, the licensee should review the ETE periodically to identify changes that may have occurred. When population increases occur that cause ETE values to significantly increase, the licensee must update the ETE analysis in accordance with the requirements of Section IV of Appendix E to 10 CFR Part 50. Licensees must provide an updated ETE analysis to the NRC within 365 days of:

1. The availability of U. S. Census Bureau decennial census data; and,
2. When a population increase within the EPZ causes certain ETE values to increase by 25 percent or 30 minutes, whichever is less.

The reference start date of the decennial census of the United States is April 1 in years ending in zero. The census data collected are typically released 1 year later, and updates to the ETE analysis are required within 365 days of the availability of the decennial census data. Licensees may also be required to update the ETE study during the decennial period following the decennial census update. The "decennial period" is the period of time from the date the updated ETE analysis is required to the reference start date of the next decennial census. Figure 5.1 illustrates an example census timeline and the start and end of the decennial period.

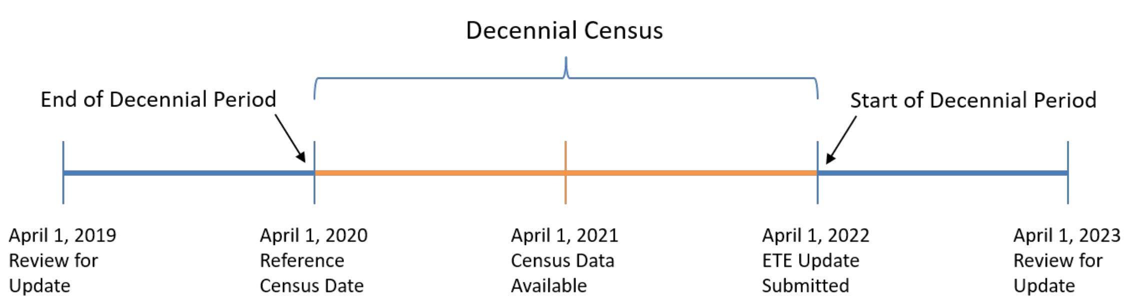


Figure 5-1 Example Timeline for the ETE Decennial Update and Start and End of the Decennial Period

Under Section IV.5 of Appendix E to 10 CFR Part 50, licensees must estimate EPZ permanent resident population changes at least annually during the decennial period using U.S. Census Bureau data and, if available, state and local government population data. These estimates must occur no more than 365 days apart. Licensees must keep these estimates available for NRC inspection during the period between censuses and submit these estimates to the NRC with any updated ETEs. ETE studies should include the release date of the most recent census data.

If at any time during the decennial period, the population increases so that the ETE for the 2-mile zone or 5-mile zone, including all affected ERPAs, or for the entire EPZ, increases by 25 percent or 30 minutes, whichever is less, for the scenario with the longest ETE, Section IV.6 of Appendix E to 10 CFR Part 50 requires the licensee to update the ETE analysis to reflect the impact of that population increase. Licensees should perform a population sensitivity study during development of the ETE to determine the population value that will cause ETE values to increase by 25 percent or 30 minutes, whichever is less. The sensitivity study should be performed and included with the baseline ETE. For example, assume the sensitivity study shows that an increase of 25 percent or 30 minutes occurs with a permanent resident population increase of 10,000 people. The licensee would review the EPZ population annually and when an increase of 10,000 people occurs, an updated ETE analysis will be developed and submitted within 365 days. Licensees can assume that the roadway infrastructure and capacity values, trip generation times, and transient populations are unchanged from the baseline ETE analysis when performing the population sensitivity study.

The NRC will use the evaluation criteria in Appendix B, "Evacuation Time Estimate Evaluation Criteria," during the reviews of the updated ETE analyses to confirm their completeness. Under Sections IV.4 and IV.6 of Appendix E to 10 CFR Part 50, each licensee is required to submit updated ETE analyses to the NRC at least 180 days before the licensee uses them to form protective action recommendations or provide them to offsite authorities for use in developing offsite protective action strategies.

