Analysis Procedures Manual

Version 2

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Oregon Department of Transportation
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Overview of Manual Purpose

The Analysis Procedures Manual (APM) was created to provide a comprehensive source of information regarding current methodologies, practices and procedures for conducting analysis of Oregon Department of Transportation (ODOT) plans and projects. Although this information is extensive, it is not intended to be exhaustive. For example, this manual does not fully address detailed topics such as Region safety investigations, the traffic signal approval process, or development review policies which are covered elsewhere.

The APM shall be utilized by ODOT staff as well as external consultants and contractors conducting and reviewing plans, projects and/or studies for ODOT. It also applies to work performed under ODOT Grants.

The procedures addressed in this manual have been generally organized to follow the progression of analysis conducted for a typical transportation plan or project. It begins with project scoping and data collection, proceeds through the analysis and concludes with the production of the final report. There are examples provided to “walk” the user through a process.

The APM is generally based on methodologies found in the Highway Capacity Manual. However, there are many locations in the APM, either because of limitations in the HCM or because of ODOT policies, where the APM recommends different methodologies to address these issues. Traffic analyses shall use the current edition of the HCM in effect at the start of the analysis unless otherwise specified in the APM.

While the direction provided represents recommended practices for producing consistent and accurate results, it should be recognized that every project analysis presents a unique set of opportunities and constraints. Persons applying the APM should consider relevant situation-specific factors including, but not limited to, cost, funding availability, environmental impacts, sustainability, economic development needs, community support, community vision, land use planning context, practical design, and other similar considerations as appropriate. The best alternative from a traffic analysis standpoint, may not be the best alternative for the project.

While working on various types of projects, a number of situations may arise requiring analysis methodologies not discussed in this manual. If ODOT does not have a preferred analysis methodology to offer, there are a number of technical resources available for consultation. Non-standard analysis proposals shall include thorough documentation of assumptions, methods and calculations in a methodology memorandum. Alternative methodologies must be approved by ODOT prior to analysis.

This manual is not intended to replace the need for sound engineering judgment, which must continue to be a vital part in the process of applying the methodologies to individual studies. Thorough documentation of key assumptions, decisions, and findings should be provided and archived with project files for future reference/use. Further, early and frequent collaboration
between jurisdictional staff, consultants, contractors, and stakeholders involved in the analyses will help ensure that the project goals are met.

Note: All references in this manual to the Department refer to ODOT, and all references to Regions relate to ODOT Regions.

**Manual Structure**

Acronyms are shown in parenthesis after a term, phrase or reference is listed the first time. The acronym is used thereafter in the text.

*Manuals, papers and other publication titles are italicized.*

There are a number of references to web sites, web pages and web accessed documents. Many of these references are links within the document shown with blue, underlined text.

Examples are identified with a solid bar the width of the page at the beginning and end of each example.

*Points that are critical for the analysis process are displayed as a box in italics with the stop sign icon.*

*Additional information to consider is displayed as a box in italics with the yield icon.*

**Manual Updates**

Analysis techniques and project requirements change over time. The ability to immediately incorporate new information into this manual is essential to providing users with the most current resource possible. To accommodate expedient updating, the APM has been designed as an on-line tool, and the on-line version is the official document.

As this is an on-line document, and will not be published and distributed as a traditional publication, there is no user list for update notifications. It is the user’s responsibility to verify they are using the most current version of information as their reference. Updated pages will have the change date as part of the document footer.

**Manual Website**

The on-line version of this document is available at:


Detailed document updates are available on the web page so that users can identify what has changed and when. Supporting information, data and tools used in this manual are available on the Planning Section Technical Analysis and Tools webpages at:


http://www.oregon.gov/ODOT/TP/Pages/Data.aspx

http://www.oregon.gov/ODOT/TP/Pages/Tools.aspx
**Periodic Training**
TPAU offers some training related to this manual, generally related to new topics or procedures. ODOT staff should be aware of the general quarterly meetings of the ODOT APM User Group. Non-ODOT staff may contact TPAU to inquire about training opportunities.
1 ODOT INFORMATION

1.1 Purpose

This chapter is an overview of ODOT, how it is organized and where transportation analysis is within the organization. This section also lists some of the typical units and groups that analysts may need to work with.

1.2 Coordinating with ODOT

The Oregon Department of Transportation (ODOT), through its various Divisions, is responsible for developing Oregon's:

- System of highways and bridges
- Bicycle and pedestrian paths
- Public transportation services
- Rail passenger and freight systems
- Driver licensing and vehicle registration programs
- Motor carrier operations, and
- Transportation safety programs

The following section describes various divisions, sections and units within ODOT that are commonly involved in decision making regarding transportation system planning, design and operations. One or more of these units may need to be contacted for input or to discuss problems and possible solutions regarding a specific project. It is preferable to begin with staff at the Region or District level.

1.2.1 Transportation Development Division

The Transportation Development Division (TDD) is the part of ODOT that:

- Facilitates long and short-term transportation planning
- Keeps statistics about transportation
- Considers transportation policy
- Conducts research to help engineers, planners and project designers
- Helps local governments with transportation through a variety of programs and services.

TDD is comprised of four sections: 1) Active Transportation, 2) Planning; 3) Research; and 4) Transportation Data.

Active Transportation Section
The Active Transportation Section is comprised of the following: 1) Economic & Financial Analysis Unit; 2) Program & Funding Services Unit; 3) Statewide Programs Unit.
The Economic and Financial Analysis Unit provides Highway Fund revenue forecasts, economic and feasibility studies, cash flow forecasting, revenue impacts, and DMV transaction analysis. In addition, the unit provides economic, financial and policy studies to determine Highway cost allocation, tax comparisons, transportation finance, value of travel time and cost of delay estimates, and job and income generation impacts of construction projects.

The Program and Funding Services Unit of the Active Transportation Section is responsible for the development of the Statewide Transportation Improvement Program (STIP), Project Funding, Financial Plan and Project Accounting.

The Statewide Programs Unit provides educational opportunities, technical support and federal oversight to ODOT Regions, local agencies, consultants, and other transportation partners. The Unit administers the following programs including:

- Bicycle & Pedestrian Program (This includes the planning and funding/grant programs only as the designs and standards are under the Highway Division’s Traffic-Roadway Section)
- Certification Program for local agencies
- ConnectOregon
- Funding Programs
- Transportation Enhancement
- Safe Routes to Schools
- Scenic Byways
- Sustainability

**Planning Section**

ODOT’s central Planning section is comprised of four units: 1) Programs and Economic Analysis Unit; 2) Transportation Planning Unit; 3) Freight Planning Unit; and 4) Transportation Planning and Analysis Unit (TPAU). This section provides direction for long term management and improvement of Oregon's transportation system and to promote the cost-effective use of public funds through effective research, development and technology transfer.

The Programs and Economic Analysis Unit (PEAU) manages the Transportation and Growth Management Program (TGM), the State Planning and Research Program (SPR), Economic Analysis Services for the entire agency and jointly manages significant plans, initiatives, and projects. These currently include Least Cost Planning, and Tolling Policies and Rules for example. PEAU works closely with programs such as Flexible Funds, Connect Oregon, and others to help ensure planning program consistency, coordination, and implementation. There are also TGM planners based in the five ODOT Regions to lead and coordinate the TGM program.

The Transportation Planning Unit (TPU) is responsible for statewide long range planning and policy development, including creation and maintenance of the Oregon Transportation Plan and other modal plans, such as the Oregon Highway Plan. In addition, TPU is responsible for implementation of plans and policies through the preparation and dissemination of multi-modal, modal, and topic plans, policies, guidelines and administrative rules. A primary role is to provide assistance designed to help achieve statewide consistency for transportation planning products and activities. In the development of planning and implementation materials, TPU actively works with stakeholder committees and works to balance needs. They also respond to legislative...
requirements, including initiatives such as Least Cost Planning and greenhouse gas (GHG) reduction planning, known as the Oregon Sustainable Transportation Initiative.

In addition, each of the five ODOT Regions also has long-range planners who are familiar with the local government Transportation System Plans (TSPs) and Comprehensive Plans. They coordinate directly with City and County jurisdictions, within their respective Region, to ensure transportation impacts due to private and commercial development are sufficiently mitigated. These planners typically lead the various transportation planning efforts such as refinement plans, interchange area management plans, and transportation system plans.

The Freight Planning Unit (FPU) coordinates public-private, state-local and state-federal freight transportation investment decisions and activities on a state-wide and state-to-state basis to support goods movement and the Oregon economy. FPU is responsible for developing and implementing the Oregon Freight Plan, and supporting the integration of freight issues into the State’s modal plans, corridor plans, and other planning documents and activities. They manage freight transportation studies and intermodal planning programs and projects, including highway, rail, marine, pipeline and air transportation.

The Transportation Planning Analysis Unit (TPAU) provides support and guidance for the development of corridor and urban transportation system plans, transportation model development and use of computer models to forecast transportation needs. TPAU also supports ODOT’s project development process by conducting transportation analysis to aid project selection for the Statewide Transportation Improvement Program (STIP) and developing data for environmental analysis. TPAU often acts as a resource to Region Traffic Units requesting technical assistance. TPAU performs analysis and modeling for Regions 2-5. Analysis conducted in Region 1 is the responsibility of the Region 1 Traffic Section. TPAU is made up of three teams:

- The Facility Analysis and Simulation Team conducts, reviews, and provides technical support on a wide variety of studies, including transportation system plans (TSPs), refinement plans, project development, and management plans. The team also maintains the Analysis Procedure Manual.

- The Statewide and Urban Modeling Team works closely with jurisdictions throughout the state to develop, maintain, and apply state-of-the-art travel demand models for small urban areas, metropolitan areas, regions, counties, and statewide. The team also has developed and is maintaining a statewide travel demand model that integrates transportation, land use and economics to provide a reliable way to forecast and evaluate policies.

- The Systems Analysis Team is responsible for evaluating new alternative performance measures, mesoscopic tools, and system planning analysis methods. The team also does system planning analysis using the Congestion Management System (CMS) and the Highway Economic Reporting System (HERS) that decision-makers use to find cost-effective ways to manage transportation facilities that alleviate traffic congestion.

**Research Section**
The Research Section oversees the state's federally funded research, development and technology transfer program with particular emphasis on new technology intended to enhance the
performance of Oregon's transportation systems. Major current research focuses on safety, infrastructure repair and preservation, maintenance practices, innovative contracting and project delivery, sustainable environmental practices, and the land-use, transportation connection.

**Transportation Data Section**

The Transportation Data Section (TDS) collects substantial data for system inventory, volumes and crash information that can be used for the purpose of conducting traffic studies. Because much of this data is collected and processed by different units within the Department, clear and frequent communication between units regarding what is desired and what is available is critical for ensuring these resources are readily accessible. Furthermore, good communication between units will help to obtain the right data in a timely manner, which is important for maintaining project schedules. Coordinate with the appropriate ODOT department or staff as noted below.

The Crash Analysis & Reporting Unit (CARU) provides motor vehicle crash data through database creation, maintenance and quality assurance, information and reports, and limited database access. Ten years of crash data is maintained at all times. Vehicle crashes include those coded for city streets, county roads and state highways.

The GIS Unit (GISU) serves the Oregon Department of Transportation by providing geographic information products and services through the development of spatially-enabled applications, databases, mapping products, analysis, education and technical support.

Road Inventory and Classification Services (RICS) Unit collects and maintains road information necessary to classify and monitor the highways, roads, and streets within Oregon; provides mileage statistics; develops, maintains, and enhances ODOT’s corporate data base known as the “Integrated Transportation Information System” (ITIS); maintains the Public Road Inventory which is a compilation of information about the status and condition of the road system in Oregon; and films and maintains the State Highway Digital Video Log. From data gathered, reports such as the Federal Highway Performance Maintenance System (HPMS) submittal and the Oregon Mileage Report are written.

The Transportation Systems Monitoring (TSM) Unit develops and maintains a system to collect and process traffic related data on Oregon’s Highways. TSM provides traffic volumes, flow maps, trends, manual counts and vehicle class on state highways to Federal, State, Local, private and public constituents.

1.2.2  **Highway Division**

The Highway Division consists of a wide array of disciplines involved in the operations, construction and maintenance of the state's highways, bridges and other parts of the transportation system.

**Traffic-Roadway Section (TRS)**

This section prepares specifications, maintains standards for traffic devices and related facilities and provides design expertise in materials, operations and construction support services. TRS consists of five central units under the authority of the State Traffic Engineer:

- Roadway Engineering – This unit is responsible for roadway standards and manuals, including the Highway Design Manual. It issues design exceptions and technical bulletins
related to highway design. This unit includes interchange design, value engineering and the engineering portions of the bicycle and pedestrian program.

- Office of Project Letting (OPL) – This unit is responsible for the preparation of project plans, specifications, cost estimates as well as the process of bid letting and quality assurance of project documentation.
- Geometronics – This unit consists of the maps and plan center, photogrammetry and the central units related to surveying which includes geodetic control and preparation of official survey documents.
- Traffic Engineering – This unit consists of groups that oversee signal operations, the speed zone investigations, highway safety engineering and traffic investigations. This is the unit that typically reviews and oversees State Traffic Engineer approvals.
- Traffic Standards; - This unit is responsible for project plans, specifications and standards for signs, striping, signals, illumination, traffic structures and work zones.

The State Traffic Engineer has delegated authority to approve the installation of all traffic control devices on state highways, including installation of new signals and major modifications to existing signals. All delegated authority requests for State Traffic Engineer approval should follow roughly the same process.