5.4.1 Extreme Conditions

In the unlikely event that the conditions of an EPZ change significantly because of major construction projects, persistent conditions as a result of natural phenomena, or for other reasons, such as a bridge collapse on a primary evacuation route, the licensee should update the ETE analysis if a sensitivity study is not already included in the ETE study. The updated ETE is necessary to account for the current state of the EPZ when these changed conditions are expected to persist for at least a few months, as it may take that long to develop an update. The impact of planned activities, such as minor construction or infrastructure projects, are assessed as part of the roadway impact scenario and are expected to have compensatory measures in place such that the activities do not significantly affect the ETE. Therefore, the extreme condition updates are intended to apply only for changes within an EPZ that are not captured in the scenario variations. An update prepared to satisfy the extreme conditions criteria does not need to include a full revision to the ETE analysis, but rather should provide a sensitivity study on those extreme condition elements that affect the ETE. The licensee should share the update with appropriate OROs.

5.5 Reception Centers and Congregate Care Centers

Evacuation planning includes the use of congregate care centers, which are temporary shelter facilities for evacuees. Reception centers are used along with congregate care centers in the evacuation process. Reception centers are facilities where evacuees are registered, and if necessary, screened for potential contamination before going to a congregate care center. Evacuees do not stay at reception centers. Reception centers and congregate care centers are located outside of the EPZ, which may be an important factor in the ETE analysis. Schoolchildren, transit dependent residents, and people with disabilities and those with access and functional needs may be bused to reception centers for screening, and then bused to congregate care centers or other special facilities that provide appropriate care. These activities

occur outside the EPZ and are not factored into the time estimates except in those cases where buses must return to the EPZ to make subsequent evacuation trips.

When return trips are needed for buses or other vehicles, the location of these facilities and logistics of offloading passengers before returning to the EPZ will directly affect the evacuation time. These logistics include such actions as unloading vehicles, screening the passengers, reloading the vehicles, and traveling to the congregate care center, as appropriate. A map identifying the location of congregate care centers and reception centers, if used, should be provided. The ETE study should discuss the assumptions for the time necessary for buses to return to the EPZ to start the next wave of evacuation. If the licensee assumes that passengers are left at the reception center and taken by separate buses to the congregate care center, then this should be clearly stated and consistent with the local emergency planning.

5.6 New Reactors

New reactors may be constructed at sites with existing reactors where emergency response programs are established, or they may be built on green field sites where such programs are not in place. For sites with existing emergency response programs, the ETE analysis developed for the new reactor should address any impacts that the new reactor may have on the evacuation time. Considerations include addressing the number of workers and suppliers at the site during the peak construction period. The addition of employees and support staff who may reside within the EPZ as well as potential growth throughout the EPZ during the construction phase is also a consideration. Generally, the support provided by local emergency response organizations has been established, and development of an ETE should include confirming the availability of any additional resources needed. For green field sites, the ETE analysis should be coordinated with the development of the emergency response program including evacuation plans and locations of congregate care centers being prepared during the licensing phase, as appropriate. Assumptions used in the ETE must be consistent with the assumptions and proposed resources and infrastructure identified within the emergency response plan to provide an accurate time estimate. ETEs for new reactor applications should be based on the most recent decennial census data projected to the year the license application will be submitted. A staged evacuation should be evaluated for initial PAR development as described in Section 1.4.2, "Staged Evacuation."

A holder of a combined license under 10 CFR Part 52 must conduct at least one review of any changes in the population of its EPZ at least 365 days before the licensee's scheduled fuel load. If the population increase criteria of Section IV.7 of Appendix E to 10 CFR Part 50 have been met, the licensee must update the ETE analysis to reflect the impact of the population increase. After beginning operations, the licensee must comply with NRC regulations concerning the frequency of ETE reviews and updates as for any other operating licensee.

5.7 Early Site Permits

The ETE developed in support of an early site permit (ESP) that includes complete and integrated emergency plans should consider all of the elements identified in this guidance document. An ETE submitted as part of major features of a plan should also consider all of the elements in this guidance. The ESP applicant should provide data and information to support current conditions and projected conditions through construction of the NPP. The ETE study can use assumptions to augment specific elements that are not yet defined, such as the location of congregate care centers. Any significant impediments that affect evacuation times should be identified. A combined license applicant should update data and information, as appropriate, to

ensure that up-to-date information is used to develop the ETE when a combined license application, which incorporates an ESP, is submitted. ETEs for ESPs should be developed based on the most recent decennial census data projected to the year the ESP will be submitted. An ETE update for the new reactor identified within the ESP is not needed unless a combined license is issued for that reactor. The licensee must then perform updates as directed in Section 5.6 for new reactors.