- Consultation with Region Traffic Unit; and
- A request sent through the Region Traffic Manager/Engineer with supporting documentation.

A list of items that require approval by the State Traffic Engineer for use on state highways can be found in the ODOT Traffic Manual.

**Region Traffic Units**

Region Traffic Units provide expertise to region and district staff on current traffic policies and procedures. Staff is responsible for overseeing all traffic engineering design (including signal and sign design) for Region projects. Staff actively participates as members of project development teams (PDT) to help insure traffic related issues are considered early in the process, and to provide traffic information to the team. They also act as the traffic liaison to local agencies on behalf of ODOT and can be a data source for traffic signal timing sheets and various operational investigations.

The Region Traffic Manager/Engineer may authorize standard applications and some modifications of traffic control devices that are in compliance with the principles outlined in the Manual on Uniform Traffic Control Devices (MUTCD) and applicable ODOT policies and guidelines. Items that may be authorized by the Region Traffic Manager/Engineer are listed in the ODOT Traffic Manual.

**Access Management Program**

The Access Management Unit (AMU) is part of the Technical Services Branch of the Highway Division. The AMU is responsible for statewide development and administration of the Department’s access management program statutes, rules, and policies.

The Access Management Unit is primarily tasked with the following:

- Training agency staff, consultants and local governments;
• Administering the approach permitting database (CHAMPS – Central Highway Approach Maintenance Permit System);
• Developing administrative rules;
• Conducting appeals procedures;
• Providing technical consultation, guidance, and training to support Region and District offices;
• Developing new program initiatives;
• Establishing statewide performance measures and customer service standards;
• Performing research and program evaluation.

In the Regions, Access Management staff implements the policies and guidelines developed by the Access Management Unit. They report to either the Region Traffic Manager or the Region Planning Manager. The Region Access Management Engineer (RAME) is the Region technical expert for access management issues. Tasks include:

• Fielding Access Management applications from private interests;
• Coordinating the Access Management Process between ODOT technical staff, the applicant, and their representatives (i.e. engineering consultants, lawyers);
• Reviewing technical data (i.e. traffic studies) submitted by the applicant, or the applicant’s representative;
• Approving or denying access application requests and issuing approach permits.

**Bicycle and Pedestrian Program**
This program is headquartered within TRS and provides technical assistance to the Department and local officials regarding pedestrian and bicycle design, construction and maintenance. The planning and grant funding portions of the program are under the Transportation Development Division (TDD) Active Transportation Section. Regions typically participate in planning and project development to ensure that bicycle and pedestrian needs are met. They are the resource whenever bicycle or pedestrian improvements are proposed or existing facilities are affected by other proposed improvements.

**Construction Section**
The Construction Section administers statewide construction policies, procedures and processes and provides construction expertise and training programs. The traffic analyst may provide traffic data to the Pavement Services Unit for use in pavement design on projects.

**District Maintenance Offices**
The District Maintenance Offices are responsible for the on-going preservation and operation of state transportation facilities and the permitting of all activities (utility, access, miscellaneous) within the highway right of way. They are familiar with local issues and the operational and maintenance history of individual highways, and can offer valuable input during the identification of needs and alternatives, in addition to tracking the status of existing permits. Because they are ultimately responsible for maintaining any proposed improvements, they should be consulted during the selection and design.

The Mobility Unit coordinates the construction/maintenance work zone and other restrictions that may impact freight movements as well as oversize loads. It mainly does this through the Highway Mobility Operations Manual. This guide sets project standards and minimum
requirements regarding communication and coordination, vertical and horizontal clearance, bridge weight restrictions, delays, detours, staging, and design.

**Region Environmental/Geo-Environmental Section**

The Geo-Environmental Section is responsible for coordinating environmental regulatory compliance for all transportation improvement programs in the state which use federal funds. The section is responsible for statewide practices, standards, training, expertise, and asset management for geology, geotechnical, and environmental disciplines within ODOT. Within the Section, the Air Quality, Acoustics & Energy Program studies and mitigates the effects of transportation projects by using the environmental traffic data furnished by the traffic analyst in order to model air quality, noise and energy impacts. Region staff includes the Environmental Program Managers (EPMs) who handle the environmental issues on projects, lead the NEPA (National Environmental Policy Act) process, and manage consultants writing environmental documents.

Potential issues requiring involvement of the central or region environmental staff includes:

- Environmental justice
- Threatened and endangered species
- Wetlands
- Historic buildings
- Air quality
- Noise
- Erosion control
- Stream-bank stabilization
- Fish passage
- Storm water quality and quantity

**Right of Way (ROW)**

ODOT’s central Right of Way Section provides expertise in real estate and other right of way matters to the Department. The ROW Section is responsible for:

- The appraisal, acquisition, and management of property acquired for public projects.
- Assisting people and businesses in relocating from the acquired rights of way.
- Administering, directing and supervising the various programs that reside in the Right of Way Section.

The five ODOT Regions each have their own Right of Way section. The Region Right of Way sections deal with the acquisition of real property and improvements necessary for the construction and maintenance of Oregon's transportation system. They also are tasked to maximize the return on the Highway Trust Fund’s real property investment through efficient management and sale of surplus property.

**Roadway Engineering**

The central Roadway Engineering group, which is part of the Traffic-Roadway Section (TRS), is responsible for many aspects of the project development process. Responsibilities such as the Highway Design Manual, Standard Drawings, and the Contract Plan Development Guide, which are essential to the development of projects and the preparation of Contract Plans.
Region Roadway Engineering is responsible for the design of new highways and highway features and is located in each of the region technical centers. Early consultation when evaluating potential improvements can help in identifying fatal flaws and ensure design standards can be met before recommending an alternative. The primary difference between Headquarters Roadway Engineering and Region Roadway Engineering; TRS Roadway sets ODOT highway design policies, plus issues specifications and standards for both ODOT and consultant technical staff. Region Roadway Engineering staff implements the design standards by developing plans, cost estimates and specifications for roadway project within their respective Region.

1.2.3 Other Key ODOT Divisions

Public Transit Division
Public Transit Division is the grantee for Federal Transit Authority (FTA) funds, and is responsible for state-level transit program development and management. The division is responsible for assuring the compliance requirements associated with FTA and state funds are met, even when compliance is primarily the obligation of its recipients. Public Transit provides grant management and oversight of projects and activities supported with state and federal transit funds. Technical assistance is provided on an ongoing basis to transit agencies.

Rail Division
The Rail Division has jurisdiction over railroad crossings and traffic control devices used within crossing areas. They also have exclusive legal authority over public grade crossings and provide coordination with the railroads for affected private rail crossings. The Rail Division should be contacted any time a project may have an impact directly to or within 500 feet of a railroad or rail crossing.

Traffic Safety Division
The Traffic Safety Division provides information, direct services, grants and contracts to the public and to partner agencies and organizations. More than half the funding comes from federal funds earmarked for safety programs.

1.2.4 Other Groups

The Aviation Department establishes and enforces airport planning rules, funds infrastructure improvements, and coordinates efforts to improve airport and airplane safety. When developing projects adjacent to a public or private airport, the airport’s runway flight triangles must be taken into consideration, to avoid conflicts. Also, it is a mode of transportation, which should be considered by ODOT staff and consultants when developing Transportation Impact Analyses (TIA), Transportation System Plans (TSP) and other plans.
2 SCOPING PROJECTS

2.1 Purpose

The purpose of this chapter is to provide guidance to identify the various steps for scoping the analysis of a transportation study or project. The general flow of traffic analysis steps and the corresponding APM chapters are shown in Exhibit 2-1 below.

The first step is to have a thorough understanding of the work which is identified in a problem statement. The next step is to identify the appropriate level of detail and tools. The last step is to then create a scope of work for the study or project.
Exhibit 2-1: Process of Traffic Analysis

Purpose and Scope of Project/Study
   Chapter 2

Inventory
   Chapter 3

Field Data
   Chapter 3.3

Counts
   Chapter 3.4

Crash Data
   Chapters 3.2.1 and 4

Develop Volumes
   Existing and No-Build, Chapters 5-6

No-Build Conditions Analysis
   Chapters 7-16

Develop Preliminary Alternatives
   In Cooperation with Stakeholders

Develop Build Volumes
   Chapter 6

Draft Memos
   Chapter 17

Preliminary Alternatives Screening and Analysis
   Chapters 7-16

Discarded Alternatives

Final Analysis of Selected Alternatives
   Chapters 7-16

Air and Noise Traffic Data
   Chapter 16

Final Report
   Chapter 17
2.2  **Problem Statement**

2.2.1  **Project Understanding**

One of the most important steps in conducting analysis work is to clearly define the scope and purpose for the work. Every plan and project is unique with its own set of assumptions and applicable methodologies. There needs to be a clear understanding of what needs to be done by when and at what cost. The understanding should be conveyed through a problem statement that clearly defines the purpose and need for the work. The problem statement is the basis for either creating an analysis work plan for in-house work or for creating a scope of work for contracted work. A detailed scope of work or work plan helps to limit scope creep and lays out expectations for all parties. A problem statement template is available in Appendix 2A.

Information on geometrics, safety, volumes, past studies, prior projects, other analysis performed along with standards, guidelines, and procedures is available and should be used to gain general knowledge of the study area. There may be a project prospectus or initial planning/environmental documents available as well. The analyst should consult or coordinate with the project team to complete the problem statement. There are many useful tools and resources available on the ODOT website. Major sources are explained in Chapter 3.

2.2.2  **Project Constraints**

Various constraints need to be considered when the work is scoped. If any of these change during the project duration, the problem statement and scope of work should be reassessed and consequences determined. Most constraints fall into two categories. The first is project specific, given the details of what is needed. The second is the project delivery constraints related to delivery/completion date and budget for the work.

The analysis work is controlled by various project factors, issues and concerns. The following questions can focus the problem statement:

- What is the Purpose and Need for the work?
- What questions need to be answered?
- What key issues should be considered?
- What are the Goals and Objectives of the work?
- Who is the audience?
- At what level will the work need to be analyzed and evaluated?
- What types of alternatives need to be evaluated?
- What evaluation measures will be used?
- What is the overall and traffic analysis study area, if different?
- What types of useable information and tools are available and practical?

The purpose and need, goals and objectives and questions and issues typically are determined by a project team, however direction can come from statutes (ORS), rules (OAR), legislation, the Oregon Transportation Commission (OTC), ODOT management, or local jurisdiction. The level of work, types of alternatives and the evaluation measures comes from a process or project/study management team. The study area, tools and information available influence the work. For
example, a study in the Portland Metro area can rely on data from “PORTAL” which has very detailed volume information on the freeways. The rest of the state must rely on physical counts or nearby data recorders to obtain volume information. This difference can be a constraint on the project. Similar to data, the choice of performance/evaluation measures can also be a constraint. Chapter 10 provides more guidance on performance measures and their data needs.

### 2.2.3 Schedule, Resource, and Budget Constraints

The work is driven by a need to deliver an answer in an identified time frame with an identified resource. Questions to identify these factors include:

- What is the timeframe for the analysis work?
- What are the impacts from changes to Purpose and Need?
- What are the risks from outside sources such as other jurisdictions, stakeholders, and private citizens? For example, local concerns/issues/politics can easily add time to a projected schedule.
- Are there outside factors or time constraints that may dictate delivery of work items? For example, crash information is needed but cannot be obtained in the specified time frame.
- What resources are available? Are they internal or external?
- Are tasks dependent on resources not within analyst’s control?
- Does the project funding require certain analysis tools and procedures?
- Is the budget adequate to perform the desired analysis and data collection?
- What is the availability and quality of existing data?
- Can the work be divided? Are tasks independent of each other? Are tasks sequential or concurrent?

### 2.2.4 Additional Details

After the problem, schedule and budget constraints are completed, additional thought needs to be given to what likely performance measures and tools will be used in the project. A project objective will have specific evaluation criteria/measures that will require a particular performance measure which then will require a certain tool to be used. Level of detail (see Section 2.3), and constraints will determine which tools (see Section 2.4) are practical for the effort. This can be somewhat iterative, so the problem statement may need to be modified as the scope of work or internal work plan is constructed.

For example, under a project goal or objective of mobility, the evaluation measure may be travel time. This might be measured by the buffer index which would require either a travel demand model or a micro-simulation depending on the level of detail needed at a particular step in the process.

Once the steps in this section and the previous sections are completed, this will give the analyst the basis to create the scope of work analysis tasks or an internal analysis work plan.

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**Example 2-2-1 Problem Statement**

The below is an example project statement which includes a summary of the field scoping conditions and the defining statement questions and constraints.
OR193 is an older congested regional highway (not a freight route) in an urban arterial corridor within the city of River City. The highway is mostly four lanes undivided (no center turn lane) with a 35 mph posted speed and an average daily traffic load that exceeds 25,000. The corridor has dense retail/service commercial development with limited right-of-way along its length. There are numerous driveways, many closely spaced, because of past uneven growth patterns. Parking and bike lanes are spotty along the length. Sidewalks are curb-tight with many poor slopes in driveway areas and sub-standard curb ramps. In addition, a number of the intersections are high-crash locations. Congestion extends through the peak hour as a significant bottleneck exists in the study area at a bridge over a local small river. The bridge is still structurally acceptable but functionally obsolete with only two lanes, no bike lanes, narrow lanes and sidewalks. The city wants revitalize the corridor with urban renewal and thus wants to improve it for all users, not just vehicles. Efforts to improve access management in the past have met with resistance from property owners. An improvement project has been listed for this location in the City’s Transportation System Plan.