An ETE analysis may also be used to determine whether there are any physical characteristics of a proposed site that could pose a significant impediment to the development of emergency plans. An ETE used solely to support evaluation of the siting criteria of 10 CFR 100.20(a), 10 CFR 100.21(g) or 10 CFR 52.17(b)(1) does not need to consider all the scenarios identified in this guidance. Assumptions about population based on a single representative scenario—such as summer, daytime, midweek—are sufficient to identify any unique site characteristics. The licensee should consider special conditions that would persist, such as expected extended periods of heavy snow, and include additional scenarios as appropriate. At a minimum the ETE analysis should consider the following elements:

- permanent resident and transient populations
- factors that would affect trip generation time (such as adverse weather, special facilities with longer mobilization times or specialized transportation resources)
- roadway impact scenarios for critical infrastructure such as a bridge on a major evacuation route

For assessing physical characteristics of the proposed site, the licensee may use a representative single trip generation time for the permanent resident and transient population. Mobilization times should be adjusted based on known influencing factors specific to the site. The ETE study should identify permanent facilities or special populations that may have longer than average mobilization times. Development of mobilization times for various populations and scenarios is necessary when developing an ETE that will be used to inform protective action strategies. The ETE developed in support of an ESP that includes major features or complete and integrated emergency plans, should consider all of the elements identified in this guidance document for estimating trip generation times.

6 GLOSSARY

Demand Estimation – The total number of evacuees by population group. Vehicle occupancy is used to express demand as the total number of vehicles per population group.

Emergency Response Planning Areas (ERPAs) – Defined areas that constitute the EPZ and for which emergency response plans have been developed. These areas are typically defined by geographic or political boundaries to support emergency response planning and may also be referred to as subareas, protective action areas, or other local terms.

Evacuation Tail – A small portion of the population that takes a longer time to evacuate than the rest of the general public and is the last to leave the evacuation area. The tail generally conforms to about the last 10 percent of the population.

Keyhole Evacuation – An evacuation of a radial zone around an NPP and the affected downwind sectors within the EPZ, forming a keyhole configuration.

Link – A segment of roadway between two nodes.

Loading Curve – The rate at which vehicles are entered onto the roadway network.

Measure of Effectiveness (MOE) – Statistics used to describe performance. As applied in this document, these include output data that provide key performance characteristics of the roadway network and the evacuation time.

Node – An identification designator used to connect links in a roadway network model or to apply input data onto the network. Nodes are at intersections, ramps, and other junctions, have characteristics such as traffic control, and may be used as input points to assign loading of vehicles.

Permanent Resident – All people having a permanent residence in the area.

Roadway Capacity – The maximum rate at which vehicles can be reasonably expected to traverse a point or uniform section of roadway during a given time period under prevailing conditions.

Shadow Evacuation – Evacuation of persons from areas outside any officially declared evacuation zone.

Special Event – An activity at which large transient populations are present for a limited period of time.

Special Facilities – Facilities where residents are confined or dependent on facility personnel for transportation, including nursing homes, assisted living centers, hospitals, jails, prisons, and other similar facilities.

Staged Evacuation – A protective action in which one area is ordered to evacuate while adjacent areas are ordered to shelter in place until ordered to evacuate.

Transient Population – Tourists, shoppers, employees, and others who do not reside within the EPZ, and other people temporarily visiting the EPZ.

Trip Generation Time – Time elapsed for each population group from when the evacuation order was disseminated until the time when the evacuation trip actually begins (e.g., when the car leaves the driveway).

Vehicle Occupancy – The number of persons per vehicle.

7 REFERENCES

Department of Transportation (DOT). "Evacuation Management Operations (EMO) Modeling Assessment: Transportation Modeling Inventory," Research and Innovative Technology Administration (RITA) Intelligent Transportation System Joint Program Office, October 2007. (DOT, 2007).

Federal Highway Administration (FHWA). FHWA Publication No. FHWA-HRT-04-039, "Traffic Analysis Toolbox Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools," July 2004. (FHWA, 2004a).

Federal Highway Administration (FHWA). FHWA Publication No. FHWA-HRT-04-131, "Identifying and Assessing Key Weather-Related Parameters and Their Impacts on Traffic Operations Using Simulation," September 2004. (FHWA, 2004b).

FHWA. FHWA Publication No. FHWA-HRT-04-040, "Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software," July 2004. (FHWA, 2004c).

FHWA. FHWA Publication No. FHWA-HOP-08-054, "Traffic Analysis Toolbox Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness," January 2007. (FHWA, 2007).