The project has been scoped and meets the needs for an Environmental Assessment (EA) because of the potential impacts. A draft project Purpose and Need (P&N) has been developed: “The purpose of this project is to improve multimodal mobility, increase safety, and enhance the economic development potential of the corridor.” Some draft Goals and Objectives have been formed aligning with the P&N on mobility, safety, environmental, limiting natural and built-up impacts, and economic development.

The project needs to conform to practical design objectives so that the alternatives can stay within a 25-50 million dollar range. This would keep the project reasonably likely so it could be included in the next available State Transportation Improvement Plan. A travel demand model is available for the area.

**Problem Constraints**

- **What is the Purpose and Need for the work?**
  - From the draft P&N: “The purpose of this project is to improve multimodal mobility, increase safety, and enhance the economic development potential of the corridor.”

- **What questions need to be answered?**
  - From the base conditions to help define the project need? What are the actual congestion and safety problems? What are the future conditions? What is the impact of access management on congestion? What are the pedestrian, bike, and transit needs in the corridor? Are there cost-effective alternatives available that can address most of the issues?

- **What key issues should be considered?**
  - Whether to widen or to build a new vehicle and/or ped/bike bridge
  - Balancing different modal needs
  - Access management and parking impacts to properties

- **What are the Goals and Objectives (G&O) of the work?**
  - From draft G&O document: Mobility, safety, environmental, limiting natural and built-up impacts, and economic development.

- **Who is the audience?**
  - The audience is multilevel with state and local staff and stakeholders (i.e business
groups, bike community, neighborhood associations, freight users) and the general public.

- At what level will the work need to be analyzed and evaluated?
  - Alternative concepts will need to be evaluated on a screening basis.
  - Once concepts are more developed into alternatives, then the alternatives can be analyzed at key locations using deterministic tools.
  - The final set of build alternatives that go into the EA (including the no-build) are analyzed in full detail including simulation, multimodal and predictive safety tools. Air & Noise traffic data will be required for the final alternatives.

- What types of alternatives need to be evaluated?
  - No-build (this is what other alternatives are measured against)
  - Possible future land use alternatives as this drives the future improvement needs (this would need to be settled first before getting into detailed analysis).
  - Couplet (new) alignments
  - Bridge replacement
  - Road diet to better accommodate other modes
  - Wider or better utilized right-of-way to improve multimodal, parking and mobility needs including bridge widening.
  - Transportation System Management (TSM)/Safety improvements including painted/raised medians, center turn lanes, improved crosswalks, and improved access management.
  - Alternative strategies such as a new ped/bike bridge, off-street parking, transportation demand management (TDM), or TSM.

- What evaluation measures will be used?
  - Ones that are applicable to this project area include: These can include: volume-to-capacity ratio (v/c), level of service (LOS), queuing, travel time, delay, emergency response time, multimodal level of service (MMLOS), ped/bike system connectivity, accessibility, duration of congestion, percent crash reduction, expected crashes, access spacing, and conflict points.

- What is the overall and traffic analysis study area, if different?
  - Land use and bridge scenarios will require a city-wide look initially to determine if any significant negative impacts exist on areas potentially outside the project limits. If these occur, and the alternatives will still be pursued, then the project limits and/or the analysis study area may need to be modified.
  - Because this is a congested area and traffic simulation will be necessary, the study area will need to go out two signalized intersections outside of the project limits (area of potential impact). The project will at least need to go a couple of block on each side of the highway to accommodate the couplet alternatives.

- What types of usable information and tools are available and practical?
  - Inventory data, some counts, analysis and modeling work done for TSP
  - A travel demand model and local modeling staff time is available.
  - Mesoscopic methods (i.e. windowing out of a model area)
  - Highway Capacity Manual (HCM) and Highway Safety Manual (HSM) methods
  - Micro-simulation
Schedule, Resource, and Budget Constraints

- What is the timeframe for the analysis work?
  - This project is going to kickoff in July, so counts will need to be obtained immediately to capture the 30th highest hour conditions.
  - The project is one of the Region’s top priorities
  - Since this is an EA, the end date is somewhat unknown but is expected to last at least 36 months.

- What are the impacts from changes to Purpose and Need?
  - Likely impacts could be additional alternatives, rework of analysis which will lead to more time required to do the work.

- What are the risks from other sources such as other jurisdictions, stakeholders, and private citizens? For example, local concerns/issues/ politics can easily add time to a projected schedule.
  - Access management and parking concerns will likely cause delay or create issues with the city council/planning commission.
  - Potential issues with internal and/or outside business groups
  - Environmental/Riparian issues along the river
  - Potential additional bridge routes/alignments

- Are there outside factors or time constraints that may dictate delivery of work items? For example, crash information is needed but cannot be obtained in the specified time frame.
  - Counts will need to be obtained between July and September in order to stay on schedule.
  - Staff time to perform analysis is limited because of other legislative high-priority work. Will likely need to have help from consultant to stay on schedule.

- What resources are available? Are they internal or external?
  - Internally, there is the project lead (manager) and at least one analyst available. The EA consultant has additional analysis staff available to help out on contingency.

- Are tasks dependent on resources not within analyst’s control?
  - Yes, model applications are dependent on current workload; alternatives are dependent on region designers, alternative development process is dependent on feedback from stakeholders, public open houses and the teams themselves.

- Does the project funding require certain analysis tools and procedures?
  - The project falls under NEPA requirements so full counts and inventory data will be necessary to stay consistent with land use requirements and to support the environmental analysis. In addition, the travel demand model is required to be used.

- Is the budget adequate to perform the desired analysis and data collection?
  - The budget is adequate for the data collection, and up to three detailed alternatives in the EA document.

- What is the availability and quality of existing data?
  - State inventory data is current. The TSP analysis is still usable but more counts and data will be needed for the project analysis.

- Can the work be divided? Are tasks independent of each other? Are tasks sequential or concurrent?
  - Most work can be divided into concurrent tasks, but simulation work must be...
done sequentially from a single source to avoid inconsistencies in assumptions. Generally, no-build work must precede alternative work.

**Additional Details**

- Given the above mentioned evaluation measures and other issues what are the likely performance measures that will be needed?
  - Volume to capacity ratio for the state highway and level of service for the local system will be required to compare with established performance targets and standards. In addition, travel time and queuing will be needed to test the overall efficiency of alternative operations. Multimodal level of service will be used to gauge the impact of mobility alternatives on the pedestrian/bike/transit operations and vice versa.

- Likely tools to be used?
  - Analysis of the no-build and the alternatives will require the use of the travel demand model to help develop the volumes and to create high-level screening measures to test any model-usable concepts (i.e. road diet, couplet and other network changes). Tools such as Highway Capacity Manual-based software (i.e. HCS and Synchro) and the multimodal tools will be needed to develop the detailed analysis. Micro-simulation will also be needed to create the travel time measures for the detailed analysis and to create the queuing data.

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**2.3 Level of Detail**

There are many types of analysis work done for transportation related issues. The analysis ranges from high-level policy and procedures, through subject or facility plans to specific issues, locations or improvements projects. For example, a 10-mile long facility plan should have a different level of analysis than a single intersection realignment. The analysis process can have multiple levels such as single-issue or fatal flaw screening through detailed reporting like micro-simulation.

**2.3.1 Types of Work**

**Planning Studies**

These studies are generally limited to a specific geographic area or corridor or can cover multiple topics/issues. All of these can be either rural or urban and can overlap into different elements as well as varying level of detail. In some regions, the terms “corridor”, “facility”, “refinement” all mean the same level of effort. Expressway plans are similar but deal with a certain facility type and condition reports only deal with existing or future no-build needs yet the plans may not look different from a typical refinement plan.

The key difference in plans will be what are the specific questions needing answers and the detail level needed to answer them regardless of what the plan is named. For example the I-205 corridor in a dense urban area would involve use of a regional travel demand model, dynamic traffic assignment (DTA), and micro-simulation while the comparatively rural US395 corridor
would only have an urban model in a couple locations, and use a higher segment-based analysis.

Examples of each can include:

- **Statewide Policy / Plans** - This work is generally of a statewide nature but can be topic specific; typically guidance or an overriding policy such as:
  - Greenhouse Gases (GHG)
  - Least Cost Planning (LCP)
  - Legislative Studies / ORS / OAR
  - Performance Measures like Alternative Mobility Standards
  - OTP and Modal Plans (OHP, Freight Plan, Rail Plan, Bike/Ped Plan)

- **System Plans** – these focus on:
  - Metropolitan (urbanized) areas – Regional Transportation Plan (RTP)
  - County/multiple jurisdictional – County TSP, Regional Transportation Plan.
  - City – City Transportation System Plans

- **Corridor/Facility Plans** – these focus on:
  - Specific highway corridor
  - Land Use (TPR-type zone change, UGB expansion)

- **Refinement Plans** – these focus on:
  - Topic (Road Diet or Conversion of Two-Way to One-Way)
  - Feature (IAMP),
  - Mode (Safe Routes to Schools)
  - Highway segment
  - Sub-Area

**Projects**
This operational analysis is limited to specific locations often with specific guidelines or parameters that influence the work. They include

- **Modernization** – this work covers large issues / needs that must be measured against specific data needs or standards. The intent is to bring the facility/project up to standards and/or formalize exceptions.

- **Safety / Operations / Preservation** – this work is specific in nature and may allow deviation from standards. For example on a facility with a high crash rate fitting a minimal left turn lane within the given right-of-way may not have standard widths and tapers.

- **Traffic Impact Analysis (TIA)/Traffic Impact Studies (TIS)** – this work is driven by the development itself. The analysis is to determine facility adequacy, significant effects and required mitigation.
  - Transportation Planning Rule (TPR)/Zone Change – When a proposed development requires a change in land use and has a significant effect to the state facility, certain criteria must be met.
  - Conforming Use Development- When a proposed development does not fall in the TPR/Zone change, the analysis is dependent on local land use code and approach permitting

- **Approach Permitting** – These are for developments that do not require a TIA. This driveway type and location considerations such as sight distance, conflict points, influence areas.
Other Procedural / Research Studies
This is analysis work in support of a specific topic or tool, such as but not limited to trip generation studies, determination of analysis factors, procedures or calculators. These studies should conform to appropriate national methods and accepted analytical processes. This work needs to be detailed out with specific deliverables and agreed to by the parties requesting and accepting the work.

2.3.2 Level of Analysis
The questions being asked and the data available can determine the level of analysis needed. This can range from policy and systemic reporting to a very detailed specific need. Resources are limited, so the level of analysis needs to be tailored to the questions.

- Rules of Thumb – Generalization based on common conditions with very little detail. Can be in tabular or checklist format or “canned.” For example, when AADT exceeds 60,000 then six lanes are needed. These need to be taken into context as a general ballpark only. They may be used to help determine a starting point. Actual decisions need to be based on more detailed analysis.
- Broad Brush (a.k.a. “30,000 or 10,000 foot view”) – Big picture generalized planning analysis or a preliminary estimate of a more detailed later task. This could include using daily traffic volumes (AADT’s), assumed roadway geometrics, or default values. This is typically at the system or corridor level (not intersection level). Data is typically at an aggregated level.
- Screening – A mid level analysis where some plan/project specific data is available but likely not fully developed. This process is used to whittle down large number of scenarios/concepts/alternatives/options to a more reasonable number. This can include both qualitative and quantitative elements. Measures can include items such as policy/standard compliance (a.k.a. fatal flaw analysis), natural and built environmental constraints, segment demand-to-capacity ratios, and key intersection volume to capacity ratios. Context sensitivity / practical design considerations are important at this level and below. Typically in a plan or project, multiple levels of screening are used in increasing detail.
- Detailed – This is a comprehensive look a study area or topic. This uses study-specific data where the use of defaults is limited. This analysis typically furnishes detailed numbers for establishment of standards or policies or details for a specific design (i.e. storage lengths, signal progression). Actual plan or project decisions can be made from information derived from this level.

2.4 Tools
There are many tools used for transportation and planning analysis. They are a mixture of commercially developed and internally created programs serving anything from analyzing the effect of a specific policy to a specific project detail. Often a particular process becomes identified as a tool and is included for discussion purposes.
2.4.1 Individual Tool Descriptions

The following tool descriptions are not exhaustive list and mainly concentrate on the ODOT-used ones. Some of these tools are discussed in more detail in following chapters. Some of these tools could be considered a process, i.e. sub-area modeling or zonal cumulative analysis. Some tools may package together multiple tools (i.e. HCM analysis and simulation) in a suite format. Other tools and methodologies not listed here or later in the APM may be acceptable if explained and documented in a methodology memorandum and approved by ODOT. For more information or availability of these tools, please contact TPAU staff. The higher model–based tools are discussed further in the Senate Bill 1059: GHG Modeling and Analysis Tools Report:


SWIM (StateWide Integrated Model) – This model is used for high level projects of statewide importance that involve freight movements and/or long-term economic impacts. SWIM is not designed to analyze small or isolated projects.

LUSDR (Land Use Scenario DevelopeR) – This tool is used with a travel demand model for large-scale regional planning to develop and test a range of future land-use scenarios. A single or weighted average of these scenarios can be used in system and refinement planning efforts such as TSP’s and IAMP’s. LUSDR can inform local jurisdictions of future land use development issues and possibilities and influence decisions on growth areas, the comprehensive plan, and the future land use patterns.

GreenSTEP (Greenhouse gas Strategic Transportation Energy Planning model) – This model is used for large-scale regional emissions planning as part of an area’s Greenhouse Gas (GHG) reduction efforts. The model is used to help establish a transportation strategy for meeting greenhouse gas targets.

HERS-ST (Highway Economic Requirements System-State Version) – Typically used on a corridor-basis for determining needs (deficiencies) including capacity, geometric alignment and pavement based on identified funding thresholds. Data is available for the state highway system as the HERS-ST input datasets are created mainly from internal ODOT inventory databases and is updated yearly. Local HERS-ST data can be created if the appropriate data and resources are available. With varying levels of effort, HERS-ST can be linked to travel demand models. This produces simplified HCM segment capacities, typically in volume to capacity ratios. Like with all HCM-based tools there are no interactions between segments. Also, while some intersection data is included, HERS-ST will not produce intersection performance measures. HERS-ST can be used to produce benefit-cost ratios for different project improvements which can be used for screening alternatives or used for high-level project management decisions. It also can be used as the primary tool for determining existing and future year v/c’s and needs in corridor and facility plans.

Urban Models (4-Step Travel Demand Models) – Travel Demand Models are generally built as system-level tools so detail is limited at a facility level; including basic characteristics such as number of lanes and speed limits. These models can be used as a screening tool using district travel patterns (origin-destination), demand-to-capacity ratios, percent volume differences, and high level estimates of travel times. Travel Demand Models are also used to develop future
volumes for plans and projects through post-processing methods. See the available TPAU and MPO urban model map on TPAU’s website at: http://www.oregon.gov/ODOT/TD/TP/pages/tools.aspx

IDAS – (ITS Deployment Analysis System) - This is used for integrating ITS (Intelligent Transportation System) operations into a travel demand model assignment. IDAS allows global settings of traffic signal timing, variable messaging and ramp meters in order to modify imported model assignments. IDAS is only for ITS applications only on a system basis rather than a corridor or point basis. For smaller areas, IDAS can be applied to a cut-out (window) model network. IDAS can compare multiple ITS scenarios including on a benefit-cost basis.

Dynamic Traffic Assignment (DTA) - DTA is an alternative mesoscopic method that assigns traffic across time periods so that adjacent time periods and congestion affect each other. DTA is useful when the typical peak hour traffic spreads across multiple hours. The assignment is more detailed as it incorporates basic signal timing and platoons of vehicles which allow for queuing to be modeled. DTA is a further level of effort and refinement of the model assignment between the typical travel demand model and micro-simulation. Common DTA software tools are Dynus-T and Dynameq.

Subarea modeling – This is a mesoscopic technique by cutting out a portion of a travel demand model (also called windowing) to be used separately or adding detail to a portion of a model (also called focusing). Both methods involve adding detail to the model (signal timing, smaller zones, additional centroid connectors, better refined capacities, etc). This additional detail will improve calibration between the model and field counts, possibly to the point that post-processing is very limited. Typical software for the windowing method would be VISUM.

HCS (HCM) – Highway Capacity Software is a faithful implementation of the Highway Capacity Manual methodology. These methods are point/segment based and are isolated so adjacent sections do not affect each other. This is the only source of deterministic analysis tools for freeway operations (segment, merge, diverge, and weave). HCS/HCM also considers pedestrian, bike and transit multimodal analyses. The HCS/HCM is mostly operational (high detail level) based but there are some planning-level methodologies available using mostly default values and average daily traffic volumes.

Synchro – Synchro is mainly for the operation and system optimization of signalized study area networks. Synchro is mainly focused on the analysis of signalized intersections, but can do unsignalized intersections, roundabouts, and intersection-level multimodal analysis following current HCM methodologies.

SimTraffic – SimTraffic is a micro-simulation based on the arterial portion of CORSIM and thus is best suited for simulating arterial networks. This allows system-level analysis of a study area network for queuing impacts, travel time, delay of individual vehicles as well as network wide.

VISSIM – VISSIM is a complex but comprehensive micro-simulation which can be used to model virtually any road network. VISSIM also has the capability to handle DTA and multiple modes. The software is extremely customizable but requires significant effort to calibrate and report out useable data.
Trip Generation - This process implements the ITE Trip Generation Manual procedures based on land uses and other site size and type characteristics.
SigCap – SigCap is currently used as a quick sketch-type analysis and is mainly used to develop signalized intersection LOS C values for the environmental traffic data process.

Unsig – Unsig is currently used as a quick sketch-type analysis and is mainly used to develop unsignalized intersection LOS C values for the environmental traffic data process.

EISBase – EISBase is database tool used to calculate the resulting speeds of traffic flows, based on volumes of auto and trucks, for the environmental traffic data process.

Zonal Cumulative – The Zonal Cumulative volume development process is mainly a manual three-step (generation, distribution and assignment) analysis. This involves creation of zones, uses ITE Trip Generation methodologies, external trip origin-destinations, and gravity-based distribution. Calibration is also required. The VISUM modeling software is used to streamline the assignment process.

Future Volume Tables – These show the future annual average daily traffic volumes for state highway segments based on either 20 years of historical traffic counts or travel demand model based growth trends depending on the location. These are updated annually.

Other Planning Analysis Tools – There are a number of less complex tools that can be used to evaluate a system at a relatively high level. These also can be used as part of a more detailed plan or project analysis as an alternative screening tool. Most of these are based on average daily traffic. Some examples are preliminary signal warrants (PSW), other PSW-based tools, and the capacity nomographs.

IHSDM – The IHSDM (Interactive Highway Safety Design Model) implements the HSM Part C predictive method for rural and urban highway segments. The IHSDM evaluates the effects of geometric changes on safety. The IHSDM has a very high input detail level as it requires full geometric design data (curves, grader, stationing, super-elevation, etc). This is best suited for evaluating final design alternatives.

PlanSafe – This is for comparing relative safety levels on a transportation analysis zone or district basis within a travel demand model. PlanSafe does not use HSM methods.

NCHRP Spreadsheets – These are a free download implementing the Highway Safety Manual Part C predictive safety analysis methods. These are not technically supported and may not reflect current changes/fixes in HSM procedures.

HiSafe – HiSafe is a software application implementing the Highway Safety Manual Part C predictive safety analysis methods.

Crash Decoder Tool – This macro-based spreadsheet tool converts the extensive numerical codes in the typical “long-form” comprehensive PRC crash listing to words. This eliminates the need for the analyst to be familiar with the crash coding manual. The tool will also summarize and graph the crash characteristics.
2.4.2 Tool Evaluation/Selection

The second step for scoping is to determine what tools are available and can be used at particular stages in the analysis effort. Selection of the appropriate analysis procedures from this manual will often be determined by project-specific characteristics such as the type of project, the surrounding environment and land uses, availability of data and the type of traffic controls present in the field. Generally, similar types of projects will use the same analysis procedures to varying degrees. Depending on the study and the project’s purpose and need, additional data may be required. For further information on project scoping and selection of traffic analysis procedures, refer to the Federal Highway Administration’s (FHWA) website for the Traffic Analysis Toolbox: http://ops.fhwa.dot.gov/trafficanalysistools/

In this manual, tools are broken into two basic categories: deterministic and stochastic and two sub-categories: systemic and specific. Considering the project needs and constraints, the tool selection can greatly impact the resources and time necessary to do the analysis.

- **Deterministic** – These tools use a set of fixed inputs and result in a single set of outputs. These include, for example, Highway Capacity Manual procedures and the 3- or 4-Step travel demand models.
- **Stochastic** – These tools use a set of inputs and create multiple sets of outputs. These include, for example, micro-simulation and dynamic traffic, land use and economic assignment models. These tools are much more time-intensive for inputs, process, and analysis of outputs.
- **Systemic** – These tools often cover multiple points that interact / influence with each other.
- **Specific** – These tools analyze a single location

In the sections that follow, the tools are grouped first by study type and then by analysis type, however, the tables are not exhaustive. Studies likely require more than one type and related tools over their duration. Even within these tools there is a range of uses from high-level planning to project specific. Some tools can be used for widely varying efforts depending on the questions asked. An “X” indicates the tool type in the following exhibits.

The following discussion assumes that these tools have been created, tested, and operational. If a tool is not fully updated and usable, additional time or special considerations may be needed in tool selection.

For each tool, the general data needs, staffing requirements, and time required are shown. Many tools may have a range depending on the task at hand which may be “high” for a simulation model, to “medium” for facility analysis, and to “low” for individual intersection analysis. The following exhibits attempt to reflect a relative difference between the tools and may not capture every specific circumstance.

- “High” (H) generally means obtaining large quantities of data, confidential data, data not readily available, or in the correct format. Long times to collect data or the cost of collection is also considered. These tools can require a special separate project effort to collect and clean the data or to customize the tool to the location. Use of default values is
very limited. Some tools may require many staff members such as updating a travel demand model or may require many hours from a single person, such as micro-simulation. Processes may take months or years in some cases.

- “Medium” (M) generally means data obtainable in the field or from available information/databases although it might still need conversion or cleaning. Staffing requirements will be a single to a few staff members. Time requirements are generally on the order of weeks.
- “Low” (L) generally means published data or available data in correct formats and can be immediately used. The tool may have a high use of default values. Overall data requirements are limited in total amount or elements. These tools can be used by a single staff member and time requirements are on the order of days.

Tools Grouped by Study Type

Policy Tools
Used for answering policy level questions such as for the Oregon Transportation Plan or Oregon Highway Plan. These questions can be from the legislature or upper management. Questions can be very complex, in order to determine the effects of potential policy decisions involving many diverse factors in broad areas including economics, land use and transportation. SWIM and HERS-ST are the primary tools used for this purpose.

Exhibit 2-2: Policy and Statewide Planning Tools

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<thead>
<tr>
<th>Tools</th>
<th>Deterministic</th>
<th>Stochastic</th>
<th>Systemic</th>
<th>Specific</th>
<th>Data Needs</th>
<th>Staffing</th>
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Statewide Planning Tools
Used for statewide or multiregional analysis studies such as the Bridge Limitation Strategy. These studies usually involve the highway network or elements such as freight movement, congestion, economic impacts of delay/detours, etc. SWIM is used for general flows including freight movements and economic impacts while HERS-ST is a segment-based tool for prioritizing/analyzing highway needs (deficiencies) and overall benefit/costs across the statewide network.

System Planning Tools
Used for regional, county or city planning studies such as Regional Transportation Plans (RTP) and Transportation System Plans (TSP). The tools cover a wide range of uses. GreenSTEP is used for greenhouse gas emissions in urbanized areas. LUSDR is used to help determine future land use allocations when there are too many unknowns to use the normal processes. The urbanized area, county and small city travel demand models are used to determine system travel patterns or behavior, to compare multiple land use and network scenarios, or can be used to
develop post-processed volumes for more detailed analysis for specific locations.

PlanSafe is used on a transportation analysis zone (TAZ) or district basis to compare between network scenarios to determine relative safety levels. Historic crash analysis using the Crash Decoder Tool is needed to identify current issues as well as support the PlanSafe model if a travel demand model is available. IDAS can be used to refine vehicle assignments from travel demand models to help incorporate effects of transportation system management (TSM) and intelligent transportation systems (ITS) such as ramp metering and variable message signs. HERS-ST and IDAS can both calculate benefit/costs for alternatives. If no travel demand models exist, then a zonal cumulative or a traditional historic volume growth process may be used.

Other tools cover specific routes, segments, or locations. Multimodal analysis would be typically done for major facilities across all applicable modes using HCM methods. HERS-ST can be used for determining operational results of state highway segments or across an entire area if the data is available. Highway Capacity Manual operational or planning analysis techniques can be used to determine operational results of roadway segments for all modes. Other planning analysis tools include daily-traffic based intersection tools for determining needs or general traffic control types.

Exhibit 2-3: System Planning Tools

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<th>Systemic</th>
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</table>

Corridor Planning Tools
Used for specific highway segments, either over an entire highway or a smaller section within or between cities. Corridor plans have more detail than system plans yet lack the specific details of project refinement plans and are limited to the specific roadway in question. These tools form the full range from systemic travel demand model-based tools to intersection operational analysis to micro-simulation. Travel demand model based tools are used to compare scenarios or help screen alternatives. Some tools like dynamic traffic assignment (DTA) or IDAS are used to incorporate shifting demand or TSM/ITS into the model assignments to better match the field conditions and limit the amount of post-processing needed. If no travel demand models exist, then a zonal cumulative or a traditional historic volume growth process may be used.
Historic crash analysis is needed at the corridor planning level. Predictive crash analysis may be used on the final solutions for urban arterials and rural non-freeways. The NCHRP HSM spreadsheets and HiSafe are used to do the predictive analysis while the Crash Decoder Tool is used to simplify the historic crash analysis.

Analysis would be typically done across all applicable modes at varying levels of detail from HCM-based analysis to micro-simulation. HERS-ST or HCM planning analysis can be used for determining operational results of state highway segments along the corridor. Both HERS-ST and IDAS can be used help determine benefit/costs of alternatives. If intersection analysis is needed then any of the HCM-based methods and tools (such as HCS or Synchro) can be used. Typically, micro-simulation will not be needed in corridor plans other than in metropolitan areas. VISSIM is typically used for freeway operations, complex configurations, and/or including multimodal issues and SimTraffic is used for signalized arterial corridors.

Exhibit 2-4 shows this group.

Refinement Planning Tools
Refinement plans are more detailed than system or corridor plans, but they are limited to a specific area or highway segment. Refinement plans generally arise from system or corridor plans which identify need for more detailed analysis. Travel demand model based tools are used to compare scenarios or help screen alternatives. Some tools like dynamic traffic assignment (DTA) or IDAS are used to incorporate shifting demand or TSM/ITS into the model assignments to better match the field conditions and limit the amount of post-processing needed. The smaller scope of these plans allows sub-area (window) modeling to be done which will further reduce the post-processing need. If no travel demand models exist, then a zonal cumulative or a traditional historic volume growth process may be used.