FHWA. FHWA Publication No. FHWA-JPO-11-019, "Traffic Analysis Toolbox Volume XI: Weather and Traffic Analysis, Modeling and Simulation," December 2010. (FHWA, 2010a).

FHWA. FHWA Publication No. FHWA-JPO-11-020, "Microscopic Analysis of Traffic Flow in Inclement Weather - Part 2," December 2010. (FHWA, 2010b).

FHWA. FHWA Publication No. FHWA-HRT-13-026, "Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation," March 2014. (FHWA, 2014).

FHWA. FHWA Publication No. FHWA-HOP-18-036, "Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software 2019 Update to the 2004 Version," April 2019. (FHWA, 2019).

Institute for Environmental Studies (IES), University of Toronto. "The Mississauga Evacuation Final Report," June 1981. (IES, 1981).

Nuclear Regulatory Commission (NRC). NUREG-0654/FEMA-REP-1, Rev. 1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," November 1980. (NRC, 1980).

NRC. NUREG/CR-4873, PNL-6171, "Benchmark Study of the I-DYNEV Evacuation Time Estimate Computer Code," June 1988. (NRC, 1988a).

NRC. NUREG/CR-4874, PNL-6172, "The Sensitivity of Evacuation Time Estimates to Changes in Input Parameters for the I-DYNEV Computer Code," June 1988. (NRC, 1988b).

NRC. NUREG/CR-4831, PNNL-7776, “State of the Art in Evacuation Time Estimate Studies for Nuclear Power Plants,” March 1992. (NRC, 1992).

NRC. NUREG/CR-6863, SAND2004-5900, “Development of Evacuation Time Estimate Studies for Nuclear Power Plants,” January 2005. (NRC, 2005a).

NRC. NUREG/CR-6864, SAND2004-5901, “Identification and Analysis of Factors Affecting Emergency Evacuations,” January 2005. (NRC, 2005b).

NRC. NUREG/CR-6953, Vol. I, SAND2007-5448P, “Review of NUREG-0654, Supplement 3, ‘Criteria for Protective Action Recommendations for Severe Accidents,’” December 2007. (NRC, 2007).

NRC. NUREG/CR-6981, SAND2008-1776P, “Assessment of Emergency Response Planning and Implementation for Large Scale Evacuations,” October 2008. (NRC, 2008a).

NRC. NUREG/CR-6953, Vol. II, SAND2007-4195P, “Review of NUREG-0654, Supplement 3, ‘Criteria for Protective Action Recommendations for Severe Accidents – Focus Groups and Telephone Survey,’” October 2008. (NRC, 2008b).

NRC. NUREG-0654/FEMA-REP-1, Rev. 2, “Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants,” December 2019. (NRC, 2019a).

NRC. Management Directive 8.4, “Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests,” September 2019. (NRC, 2019b).

NRC. NUREG/CR-7269, “Enhancing Guidance for Evacuation Time Estimate Studies,” March 2020. (NRC, 2020).

Transportation Research Board (TRB). *Highway Capacity Manual*, National Research Council, Washington DC, 2010. (TRB, 2010).

Urbanik, Thomas. “Evacuation Time Estimates for Nuclear Power Plants,” Journal of Hazardous Materials, Vol. 75, pp. 165-180, 2000. (Urbanik, 2000).

APPENDIX A
ROADWAY NETWORK CHARACTERISTICS

The development of an evacuation time estimate (ETE) requires detailed data on the characteristics of the existing roadways within the emergency planning zone (EPZ). ETE studies typically include hundreds of links and nodes for an analysis. This information is used in the calculations to support roadway capacity calculations that influence the ETE. The ETE study should include a map of the modeled roadway network similar to Figure A-1. The figure should be divided into grids as needed to show detail and legible values for nodes and links as shown in Figure A-2.