Historic and/or predictive crash analysis is needed at the refinement planning level. The NCHRP HSM spreadsheets and HiSafe are used to do the predictive analysis on urban arterials and rural non-freeways while the Crash Decoder Tool is used to simplify the historic crash analysis. Analysis would be typically done across all applicable modes at varying levels of detail from HCM-based analysis to micro-simulation. HERS-ST or HCM/other planning analysis tools are mainly used for alternative scoping or screening. Both HERS-ST and IDAS can be used help determine benefit/costs of alternatives. Intersection-level analysis is typically needed so any of the HCM-based methods and tools (such as HCS, or Synchro) can be used. Micro-simulation (will generally be used, especially in urban or congested areas. VISSIM is typically used for freeway operations, complex configurations, and/or including multi-modal issues and SimTraffic is used for signalized arterial corridors.
Project Tools

Project analysis is the most detailed of all analysis types. Project analysis can involve the full range of tools from the travel demand model to micro-simulation and may involve specialized areas such as environmental analysis. Travel demand model based tools are used to compare scenarios or help screen alternatives and are used to create post-processed design hour volumes to be used by other tools. Some tools like dynamic traffic assignment (DTA) or IDAS are used to incorporate shifting demand or TSM/ITS into the model assignments to better match the field conditions and limit the amount of post-processing needed. The smaller scope of these plans allows sub-area (window) modeling to be done which will further reduce the post-processing need. If no travel demand models exist, then a zonal cumulative or a traditional historic volume growth process may be used.

Detailed historic and/or predictive crash analysis is needed at the project level. Tools like IHSDM, the NCHRP HSM spreadsheets, and HiSafe are used to do the predictive analysis on urban arterials and rural non-freeways while the Crash Decoder Tool is used to simplify the historic crash analysis.

Analysis would be typically done across all applicable modes at varying levels of detail from HCM-based analysis to micro-simulation. HERS-ST or HCM/other planning analysis tools are mainly used for alternative scoping or screening. Both HERS-ST and IDAS can be used help determine benefit/costs of alternatives. Intersection-level analysis is usually needed so any of the HCM-based methods and tools (such as HCS or Synchro) can be used. In congested areas or where the HCM methods no longer apply then micro-simulation is required. VISSIM is typically used for freeway operations, complex configurations, and/or including multimodal issues, and SimTraffic is used for signalized arterial corridors. Some projects may involve environmental
traffic analysis for noise, air quality and energy impacts which normally requires the use of (or the equivalent of) Synchro, SigCap, Unsig, and EISbase.

**Exhibit 2-5: Project Tools**

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**Specific Analysis Elements**

**Volume Development Tools**

These tools are used to help develop volumes to be used in the analysis at various levels of detail as warranted by the individual study. Where a travel demand model is available, model assignments can be created to help in screening and post-processing. Dynamic traffic assignment and subarea modeling techniques can be used to refine the assignment. Zonal cumulative analysis is used where a travel demand model is not available. Trip Generation is used in cumulative analysis using rates from the ITE Trip Generation manual.
Exhibit 2-6: Volume Development Tools

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Screening Analysis Tools

Screening analysis is typically a high-level analysis used to reduce the number of scenarios/concepts/alternatives to a manageable level. Most studies will have multiple levels of screening at increasing detail levels. At the top end, travel demand model-based tools are typically used for the system impacts. Middle and lower screening levels are more detailed at the intersection level which may be using key intersection volume-to-capacity ratios, or multimodal level of services. Screening analysis in a project–level analysis will be more complex than in a system plan.

Exhibit 2-7: Screening Analysis Tools

<table>
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Multimodal Analysis Tools
For a complete analysis of a system or a project area, a multimodal analysis is needed. Urban MPO (Metropolitan Planning Organization) models can be used to determine mode share for the base case as well as alternatives. The HCM-based multimodal level of service (MMLOS) is used to create qualitative comparisons across the auto, pedestrian, bicycle, and transit modes. HCS has all the modes and does intersections and segments while Synchro does not include transit and does only intersections. In congested areas or in areas where non-auto modes are very common mixing with vehicular traffic such as light rail, streetcar, and buses, VISSIM micro-simulation will be needed to judge the impacts of these modes on each other. VISSIM, and in some cases SimTraffic, is also needed where heavy rail modes cross roadways. Analysis of the actual modal operations requires different resources not covered in this manual, such as the Transit Capacity Quality of Service Manual (TCQSM).

Exhibit 2-8: Multimodal Analysis Tools

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Safety Tools
Most studies will require some sort of safety analysis. At a minimum, a historic crash analysis is needed. The Crash Decoder Tool simplifies the processing and analysis of individual crash records. Historic crash data is also needed to support more-detailed predictive analysis. Travel demand model-based relative comparisons can use PlanSafe, which analyzes crashes on the TAZ level. Plans and projects can use Highway Safety Manual (HSM)-based screening methods for establishing critical crash rates within a community or predicting the number of crashes associated with changes to roadway segments or intersections. Additional HSM-based tools are available to conduct predictive analyses methods, such as the free NCHRP spreadsheets or HiSafe software. Interactive Highway Safety Design Manual (IHSDM) software allows for very detailed evaluation of safety effects of geometric design decisions and requires a project-level data collection effort to be used appropriately.
### Exhibit 2-9: Safety Tools

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### Environmental Traffic Data Tools

Sometimes, plans and projects will require some sort of environmental analysis. This can range from high level travel demand model based efforts to very detailed traffic volume development. GreenSTEP is a model based tool that estimates greenhouse gas emissions across a metropolitan region and thus will be mainly used in the development of regional transportation plans (RTP). Development of RTP’s requires an air quality conformity determination. Also some metropolitan and smaller urban areas have been (none currently are) non-attainment areas for air quality. The urban models feed data into the air quality model (MOVES) which is the tool for determining air quality conformance. Project analyses will generally involve at least a noise study with many larger projects needing air quality or energy studies. Tools such as Synchro, SigCap, Unsig, and EISbase support the creation of the environmental traffic data to be later used for environmental analysis. Simulation tools can be used to create simple system-wide deterministic measures such as fuel used and pollutant levels.

### Exhibit 2-10: Environmental Traffic Data Tools

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2.5  Creating a Scope of Work (SOW)

The third step for scoping is to determine the specifics for the scope of work. SOW’s can be written for TSP’s, Corridor/Facility Plans, Refinement Plans, IAMP’s and projects. Traffic Impact Analyses/Statements (TIA/TIS) also have a SOW but specific criteria should be consistent with Chapter 3 of ODOT’s Development Review Guidelines.

The purpose of establishing a scope of work (SOW) for a transportation study is to define critical parameters such as the study area boundaries, analysis requirements, data needs and the identification of specific concerns to be addressed. An effective scope of work should always produce a completed study that satisfies the needs of the corresponding project.

Common elements for most types of transportation studies include:
- Background or Purpose Statement
- Objectives of the Study
- List of Work Tasks
- Identification of Deliverables
- Project Schedule
- Project Budget

It is important that the work tasks and corresponding deliverables be clearly defined, and that the party responsible for completing them is identified. The distribution list for deliverables should generally include all the pertinent teams/groups and specific ODOT sections needed for review.

All ODOT analyses must have a discussion on methodologies and assumptions used. For SOW’s there must be a requirement for a Methodology Memorandum clearly shown. This memorandum details out the methodologies and assumptions that are to be used in the existing and future volume development and analysis. A methodology memorandum significantly reduces the amount of review by ODOT and potential re-working by the Contractor. The SOW must require that the methodology memorandum is completed by the Contractor and reviewed by and agreed to by ODOT prior to the Contractor starting any volume development and/or analysis tasks. In the absence of a SOW requirement, the APM requires use of the same methodology memorandum.

2.5.1  Traffic Scoping Considerations

Each SOW likely has specific individual issues; however, there are many common needs such as professional engineer licensing requirements and specific requirements for the state highway system. Some typical SOW traffic analysis statements are shown below.

The following lists are typical of suggested statements used in SOW’s for the traffic analysis tasks and are not exhaustive. Not all of these statements will apply to a single study. These tasks may be modified as desired to fit a study’s particular needs.
• Final versions of the Contractor’s transportation analysis must be stamped by an Oregon-registered Professional Engineer (P.E.) with license being current and in good standing, with expertise in civil or traffic engineering.


• Contractor shall coordinate all traffic analysis with ODOT’s Transportation Planning Analysis Unit (TPAU) and Region [1-5] Traffic Section. [Coordination with local jurisdictions or groups such as MPO’s, may be necessary.]

• Consultant shall obtain approval of existing and future analysis methodology from TPAU and Region [1-5] Traffic via a methodology memorandum prior to beginning analysis.

• All documents will be readable and usable in black and white [Exceptions can be specified for certain deliverables.]

• All documents must be written in plain language and use an easily understood format.

• Contractor shall review all applicable plan/past project documents to the study area

• Contractor shall allow two weeks for review of written and analysis deliverables or as agreed to by the contract administrator.

• Contractor shall furnish written and electronic documentation for all assumptions, data, calculations, and results. This includes paper and computer files (i.e. spreadsheets and analysis software files).

Inventory

• Counts should be broken down by type and duration as suggested in the Analysis Procedure Manual Chapter 3. For clarity, the count locations, types, durations should be identified on a map as follows:
  o Contractor (or ODOT/Agency) will provide 16-hr intersection classification traffic counts with 15-minute intervals at the morning and afternoon peak hours at the following locations:
  o Specific locations in list
  o [Note: Similar language is needed for any peak period counts or any road tube counts]
  o All counts must have at least 15-minute breakdowns from 2-6 PM. All counts must include bicycles, pedestrians, and turning movements.
  o State highway volumes and classification information is available here: http://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm

• Field inventory information – lane configurations, traffic controls, speeds, operational issues (queuing, unique driving behaviors, etc) will need to be obtained by the Contractor.

• If micro-simulation is desired, then Contractor shall obtain necessary calibration data.

• [Note: Use five years for projects, detailed plans (i.e. IAMP’s), or roadway/study areas with low number of crashes. Three (3) to five (5) years of crash data shall be obtained from ODOT’s Crash Analysis & Reporting Unit for state highways and any local roadways desired in the study area.]

Volumes
• All traffic volumes must be adjusted to reflect the 30th highest hour [Note: use the alternative standard (i.e. average volumes) if it applies to the study area].
• Areas that are covered by a travel demand model must use the model to develop future no-build and build alternative volumes.
• Contractor must submit a model request to ODOT’s Transportation Planning Analysis Unit (TPAU) at least three weeks before the data is needed. The model request form is available at: http://www.oregon.gov/ODOT/TD/TP/Tools/Model_Run_Request_Form_20130212.doc [Note: This is for travel demand models that TPAU has developed only.]
• All raw model numbers must be post-processed or used only in relative (percentage) comparisons.
Analysis

- Analysis locations will include at least the traffic count locations. Exact intersection analysis locations will be determined during negotiations.
- Traffic analysis must follow methods in the Highway Capacity Manual (HCM) 2010 published by the Transportation Research Board (TRB) or as agreed to by ODOT. All traffic analysis software programs used must follow Highway Capacity Manual 2010 procedures. Signalized intersections shall use HCM 2000 methods in order to produce intersection v/c ratios. Synchro/ SimTraffic is the ODOT standard software program and is the preferred format.
- Contractor shall prepare and submit a Methodology Memorandum documenting methodology and assumptions to be used for existing conditions (i.e. seasonal factors used), future conditions (i.e. volume development/post-processing methodology), and alternative analysis (i.e. peak hour factors, analysis parameters, calibration, etc) to TPAU and Region [1-5] Traffic Section. Consultant shall obtain approval of methodology from TPAU and Region [1-5] Traffic Section prior to beginning analysis. Consultant shall obtain approval of analysis and conclusions from TPAU and Region [1-5] Traffic Section prior to submitting Draft Tech Memos.
- [Note: for existing conditions] Contractor shall obtain the past five years of crash data from Agency’s Crash Data & Reporting Unit for both state and non-state roadways and perform crash analysis. Contractor’s data for state highways shall include locations of Safety Priority Index System (SPIS). If the local agency or region has established a critical crash rate for intersections or if each intersection type within the study area includes a minimum of 5 study intersections, Contractor shall use the Highway Safety Manual Part B Network Screening Critical Crash Rate method for intersections to compare intersection crash rates to a critical rate. Each reference population used in the critical crash rate method must have at least 5 (five) sites. If this is not met, intersection crash rates need to be compared with the published 90th percentile rates (See ODOT Analysis Procedure Manual Chapter 4).
- If the local agency or region has established a critical crash rate for segments or if each segment type within the study area includes a minimum of 5 study segments, Contractor shall use the Highway Safety Manual Part B Network Screening Critical Crash Rate method for segments to compare segment crash rates to a critical rate. If fewer than 5 segments exist for a segment type, segment data must be compared with the official published crash rates (ODOT Crash Tables – Table II) for similar facilities [Does not apply to urban areas]. Segments must be homogenous in number of lanes, area type, and volume.
- For intersections that exceed the identified critical crash rate and/or the published 90th percentile rate, crash patterns, evaluation of causes and potential countermeasures must be identified for each site. Consultant shall map locations of these safety issue areas and the Safety Priority Index System sites. Consultant shall utilize the Crash Data and MMLOS/LTS to identify potential countermeasures and safety improvement alternatives.
- For segments that exceed the identified critical crash rate or published crash rate and intersections that exceed the identified critical crash rate, analysis of crash patterns, identification of contributing factors, and potential countermeasures need to be completed. Contractor shall map locations of these safety issue areas and the SPIS sites.
- [Add to the above before the last sentence for projects and detailed refinement]
plans/IAMPs]. Contractor shall perform HSM Part C predictive analysis for all screened locations exceeding segment or critical rates for the existing conditions.