Figure A-1 Roadway Network Identifying Nodes and Links

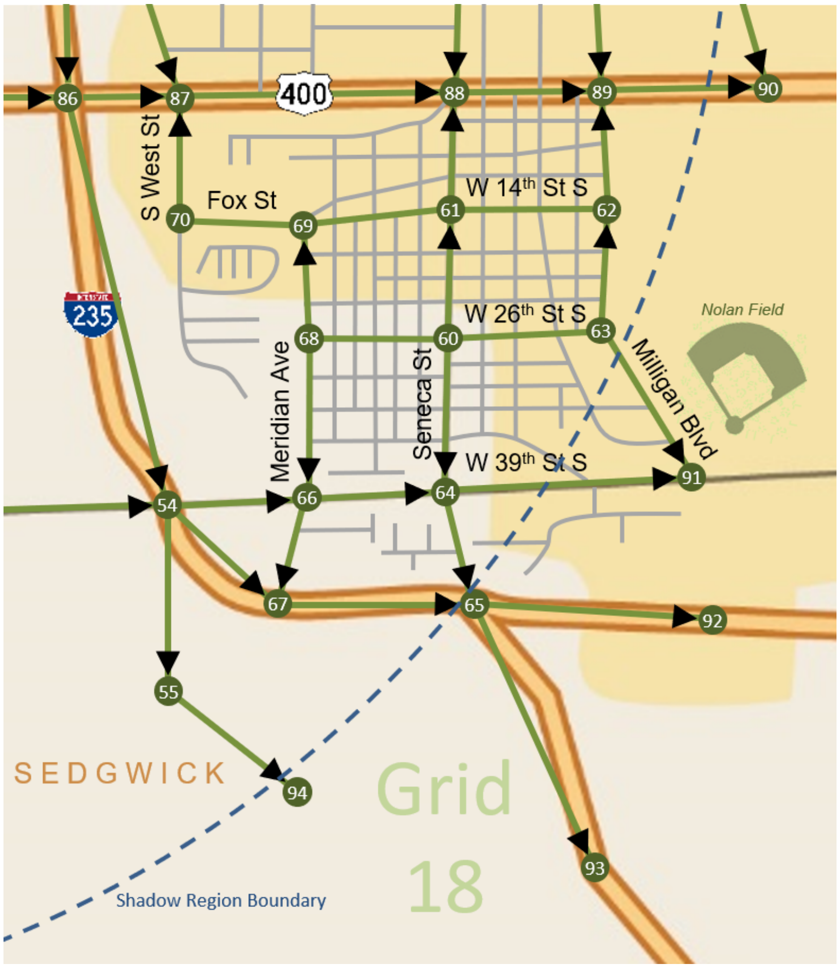


Figure A-2 Grid Map Showing Detailed Nodes and Links

APPENDIX B
EVACUATION TIME ESTIMATE EVALUATION CRITERIA

Table B-1 ETE Review Criteria Checklist

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
1.0 Introduction		
a. The emergency planning zone (EPZ) and surrounding area is described.		
b. A map is included that identifies primary features of the site including major roadways, significant topographical features, boundaries of counties, and population centers within the EPZ.		
c. A comparison of the current and previous ETE is provided including information similar to that identified in Table 1-1, "ETE Comparison."		
1.1 Approach		
a. The general approach is described in the report as outlined in Section 1.1, "Approach."		
1.2 Assumptions		
a. Assumptions consistent with Table 1-2, "General Assumptions," of NUREG/CR-7002 are provided and include the basis to support use.		
1.3 Scenario Development		
a. The scenarios in Table 1-3, "Evacuation Scenarios," are developed for the ETE analysis. A reason is provided for use of other scenarios or for not evaluating specific scenarios.		
1.4 Evacuation Planning Areas		
a. A map of the EPZ with emergency response planning areas (ERPAs) is included.		
1.4.1 Keyhole Evacuation		
a. A table similar to Table 1-4 "Evacuation Areas for a Keyhole Evacuation," is provided identifying the ERPAs considered for each ETE calculation by downwind direction.		
1.4.2 Staged Evacuation		
a. The approach used in development of a staged evacuation is discussed.		

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
b. A table similar to Table 1-5, "Evacuation Areas for a Staged Evacuation," is provided for staged evacuations identifying the ERPAs considered for each ETE calculation by downwind direction.		
2.0 Demand Estimation		
a. Demand estimation is developed for the four population groups (permanent residents of the EPZ, transients, special facilities, and schools).		
2.1 Permanent Residents and Transient Population		
a. The U.S. Census is the source of the population values, or another credible source is provided.		
b. The availability date of the census data is provided.		
c. Population values are adjusted as necessary for growth to reflect population estimates to the year of the ETE.		
d. A sector diagram, similar to Figure 2-1, "Population by Sector," is included showing the population distribution for permanent residents.		
2.1.1 Permanent Residents with Vehicles		
a. The persons per vehicle value is between 1 and 3 or justification is provided for other values.		
2.1.2 Transient Population		
a. A list of facilities that attract transient populations is included, and peak and average attendance for these facilities is listed. The source of information used to develop attendance values is provided.		
b. Major employers are listed.		
c. The average population during the season is used, itemized, and totaled for each scenario.		
d. The percentage of permanent residents assumed to be at facilities is estimated.		
e. The number of people per vehicle is provided. Numbers may vary by scenario, and if so, reasons for the variation are discussed.		

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
f. A sector diagram, similar to Figure 2-1, "Population by Sector," is included showing the population distribution for the transient population.		
2.2 Transit Dependent Permanent Residents		
a. The methodology (e.g., surveys, registration programs) used to determine the number of transit dependent residents is discussed.		
b. The State and local evacuation plans for transit dependent residents are used in the analysis.		
c. The methodology used to determine the number of people with disabilities and those with access and functional needs who may need assistance and do not reside in special facilities is provided. Data from local/county registration programs are used in the estimate.		
d. Capacities are provided for all types of transportation resources. Bus seating capacity of 50 percent is used, or justification is provided for higher values.		
e. An estimate of the transit dependent population is provided.		
f. A summary table showing the total number of buses, ambulances, or other transport assumed available to support evacuation is provided. The quantification of resources is detailed enough to ensure that double counting has not occurred.		
2.3 Special Facility Residents		
a. Special facilities, including the type of facility, location, and average population, are listed. Special facility staff is included in the total special facility population.		
b. The method of obtaining special facility data is discussed.		
c. An estimate of the number and capacity of vehicles assumed available to support the evacuation of the facility is provided.		
d. The logistics for mobilizing specially trained staff (e.g., medical support or security support for prisons, jails, and other correctional facilities) are discussed when appropriate.		

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
2.4 Schools		
a. A list of schools including name, location, student population, and transportation resources required to support the evacuation, is provided. The source of this information should be identified.		
b. Transportation resources for elementary and middle schools are based on 100 percent of the school capacity.		
c. The estimate of high school students who will use personal vehicle to evacuate is provided and a basis for the values used is given.		
d. The need for return trips is identified.		
2.5 Other Demand Estimate Considerations		
2.5.1 Special Events		
a. A complete list of special events is provided including information on the population, estimated duration, and season of the event.		
b. The special event that encompasses the peak transient population is analyzed in the ETE.		
c. The percentage of permanent residents attending the event is estimated.		
2.5.2 Shadow Evacuation		
a. A shadow evacuation of 20 percent is included consistent with the approach outlined in Section 2.5.2, "Shadow Evacuation."		
b. Population estimates for the shadow evacuation in the shadow region beyond the EPZ are provided by sector.		
c. The loading of the shadow evacuation onto the roadway network is consistent with the trip generation time generated for the permanent resident population.		
2.5.3 Background and Pass-Through Traffic		
a. The volume of background traffic and pass-through traffic is based on the average daytime traffic. Values may be reduced for nighttime scenarios.		
b. The method of reducing background and pass-through traffic is described.		

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
c. Pass-through traffic is assumed to have stopped entering the EPZ about 2 hours after the initial notification.		
2.6 Summary of Demand Estimation		
a. A summary table is provided that identifies the total populations and total vehicles used in the analysis for permanent residents, transients, transit dependent residents, special facilities, schools, shadow population, and pass-through demand in each scenario.		
3.0 Roadway Capacity		
a. The method(s) used to assess roadway capacity is discussed.		
3.1 Roadway Characteristics		
a. The process for gathering roadway characteristic data is described including the types of information gathered and how it is used in the analysis.		
b. Legible maps are provided that identify nodes and links of the modeled roadway network similar to Figure A-1, "Roadway Network Identifying Nodes and Links," and Figure A-2, "Grid Map Showing Detailed Nodes and Links."		
3.2 Model Approach		
a. The approach used to calculate the roadway capacity for the transportation network is described in detail, and the description identifies factors that are expressly used in the modeling.		
b. Route assignment follows expected evacuation routes and traffic volumes.		
c. A basis is provided for static route choices if used to assign evacuation routes.		
d. Dynamic traffic assignment models are described including calibration of the route assignment.		
3.3 Intersection Control		
a. A list that includes the total numbers of intersections modeled that are unsignalized, signalized, or manned by response personnel is provided.		