- [Note: Future safety for TSP’s, similar detail level plan, and project development screening] For each alternative developed to specifically address a safety concern, Contractor shall summarize safety impacts of each design. Contractor shall use the Crash Modification Factors (CMF) in the HSM Part D and/or the FHWA CMF Clearinghouse to indicate the potential crash reduction for each safety alternative or countermeasure. ODOT guidance on the CMF Clearinghouse is available here: http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/pages/crash_mod_factors.aspx. The ODOT CMF standard is to only use CMF’s with a quality rating of 3 stars or better.

- [Note: Future safety for projects or detailed refinement plans/IAMP’s] For each alternative developed to specifically address a safety concern, Contractor shall summarize safety impacts of each design using HSM Part C predictive methods. Full predictive analysis should only be completed on and reported out on the final alternatives (including the future no-build) to be included in the [plan/project].

- Consultant shall conduct a qualitative (“Good, Fair, Poor”) multimodal assessment for the Project Area collectors and above as per APM Chapter 14. The assessment analysis must include bicycle, pedestrian, and transit (if applicable) operations.

- Consultant shall conduct Level of Traffic Stress (LTS) analysis for all roadways in the Project Area as per APM Chapter 14. As much as possible, data should be obtained from current aerial photography and (TSP) roadway inventories before field data collection. Bicycle LTS will be evaluated and results graphically displayed for the existing conditions.

- Contractor shall conduct a high level MMLOS analysis for [indicate roadways to be studied] in the study area. MMLOS analysis must include vehicle, transit, bicycle, and pedestrian operations. Pedestrian analysis should not include the effective width of sidewalk data and calculations but rather assume a clear sidewalk width for each side of each segment. Bike analysis should use the link-level analysis only. Transit analysis should use as much general or average data from available transit district information as possible.


- Traffic analysis at non-state intersections needs to be compatible with ODOT procedures and must follow standard engineering procedures and practices.

- ODOT may approve a different or additional intersection analysis method prior to use when the different method can be justified for local and ODOT facilities. Contractor must provide documentation fully explaining the issue and the reasons for the proposed change. Contractor must obtain approval before use.

- Operational targets for state facilities should include the volume to capacity (V/C) ratio. Existing conditions and future no-build must be compared to the Oregon Highway Plan (OHP) v/c targets. Build alternative v/c’s are to be compared with ODOT’s Highway Design Manual v/c’s. Standards for non-state facilities can be v/c and level-of-service (LOS) or a combination of v/c and LOS, depending on the local standards.

- Other performance measures may be required which can include queuing, MMLOS,
Simulation-based MOE’s, etc. All secondary performance measures shall be included in the methodology memorandum.

- Simulation to determine queues or other measures of effectiveness should be used if v/c’s exceed 0.70 and simulation shall be used if v/c’s are equal to or exceed 0.90. Simulation shall also be used if existing conditions show congested conditions, (i.e. intersection queuing backs into adjacent intersections/connections) or if Agency requires it.
- If simulation is desired to obtain 95th percentile queue lengths or other measures of effectiveness, then the simulation shall be calibrated following procedures in Chapter 16 of the Analysis Procedure Manual.
- Areas with complex freeway geometry/operations, transit operations (bus, light rail, etc), railroad pre-emption, require simulation and shall follow the VISSIM Protocol available at: http://www.oregon.gov/ODOT/TD/TP/pages/apm.aspx

Air/Noise/Energy Traffic Data

- Air/Noise/Energy traffic data must be obtained and reported as in the Analysis Procedure Manual Chapter 17 or as agreed upon by Agency.

Coordination with other Work Areas

- If rail facilities are within the study area, coordination with the ODOT Rail Division is required.
- If the study area is adjacent to an airport or includes any overlay zones then coordination with the Department of Aviation is necessary.
- If studied facilities are formally recognized freight routes, then compliance with ORS 366.215 “Reduction in Capacity” may be needed if alternative concepts could potentially restrict the roadway width (i.e. curb extensions, medians, etc).

2.5.2 Developing Work Plans

Once a SOW has been determined, a detailed internal workplan that outlines the analysis tasks and timelines should be developed. This will help the analyst determine the analysis process necessary to achieve the SOW deliverables. For internal ODOT-only studies, where SOW’s are not developed, then a detailed workplan is required. This is typically developed by the project analyst and should be updated as needed. The workplan tasks should be developed to line up with the Sample Analysis Process Reviewer Checklist.

Exhibit 2-1 shows the typical traffic analysis work flow.

The work plan must include the project title, highway name and number, and a purpose statement to identify the project objectives. This work plan must be consistent with the overall project schedule and should be submitted to the project leader for review of timelines. This document will help explain to the project leader/contract administrator analysis and staffing/resource needs and timelines. At the very least, this will start conversation about project expectations. Delays or additional work requests will extend the timelines. The work plan should be updated as the study proceeds especially if major changes occur. A revision date should be on the first page of the work plan. A typical analysis will include most, but not necessarily all, of the following tasks. The tasks are not necessary linear, some may be concurrent or overlap while others provide feedback to other tasks.
The following example tasks assume a typical plan or modernization/safety project. This would need to be modified to fit any specific study.

- **Task 1 – Project Identification and Understanding**

  The purpose of this task is for the analyst to have an understanding to have a purpose and need of the study, the parameters and constraints that influence it, the questions that need to be answered, and to define the level of analysis and tools to be used.

  The methodology of this task should include the following which impact the analysis:

  - Study purpose and need and goals and objectives
  - Identify any prior relevant plans (i.e. TSP’s, refinement plans), analysis (i.e. prior/adjacent projects, traffic impact analyses) that need to be considered in the study area
  - Identify any concurrent project or planning efforts in or adjacent to study area. This will require coordination (i.e. data, timelines, project progress etc) between these efforts.
  - Identify any new data needs (such as need to update a travel demand model)
  - Identify any constraints or issues that may affect the project (i.e funding, natural or built environment, politics).

  Task deliverables includes a summary of any prior or current studies in or adjacent to the study area with issues, constraints, and impacts to the analysis discussed. A traffic analysis methodology memorandum may be appropriate if the work needs to be coordinated with multiple staff and or studies.

- **Task 2 – Transportation System Inventory**

  The purpose of this task is to review existing data and collect additional inventory data for the study area. Note: Allow 6-8 weeks from date of request for counts requested from ODOT.

  The methodology for this task should specify the following:

  - Count Request – This should include count locations, types and durations and any other special considerations. Refer to Chapter 3.
  - Field inventory data needed including, but not limited to the suggestions in Chapter 3.
  - Office inventory data needed including, but not limited to:
    - 3-5 Year crash information for roadways through study area
    - Available inventory data
    - Pertinent map/aerial photograph of area for figures
    - Roadway functional class, designations and planning information
    - State and local performance measures
  - If simulation, multimodal analysis, or predictive crash analysis will be needed then more extensive inventory data will be required.
  - Other optional inventory data that may be needed, depending on project.

  Task deliverables include inventory information, project area map and photo for use in
the following tasks.

- **Task 3 – Develop No-Build (Existing and Future) Design Hour Volumes**
  The purpose of this task is to develop base year, build year and future year no-build design hour volumes (30th highest or other alternative standard). Occasionally, other interim years may be needed such as air quality or project phasing (short-term fixes) issues. The base year is the year of the study, or when most of the data was gathered. The build year is the year that has the day of opening of the project. Generally, the build year is one year (for small projects like intersections) to two or more years (for large projects like interchanges) from the let date shown on the project prospectus. The future (design) year is typically 20 years from the build year. For example, a 2015 interchange project with a let date in 2019 would have a base year of 2012, a build/opening year of 2021 and a future/design year of 2041.

  The methodology for this task is to use the manual count data to obtain the existing/base 30th highest hour volumes (30HV) using historical and seasonal adjustments in Chapter 5. A single system peak hour must be used with volume balancing as appropriate.

  The future volume development methodology should be described, whether by historical trends, cumulative analysis, or with a transportation model (see Chapter 6).

  Task deliverables include the figures/worksheets showing the traffic volume development process and the balanced base 30 HV and future no-build volumes on figures in the technical memoranda for the existing and the future no-build conditions.

- **Task 4 – Analysis of No-Build Transportation System**
  The purpose of this task is to evaluate no-build system conditions for the base, build and future years. This may help identify any deficiencies related to the study purpose and need.

  The methodology for this task should use the base year, build year and future year data developed in Task 2 along with current Highway Capacity Manual (HCM)-based analysis software to evaluate the system by performing the following:

  - Use crash data from Task 1 and perform a safety analysis following procedures in Chapter 4. This needs to include a Highway Safety Manual Part B network screening process of locations before doing more detailed safety analysis. This should cover intersections and segments and use historical and predictive methodologies as appropriate.

  - Operational analysis including preliminary signal warrants, turn lane criteria, access/street spacing, and signal progression should be covered (see Chapters X, Y, and Z).

  - Evaluate the volume to capacity (v/c) and level of service (LOS) or other performance measures as appropriate by jurisdiction for the study area for intersections, merge/diverge/weaving sections, freeway mainlines and highway segments.

  - Perform multimodal evaluation (such as HCM 2010 MMLOS) across the pedestrian, bicycle and transit modes.
- Micro-simulation modeling may be needed if there are multiple signals involved or congested conditions exist. All simulations shall be calibrated according to APM methods. Simulation outputs should at least include 95th percentile queues, travel times, speeds, and overall hours of delay. Remember to allow the additional time (least a month) to calibrate the existing condition simulation model.
- Turn bay storage lengths will be compared to the 95th percentile no-build queues. Blocking of turn bays and upstream intersections must be noted if microsimulation is performed.

The task deliverable is a technical memorandum which includes the safety and operational analysis including the various performance measures. If simulation is used, then a calibration report will be required.

- **Task 5 – Evaluate Preliminary Alternatives (Screening)**
  The purpose of this task is to work with the project team to develop and screen the preliminary alternatives.

  The methodology for this task is to review goals and objectives with the team considering identified needs, and evaluate each preliminary alternative by comparing operations at major intersections or other agreed upon key location(s) for the appropriate years. Travel demand models can also be used to screen alternatives effectively if the alternatives have the potential to change traffic patterns beyond the local area. Travel demand model screening can include relative volume comparisons and link demand-to-capacity (d/c) ratios. The future no-build alternative needs to be included in the analysis as the baseline that the preliminary alternatives are compared against.

  Any comparisons using HCM-based v/c’s need to use the current Highway Design Manual (HDM) v/c’s. Travel demand model-based link d/c’s have different methodology and cannot be directly compared to the HDM v/c’s. Travel demand model-based screening criteria should be based on relative comparisons. Comparisons may also need to be made to local jurisdiction operational standards which could be LOS, v/c or delay based.

  The task deliverable is a technical memorandum, with the screening criteria and results shown for each alternative. A summary comparison table that shows how the alternatives and the future no-build alternative perform against the screening-level criteria and each other must be included. Recommendations for keeping or dropping alternatives based on traffic analysis considerations should be included.

  Note: Post-memo project team decisions on alternatives should be documented in the next technical memorandum on build alternatives and needs to be documented for the alternatives considered but dismissed section of the final memo/narrative.

- **Task 6 – Evaluate Build Alternatives**
  The purpose of this task is to work with the project team to develop and completely evaluate the detailed alternatives that satisfy the future transportation needs for this project. All tasks need consider timelines per alternative. Ideally, no more than three detailed alternative analyses are performed. Too many full–detail alternatives will result
in excessive time or budget requirements.

The methodology for this task is:

- Develop build and future year Design Hour Volumes (DHVs) for each of the final alternatives. Either distribute the no-build volumes on the build alternatives, or create new build volumes for each alternative if currently diverting traffic that would return with the new alternative is sufficient to invalidate the use of the no-build volumes.
- Operational considerations such as preliminary signal warrants, functional area, and turn lanes will be evaluated.
- Evaluate the v/c and LOS and other performance measures for the study area for intersections, merge/diverge/weaving sections, freeway mainlines and highway segments.
- Perform a predictive safety analysis if appropriate following procedures in Chapter 4.
- Perform multimodal evaluations across the pedestrian, bicycle and transit modes.
- Microsimulation of build conditions including determining turn bay storage lengths using the 95th percentile build queues and blocking of turn bays and upstream intersections.
- The output build v/c’s must be compared with the HDM design v/c’s for state facilities. Non-state v/c or LOS need to be compared with the appropriate local operational performance measure standard.
- Work with TRS/Region Traffic if new signals or changes to existing signals are involved. A progression analysis for the study area is needed if more than one signal is included in the alternative.
- Determine if access, intersection and interchange spacing meets or improves over current conditions in the OHP spacing requirements.

The task deliverables include a technical memorandum with volumes, v/c, LOS, queues, safety, multimodal, and other measures of efficiency shown on diagrams for each alternative, a summary comparison of the alternatives (including a table) and how they fared against the evaluation criteria and each other. Also, the design storage lengths and other geometric details need to be forwarded onto the appropriate design staff, either ODOT or consultant.

- **Task 7 – Environmental (Air/Noise/Energy) Traffic Data (If Needed)**
  The purpose of this task is to produce environmental traffic data for the no-build and build alternatives. The base year and no-build future year environmental traffic data can be started immediately after the Task 3 volumes are completed. The build alternative environmental traffic data should not be started until the final build alternatives are selected. Note: need to make sure that the data collection efforts properly support this task (i.e. ADT creation-capable classification counts).

  This includes the base year, build year and future volumes. Larger projects may also require the creation of short-term future year (10 year) data. The analyst should contact the air/noise/energy specialist(s) who will be using this information before beginning this task to ensure the correct information is provided. Air quality and energy data may or may not be needed. There may be some differences in data requirements from project to project, depending on the needs of the user of the data.
The methodology for this task uses the balanced hourly volumes, the average daily traffic (ADT), and the LOS C volume thresholds. The average daily traffic volumes will need to be developed and balanced for all needed years. The LOS C volumes will also need to be developed. This volume data, in addition to truck classification data, is needed for the base, build and future years to compute the environmental traffic data. The LOS C volumes (representational of the noise hour which is the maximum number of vehicles moving at the maximum speed) are only needed for noise analysis. Use the TruckSum summary spreadsheets and the EISBase program. Work with the noise consultant to confirm years and data results requirements. In congested areas, air quality data might be needed, which involves intersection LOS and number of stopping vehicles on each approach. Energy data may be needed on large projects of regional significance (environmental impact statements) which involves vehicles miles traveled.

The task deliverables include the environmental traffic data for the base, build and future years delivered to the air/noise/energy consultant(s). Diagrams are also required as the identification/location key for the data.

- **Task 8 –Traffic Analysis Narrative/Final Technical Memorandum**
  The purpose of this task is to prepare the written documentation of the project analysis. This will assist the project team in making the preferred alternative selection. For large or complex projects a full narrative report is required. For smaller projects such as single intersection safety or operational projects can be documented with a final technical memorandum.

  The narrative/memo should draw from, summarize, and discuss information from all of the previous technical memoranda and any other analyses into a stand-alone document. Draft and final versions will need to be produced. In addition, the final narrative/memo needs to have an engineer’s stamp as it is a document of record for the traffic analysis. The narrative/memo will document all of the selected and dismissed alternatives and may or may not make any recommendations.

**2.5.3 Typical Task Times**

Every project is different so actual task times can be quite different depending on project complexity, actual staff time available or overall project schedule (i.e. fast-tracked) to name some of the factors involved. Timelines should be defined by number of weeks required to complete each task. Target completion dates for each task should be established but should allow for overall analyst workload. For example, the timeline may show three weeks to complete the task if 100% of time was available, but if only 25% of time is available then the target date should be 12 weeks out. The final task timelines are negotiated with the project leader depending on the resources involved. Actual task timeline totals will depend on the overall size of the project, how many different years are analyzed, and number of alternatives/options to be analyzed.

Here are some general guidelines for typical studies:
Project Understanding/Scoping
- Allow at least two weeks to develop work plan, identify issues, constraints and impacts to analysis in review of existing/current plans and projects.

Counts/Inventory
- Allow six to eight weeks for counts to be completed and processed
- Allow at least two weeks if crash data is to be requested from the Crash Analysis and Reporting Unit
- Count timing – can add many months if the data collection window is passed

Volume Development
- Allow a month to create the existing 30th highest hour volumes
- Time to update a travel demand model if needed (6-12 months or more)
- Allow three weeks for model application requests to be completed
- Allow a month to create the future no-build volumes (including all interim years)
- Allow about two weeks to create volumes for each alternative
Analysis

- Allow at least four weeks to perform and report on alternative screening analysis. This will depend on number of alternatives and how many levels of screening to do (i.e. travel demand model relative comparisons followed by key intersection v/c’s).
- Allow two weeks for analysis of each build alternative

Simulation

- Allow one to six weeks for simulation model construction/error checking (depends on software)
- Simulation calibration – SimTraffic (two weeks to a month); Vissim (one month +)?
- Allow one week per alternative for simulation results

Environmental Traffic Data

- Allow one to two weeks to setup link diagrams, spreadsheets, etc
- For smaller projects allow one to two weeks per existing, no-build future and alternatives (three to six weeks total)
- For larger projects allow four weeks per existing, no-build future and alternatives (12 weeks total).
- Allow one to two weeks for review of data (dependent on reviewer’s schedule).

Documentation/Review

- Allow three weeks to write and review tech memos
- Allow a week for a reviewer to review the draft tech memos/ narrative (dependent on reviewer’s schedule).
- Allow four to six weeks to write and review draft narrative; two to three weeks for final publication
- Allow one to two weeks for completed deliverable review and comment

2.5.4 Reviewing Analysis Work

Often times an analyst may be required to review work conducted by others, whether it was performed within the Department or by a consultant. All traffic analysis work (either done internally by ODOT staff or by a consultant) must be reviewed by an Oregon-registered civil or traffic engineer. At a minimum, this can be a peer review if both the analyst and reviewer are Oregon-registered civil or traffic engineers. The reviewer should be the analyst’s lead worker/supervisor as they should be involved in the flow of the work. If the analyst is not registered, then the reviewer must be the lead worker/supervisor who is registered as they must be familiar with the work as the professional responsibility falls under them. Work performed by a non-registered consultant analyst must be reviewed by their registered lead worker/supervisor prior to submission to ODOT for review.

The review parameters such as who the reviewers are, what is going to be reviewed, and what level of detail the review will be must be documented before the review starts. At least one week should be allowed for the review of memos and reports. Individual review of analysis methodology, work in-progress, figures, etc should be completed in two or three days or less.

The following section provides general guidance for reviewing traffic analysis that can be
applied to any type of analysis project. Specific guidance for the review of TISs can be found in ODOT’s Development Review Guidelines.

2.5.5 Purpose of the Review

The reviewer should know what the purpose of the review is as this establishes what the review needs to cover. Some considerations include:

- **Audience** – is this only for internal, technical staff or is this to be included as part of a public document like a traffic study or guideline?
- **Completeness** – is this a rough draft to start a process or a discussion or is this to report analysis, discussions or decisions?
- **Full Documentation** – are there short-cuts taken like referring to other past memos/reports/projects? Note that report readers may not have access to the other reports. Reports should stand alone. For example, just stating that “US 101 in the project has an OHP mobility standard v/c ratio of 0.85 in Tillamook”, leaves out the missing classification information which includes items like what is the highway classification; expressway, freight route, or Special Transportation Area designations, etc.
- **Accuracy** - need to verify things like OHP/HDM standards, speeds, lane configurations and traffic control
- **Consistency** - thinking “outside the box” may be good in some cases, but it should not carry through freely to documentation as readers are looking for specific types of information and having to sort through pages of data can be difficult.

2.5.6 Organization and General Format

The report should be set up for the specific (target) audience, using words and sentences (word size and sentence length) appropriately with acronyms defined and used minimally. Most readers need some sort of organization, so thoughts should be grouped linearly (i.e. time, location, or process) or grouped by topic (i.e. safety, configuration/geometrics, policies/standards, procedures, and findings/conclusions).

The report should have good readability. Color does not always copy well as graphics may just turn into multiple impossible to differentiate shades of gray. Graphics should use patterns to distinguish different features as much as possible. Typeface size for general text should be at least a 12 point (or larger) and should be limited to standard fonts with few “extras” (i.e. Times New Roman, Georgia, Arial, Verdana). Footnotes in text, tables or figures should not be any smaller than 8 point. Remember that clarity dissolves with copying and not all programs use all fonts.

The format should be appropriate, so there should be “white space” instead of continuous lines of text. Paragraphs after paragraphs of text lead to low readability. Tables are better but can be complex especially if multiple variables are involved. Tables should make data easy to read by making comparisons and failing values should be emphasized (bolded, shaded, etc).

Drawings and figures are better than long-winded description paragraphs, but some text is still needed to point out or explain to the reader the important features, issues, key locations, etc. Numbers should be noted and balanced appropriately (i.e. future volumes rounded and not to the
2.5.7 Checking Information

A reviewer does not have to check every fact and figure, but should cover major sections and areas that would affect the results of the work. Some of these areas are:

- **Study Area** - When reviewing analysis conducted by others, knowledge of the study area is typically beneficial. The reviewer should first examine all study area mapping and photographs available and visit the physical site, if practical to do so.

- **Roadway Classification and Jurisdiction** - This establishes what type of road it is and who controls it. This will determine what overall performance measure to use (state or local) and the specific value.

- **Analysis Methods and Processes** – The document should state its purpose and need as that establishes the level of detail needed in the analysis, the answers that are needed and what the expected results are. Review the methodology memorandum to make sure that the assumptions and parameters to be used in the existing conditions, future conditions and the alternatives is appropriate for the level of detail of the work. As long as the work follows the memorandum, then the rest of the review is streamlined for both sides. Any disagreements need to be taken care of before analysis work is started to minimize rework and issues later. Keep in mind assumptions made by the analyst performing the work can have a significant effect on analysis results, even if specific analysis procedures are followed correctly.

- **Data** - With any type of technical analysis the proper collection and processing of data is critical to obtaining accurate results. Before reviewing the analysis itself, verify the data used is appropriate for the analysis conducted. Consider things such when was the data collected, type of data used, and whether any processing of data (e.g., volume balancing) was conducted correctly.

- **Appropriate Factors** – This means checking that the count data was correctly obtained and correctly seasonally adjusted to the 30th highest hour (or other applicable alternative standard). Are seasonal adjustments less than 30%? Are all the counts adjusted to a common base year? Are other analysis parameters correct such as the peak hour factor?

- **Spot Checks** – The reviewer should do a few quick checks by pulling the cited data and verifying correctness. With the given data, can the reviewer reproduce the seasonal and growth adjustments? Or can they follow the methodology used in a volume development or future post-processing spreadsheet? The calculations performed in the analysis should be checked for computational errors, and procedures used must be appropriate for the given situation and in compliance with accepted ODOT practices. Knowledge of the study area, prevailing traffic conditions and accepted ODOT analysis procedures will aid the reviewer in determining which assumptions are appropriate, and which are not.

- **Correct Processes** – Make sure that what is reported was analyzed with the correct program. For example, queue lengths in congested systems should be from a system micro-simulation program (SimTraffic), not just the program (Synchro). Also, make sure that methodologies cited in a scope of work, workplan, or a methodology memorandum, are being followed.

- **Correct Targets/Standards** – Once the adequacy of the analysis has been verified,
compare the results to ODOT’s adopted performance measures. Check any proposed mitigation against ODOT’s design standards. Often times the review process will require coordination with other units within ODOT that have specific expertise in, or authority over, certain elements of the design or approval of the mitigation proposed.

- **Reasonableness** - In addition to technical accuracy, the results of the analysis must be evaluated using a “reasonableness” test. The reviewer should compare the subject data, such as the traffic volume counts, lane configurations and traffic controls, and determine whether the conclusions and recommendations of the study are reasonable. This type of test often helps pinpoint sources of error in analysis, and may reveal questions likely to arise when the project is presented to the public.

- **Addressing Errors** - When sources of error are detected in the analysis, the reviewer should not only note the error itself, but acknowledge the significance of the error to the results of the analysis. There may be times when correcting the error would require a substantial amount of work, but the results of the corrected analysis would not be significantly different and the recommendations of the study would remain unchanged. Noting the significance of the error ahead of time will enable ODOT to determine whether correction is necessary or cost-effective.

### 2.5.8 Documentation

For a typical report, there should be documentation of the following:

- Study area map
- Methods and assumptions
- Applicable polices, standards, background conditions
- Local street and highway system including (pedestrian, bicycle, and transit modes)
- Data and inventory summary as well as source(s) of the information
- Traffic volumes (segments and/or intersections)
- Volume development – raw counts, system peak hour, adjustment factors, unbalanced volumes, base year, build (opening) year, future years
- Trip patterns/distributions
- Lane configurations
- Land use and zoning maps
- Circulation routes
- Existing or proposed scenarios/concepts
- Existing or proposed alignments/alternatives
- Existing & future no-build and build alternative analysis
- Summaries as appropriate
- Conclusions and recommendations
- Technical data included in appendices with electronic files available upon request

Missing sections or other errors/issues found should be addressed in a comment memo or Email, so the reviewer’s comments can be documented as well. Page, section and/or line number should be identified for easy reference. Many times the team/project or planning lead will be consolidating comment from a number of reviews.
Appendix 2A – Problem Statement Worksheet

Appendix 2B – Sample Analysis Process Reviewer Checklist
3 TRANSPORTATION SYSTEM INVENTORY

3.1 Purpose

Before any analysis can begin, data for the study area must be collected from the field or other available in-office sources. This chapter provides guidance in the selection criteria and collection methods of appropriate inventory data types for use in transportation analysis. Inventory data is the foundation that all other later decisions are based on, so it is important that the scope of the data collection is appropriate and adequate to support the needs/outcomes of the plan or project.

3.2 Office Data Resources

There is a wide range of data sources that can be obtained prior to the field investigation. Gathering this information gives the analyst a “feel” of the study area and what level of data is available, what may need to be verified versus gathered.

3.2.1 Crash Data

Crash data can come from a variety of sources, and is useful for identifying problem areas of the highway experiencing an above-average frequency of crashes or reoccurring crash patterns. The analysis procedures that use this data are described in following chapters, while the data itself is described below.

Sources of Crash Data

The following describes sources of crash related data and information. Tools available for the analyst to use in crash analysis are discussed in Chapter 4.