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
b. The use of signal cycle timing, including adjustments for manned traffic control, is discussed.		
3.4 Adverse Weather		
a. The adverse weather conditions are identified.		
b. The speed and capacity reduction factors identified in Table 3-1, "Weather Capacity Factors," are used, or a basis is provided for other values, as applicable to the model.		
c. The calibration and adjustment of driver behavior models for adverse weather conditions are described, if applicable.		
d. The effect of adverse weather on mobilization is considered and assumptions for snow removal on streets and driveways are identified, when applicable.		
4.0 Development of Evacuation Times		
4.1 Traffic Simulation Models		
a. General information about the traffic simulation model used in the analysis is provided.		
b. If a traffic simulation model is not used to perform the ETE calculation, sufficient detail is provided to validate the analytical approach used.		
4.2 Traffic Simulation Model Input		
a. Traffic simulation model assumptions and a representative set of model inputs are provided.		
b. The number of origin nodes and method for distributing vehicles among the origin nodes are described.		
c. A glossary of terms is provided for the key performance measures and parameters used in the analysis.		
4.3 Trip Generation Time		
a. The process used to develop trip generation times is identified.		
b. When surveys are used, the scope of the survey, area of the survey, number of participants, and statistical relevance are provided.		
c. Data used to develop trip generation times are summarized.		

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
d. The trip generation time for each population group is developed from site-specific information.		
e. The methods used to reduce uncertainty when developing trip generation times are discussed, if applicable.		
4.3.1 Permanent Residents and Transient Population		
a. Permanent residents are assumed to evacuate from their homes but are not assumed to be at home at all times. Trip generation time includes the assumption that a percentage of residents will need to return home before evacuating.		
b. The trip generation time accounts for the time and method to notify transients at various locations.		
c. The trip generation time accounts for transients potentially returning to hotels before evacuating.		
d. The effect of public transportation resources used during special events where a large number of transients are expected is considered.		
4.3.2 Transit Dependent Permanent Residents		
a. If available, existing and approved plans and bus routes are used in the ETE analysis.		
b. The means of evacuating ambulatory and non-ambulatory residents are discussed.		
c. Logistical details, such as the time to obtain buses, brief drivers and initiate the bus route are used in the analysis.		
d. The estimated time for transit dependent residents to prepare and then travel to a bus pickup point, including the expected means of travel to the pickup point, is described.		
e. The number of bus stops and time needed to load passengers are discussed.		
f. A map of bus routes is included.		
g. The trip generation time for non-ambulatory persons including the time to mobilize ambulances or special vehicles, time to drive to the home of residents, time to load, and time to drive out of the EPZ, is provided.		
h. Information is provided to support analysis of return trips, if necessary.		

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
4.3.3 Special Facilities		
a. Information on evacuation logistics and mobilization times is provided.		
b. The logistics of evacuating wheelchair and bed bound residents are discussed.		
c. Time for loading of residents is provided.		
d. Information is provided that indicates whether the evacuation can be completed in a single trip or if additional trips are needed.		
e. Discussion is provided on whether special facility residents are expected to pass through the reception center before being evacuated to their final destination.		
f. Supporting information is provided to quantify the time elements for each trip, including destinations if return trips are needed.		
4.3.4 Schools		
a. Information on evacuation logistics and mobilization times is provided.		
b. Time for loading of students is provided.		
c. Information is provided that indicates whether the evacuation can be completed in a single trip or if additional trips are needed.		
d. If used, reception centers should be identified. A discussion is provided on whether students are expected to pass through the reception center before being evacuated to their final destination.		
e. Supporting information is provided to quantify the time elements for each trip, including destinations if return trips are needed.		
4.4 Stochastic Model Runs		
a. The number of simulation runs needed to produce average results is discussed.		
b. If one run of a single random seed is used to produce each ETE result, the report includes a sensitivity study on the 90 percent and 100 percent ETE using 10 different random seeds for evacuation of the full EPZ under Summer, Midweek, Daytime, Normal Weather conditions.		

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
4.5 Model Boundaries		
a. The method used to establish the simulation model boundaries is discussed.		
b. Significant capacity reductions or population centers that may influence the ETE and that are located beyond the evacuation area or shadow region are identified and included in the model, if needed.		
4.6 Traffic Simulation Model Output		
a. A discussion of whether the traffic simulation model used must be in equilibration prior to calculating the ETE is provided.		
b. The minimum following model outputs for evacuation of the entire EPZ are provided to support review: 1. Evacuee average travel distance and time. 2. Evacuee average delay time. 3. Number of vehicles arriving at each destination node. 4. Total number and percentage of evacuee vehicles not exiting the EPZ. 5. A plot that provides both the mobilization curve and evacuation curve identifying the cumulative percentage of evacuees who have mobilized and exited the EPZ. 6. Average speed for each major evacuation route that exits the EPZ.		
c. Color coded roadway maps are provided for various times (e.g., at 2, 4, 6 hrs.) during a full EPZ evacuation scenario, identifying areas where congestion exists.		
4.7 Evacuation Time Estimates for the General Public		
a. The ETE includes the time to evacuate 90 percent and 100 percent of the total permanent resident and transient population.		
b. Termination criteria for the 100 percent ETE are discussed, if not based on the time the last vehicle exits the evacuation zone.		
c. The ETE for 100 percent of the general public includes all members of the general public. Any reductions or truncated data are explained.		

Criterion	Addressed in ETE Analysis (Yes/No/NA)	Comments
d. Tables are provided for the 90 and 100 percent ETEs similar to Table 4-3, "ETEs for a Staged Evacuation," and Table 4-4, "ETEs for a Keyhole Evacuation."		
e. ETEs are provided for the 100 percent evacuation of special facilities, transit dependent, and school populations.		
5.0 Other Considerations		
5.1 Development of Traffic Control Plans		
a. Information that responsible authorities have approved the traffic control plan used in the analysis is provided.		
b. Adjustments or additions to the traffic control plan that affect the ETE are discussed.		
5.2 Enhancements in Evacuation Time		
a. The results of assessments for enhancing evacuations are provided.		
5.3 State and Local Review		
a. A list of agencies contacted is provided and the extent of interaction with these agencies is discussed.		
b. Information is provided on any unresolved issues that may affect the ETE.		
5.4 Reviews and Updates		
a. The criteria for when an updated ETE analysis is required to be performed and submitted to the NRC is discussed.		
5.4.1 Extreme Conditions		
a. The updated ETE analysis reflects the impact of EPZ conditions not adequately reflected in the scenario variations.		
5.5 Reception Centers and Congregate Care Center		
a. A map of congregate care centers and reception centers is provided.		

NRC FORM 335 (12-2010) NRCMD 3.7 — U.S. NUCLEAR REGULATORY COMMISSION	1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)
BIBLIOGRAPHIC DATA SHEET *(See instructions on the reverse)*	**NUREG/CR-7002, Revision 1**

2. TITLE AND SUBTITLE

Criteria for Development of Evacuation Time Estimate Studies

3. DATE REPORT PUBLISHED

MONTH	YEAR
February	**2021**

4. FIN OR GRANT NUMBER

5. AUTHOR(S)

Todd Smith

6. TYPE OF REPORT

Technical

7. PERIOD COVERED (Inclusive Dates)

8. PERFORMING ORGANIZATION - NAME AND ADDRESS (If NRC, provide Division, Office or Region, U. S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)

Division of Preparedness and Response
Office of Nuclear Security and Incident Response
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

9. SPONSORING ORGANIZATION - NAME AND ADDRESS (If NRC, type "Same as above", if contractor, provide NRC Division, Office or Region, U. S. Nuclear Regulatory Commission, and mailing address.)

Division of Preparedness and Response
Office of Nuclear Security and Incident Response
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

10. SUPPLEMENTARY NOTES

T. Smith

11. ABSTRACT (200 words or less)

The evacuation time estimate (ETE) is a calculation of the time to evacuate the plume exposure pathway emergency planning zone (EPZ). The ETE is primarily used to inform protective action decision-making and may also be used to assist in developing traffic management plans to support an evacuation. This document provides guidance for the development of ETEs, including those associated with staged evacuations. Revision 1 updates the guidance based on the study of ETEs in NUREG/CR-7269, “Enhancing Guidance for Evacuation Time Estimate Studies.” The revised guidance reflects the importance of various model parameters and identifies the measures of effectiveness useful for verifying adequate model performance. The format and guidance provided here supports consistent application of the ETE methodology and serves as a template for the development of ETE studies.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)

Emergency Preparedness
ETE
Evacuation
Evacuation Time Estimate
Shadow Evacuation
Traffic Simulation Model

13. AVAILABILITY STATEMENT

unlimited

14. SECURITY CLASSIFICATION

(This Page) unclassified

(This Report) unclassified

15. NUMBER OF PAGES

16. PRICE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555-0001

OFFICIAL BUSINESS

@NRCgov

NUREG/CR-7002, Revision 1 Criteria for Development of Evacuation Time Estimate Studies February 2021