Oregon Motor Vehicle Traffic Crash Database

ODOT’s Crash Analysis and Reporting (CAR) Unit provides the official motor vehicle crash data through database creation, maintenance and quality assurance, information and reports and limited database access. Crash data since 1985 is maintained at all times. Vehicle crashes include those coded for city streets, county roads and state highways. The CAR Unit website offers a variety of publications containing information on monthly and annual crash summaries.

Although there are other sources of information, such as police departments, local groups that collect information, and anecdotal information, the ODOT CAR Unit data is the standard source. Oftentimes these other sources include reporting calls, not the actual investigation/report, and groups often include near-misses and/or don’t have all the facts, so the report is erroneous. The CAR data has the checks and balances built into the data collection that matches “both sides of the reports” for a crash, treating all areas the same so comparisons can be made. This is also the
database used to calculate all the comparison rates published in the crash rate books.

The CAR Unit obtains documentation of reported crashes from DMV and other sources which they use to code the crash database. It should be noted that not all crashes are reportable, not all those that should be reported are reported, many of those reportable are filed out by citizens with attendant limitations on data accuracy, and even those law enforcement reported may have issues with accuracy. The documentation provided to the CAR Unit can range from being very thorough to very limited and can include conflicting or incorrect information. The documentation is carefully checked and may be corrected before being coded. Crash codes are defined in the ODOT Traffic Crash Analysis and Code manual, available on the TransData Crash Data webpage. For detailed information about the coding process contact the CAR Unit.

Depending on the level of analysis needed, there are various reports that can be obtained. It should be noted that even though this database often represents the most current data available, data for a given year is typically not available until at least 6 months into the following year.

Detailed information for individual crashes can also be obtained by contacting the CAR Unit and specifying the segment of highway (roadway) and time period of interest. Because crashes are reported by specific points, an issue may be located just outside of the analysis area. Therefore, the area of requested crash data should always be greater than the area of analysis. The additional distance should be enough to catch the character of the road such as the adjacent blocks in an urban setting and a quarter to half mile in a rural setting.

Crash data is always available from the CAR unit and should be obtained through them for complex, controversial or legal situations since they are the official reporting source. For most analysis efforts, using the on-line reports is sufficient. Crash data is available on both state highways and local roads on the ODOT Internal Crash Reports website or the External Crash Reports website.

Crash data is requested by state highway number and milepoint for specific years. Local road crashes are available at the above websites by clicking on the Local Roads tab.

Crash information is categorized first by county, then city and finally by street name. Selecting the summary detail will bring up the entire length of the roadway. The summary is only useful when the entire roadway in within the study area. If only a portion of the street is desired, the data needs to be obtained from the comprehensive report (PRC). The analyst will need to review the report and select the appropriate crashes to summarize for use in the analysis.

While several years of data may be available for any given roadway segment, it is common practice to analyze only the most recent, complete three to five (3-5) years of data as factors such as traffic volumes, environmental conditions and roadway characteristics may change with time. Three years of data gives a minimal picture and is the minimum analysis period for a safety analysis, while the five year listing gives a more desirable view. Roadways with a small number of crashes should be looked at through a five year period to get a better representative sample. In some circumstances even a longer period may be reviewed. Also, remember that the crash databases are regularly updated to include more recent data, so care should be taken to select the
correct timeframe(s).

**Safety Priority Index System**
The Safety Priority Index System (SPIS) is a method developed by ODOT in 1986 to flag potential safety issues on state highways. Major revisions have occurred from the original process. The SPIS score is based on three years of crash data, and considers crash frequency, crash rate and crash severity. ODOT bases its SPIS on 0.10-mile segments to account for variances in how crash locations are reported. To become a SPIS site, a location must meet one of the following criteria:

- Three or more crashes have occurred at the same location over the previous three years.
- One or more fatal crashes have occurred at the same location over the previous three years.

The use of this information is discussed in the Safety Chapter (4) and the documentation on how the SPIS is calculated can be found at the Safety Priority Index System website. Any SPIS listing can be obtained by ODOT staff. Non-ODOT analysts can obtain the SPIS listing by contacting ODOT Region Traffic personnel. Top 5% and 10% sites need to be included in any crash analysis of a study area.

**SPIS-All Roads (Internal Use Only)**
The program is a tool internal to ODOT which is a variation of the standard SPIS program. SPIS-All Roads contains crash data for local roads as well as the state highway. It allows the data to be filtered based on specific fields and then have the SPIS calculation reported.

**TransGIS Mapping Tool**
TransGIS is a web mapping tool designed for users of every skill level. It presents many data levels in an interactive map format in multi-level views. This mapping tool provides more detailed information on many types of safety, volume and crash data on a state map. The user can choose the information that is displayed, and can zoom into the map to increase detail as well as display city and county maps behind this data. Extensive work with individual layers may be required in the generic TransGIS application, to obtain all necessary information about a study segment. A decoded crash layer is available

For external access to the newer TransGIS 2.0 follow the link and click on “New TransGIS 2.0”

The ODOT GIS Unit may be able to produce custom maps or applications in some cases, depending on the nature of the request and work priorities. GIS maps or web applications may be possible, as well as additions to TransGIS. A web application is a custom TransGIS website with pre-defined layers. GIS software is not required. The user can zoom in/out and turn layers on/off as desired. The application may be permanent or temporary, as needed for the duration of the project. Examples are located on the GIS Unit Applications Webpage.

All requests for mapping products are submitted to the ODOT GIS Unit (GISU) from ODOT staff. Consultants may initiate a request through ODOT staff. Requests should be clearly defined prior to submittal to avoid re-work. Contact the GIS Unit for further information. Custom
mapping requests need to use the GIS Project Request form which is available by contacting the GISU.

**Crash (Collision) Diagrams**
Crash diagrams are typically used to evaluate operational and safety projects, not analytical ones. The typical project and planning analysis would not require this level of detail. The CAR Unit can create a crash diagram that depicts the crashes on a given roadway section. Depending on the size of area requested and the number of crashes in the requested area, this can be time consuming. For more information, refer to the ODOT Safety Investigation Manual available on the [ODOT Highway Safety webpage](http://www.odot.org).

**Crash Rate Tables**
Crash Rate Tables have been published annually by the CAR Unit since 1948. Tables in the front of the book list statewide crash rates for several categories of the State Highway System. More tables list the crash rates for selected sections of each state highway, as well as a rural/urban break out. Additional tables list intersection crash data and fatal crash data. These tables are discussed further in the Safety chapter and are available on the [CAR Publications webpage](http://www.carweb.org).

### 3.2.2 Roadway Data

ODOT maintains a wide variety of roadway characteristic and features data in Transviewer which is available on the [ODOT Transviewer webpage](http://www.transviewer.ohio.gov).

TransGIS including the newer TransGIS 2.0 is available on the ODOT [Internal TransGIS website](http://transgis.ohio.gov/) or the [External TransGIS website](http://transgis.ohio.gov/).

These sites are also available on the [Consultant Portal](http://consultant.ohio.gov) under the Data and Reports section on the ODOT Internet site.

This data includes and is not limited to:
- Roadway alignment – horizontal and vertical (grades)
- Roadway cross-sectional data – lane, shoulder and median widths
- Roadway features – pavement type, number of lanes, speed limits
- Roadway details – structures, connections, mile points and equations
- Segment Vehicle Classifications and Characteristics
- Summarized Traffic Information

Other data sources are also available through the above links. They include:
- Digital Video log
- Traffic Count Information
- Functional Classifications
- Highway Classifications including freight routes, scenic byways
- Operations and Performance Standards including spacing and mobility
- Design Standards
- ODOT generated maps

Additional Data that should be located includes:

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Transit Information
The following information is likely needed from the local transit authority
- Transit vehicle characteristics
- Route specifics such as paths, schedules, dwell time, headway
- Passenger boarding/alighting and occupancy data
- Transit specific control and timings

Traffic Signal Timing Sheets
Traffic signal timing sheets are needed when creating analysis files. The best source of current information for state highways is through the Region Traffic Engineer. Occasionally, the local jurisdiction will be responsible for the signal timing, so they are the source of that data along with any local signalized intersections of interest.

Traffic Plan Sheets (If available)
An analyst should obtain information related to the roadway and traffic control for the intersections of interest. Specific details such as the detector layouts and striping sheets are available for many areas. Digital PDF copies of signing, striping and signal plans are available at the FileNet Workplace website. This file sharing site is searchable. You can obtain this information by logging in as a guest.

Other useful information
Information such as zoning and local classification maps needs to come from local jurisdictions. Private entities may have aerial photos also available. Although on-line data sources such as NAVTEQ, Google and Bing may yield useful (scalable) information, they can also contain information that is not very current and may not be consistent between overhead and street/driver views. Street names often differ from the official names. Information from these sources needs to be verified.

3.2.3 Reports and Tools

Transportation Planning On-line Database (TPOD)
This is a map-based, graphical tool for locating planning studies within a specific area. This may include but is not limited to Transportation System Plans (TSP), refinement plans, Interchange Area Management Plans (IAMP) and others that may have factors that significantly impact the study. For example, a TSP may include alternative mobility standards, local jurisdiction’s operational standards, fiscally constrained project list and many more. Because this tool is only updated periodically, the most recent reports likely are not included in the data. Contact the region planning manager to verify.

FACS-STIP
This is an ODOT Asset Management database in both listing and map-based forms. Information includes data such as sidewalks, bike facilities, ADA facilities, access locations, and some traffic features. This is an evolving database that is being continually expanded as data is collected. The tool is available at:

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In addition to gathering data from TPOD and other on-line databases, the analyst should determine / locate other studies that may have bearing within the study area, including previous (related) studies, Safety Investigations, and Traffic Impact Studies. The analyst should contact local jurisdictions, the Region Traffic Manager, the Region Access Management Engineer (RAME) and the Region Planning Manager to locate any of this work.

3.3 **Field Inventory**

Specific data related to field conditions that may affect traffic safety and operations shall be collected directly during a visit to the area. In addition, inventory data collected through other sources such as previously conducted studies or databases maintained by the road authority should be field verified. There is no substitute for a field visit as an analyst cannot get a good feel for the project area otherwise. This is a check of other data sources (such as aerial photos) for accuracy. Notes, photographs and/or video should be taken of the project area in addition to the inventory data to reference, and possibly include, as graphical elements in the final report. The most common types of field data needed are discussed below.

3.3.1 **Geometric Data**

Geometric data is the physical characteristics of the facility, typically including:

- Street names
- Segment lengths
- Lane/shoulder/median widths
- Lane configurations
- Storage bay and ramp taper lengths
- Acceleration and Deceleration lane lengths and tapers
- Storage bay lengths (from stop-bar to start of taper)
- Bike/multi-use facility locations and dimension
- Parking locations and dimensions
- Raised medians/pedestrian refuges/islands locations and dimensions
- Location of stop/yield bar, intersection guidelines (dashes)
- Pedestrian facilities (type, condition, location) including crosswalks dimensions (length and width)
- Intersection and access spacing
- Access type, location, width and land use served

3.3.2 **Operational Data**

Operational data describes the characteristics of traffic control and flow, and typically includes:

- Speed limits
Saturation flow, speed and travel time studies
Intersection controls (signalized, stop-controlled, yield, merge, etc.)
Signal characteristics (timed, actuated, split-phased, protected left turns, etc.)
Signing (especially turn prohibitions)
Parking signing, striping, and maneuver frequency
Pedestrian crossings including at crosswalks and improper (jay-walking) frequency of use
Transit stop locations and amenities
Rail crossing locations, train frequency and duration of blockages
Intersection sight distance

3.3.3 Field Observation Data

Observations related to travel patterns and driver behavior. This can include:

- Perceived or actual operational problems
- Length and duration of queues
- Driver behavior for lane choice, turn paths, upstream and downstream movements or maneuvers, left turn “sneaker” (left turn drivers that turn enter and depart the intersection during the yellow or red intervals)
- Pedestrian, Bicycle or other user behavior including actual travel paths
- Evidence of crashes such as glass on the shoulder, tire marks on curbs or medians
- Tire wear on pavements
- Damaged or worn physical features

3.3.4 Simulation-Specific Data

In addition to the geometric and operational field data, additional simulation specific data is needed if a project requires simulation. Simulation-specific data typically may include:

- Number of detectors, length, and distances from stop bar or crosswalk
- Turning speeds and radii (if unusual geometrics or conditions exist)
- Free-Flow speeds on ramps, highway segments, or on intersection discharge legs approaches (can be collected using road tubes or speed guns)
- Floating car travel times and average speeds
- Important travel patterns (OD Data), Example: ~75% of traffic exiting the mall makes left at Main Street
- Lane Use
  - Details of user specific lanes (e.g. HOV, truck/bike/bus)
  - Use of the shoulder or median to move around blockage points or due to driver confusion/disregard
  - Lane-change positioning lengths or landmarks where vehicles tend to position themselves in a lane to make an upcoming turn or merge
  - Freeway/arterial guide sign locations (for lane change distances)
  - Noticeable lane imbalance issues (some lanes used more heavily than others) and
causes (i.e. lane drops, multiple turn lanes, closely spaced intersections/accesses, etc.)

- If more than one lane is available to turn into from an approach, indicate the lane that turning vehicles align into (left or right alignment) regardless if the movement is legally proper or not.

- List the approximate average and maximum queues for each lane
- If upstream intersections or bays are blocked by congestion from the observed intersection, what percentage of the site visit hour did blocking occur <5%, 10%, 25%, 50%?
- Arrival type for each approach (i.e. are the vehicles arriving in a platoon, if so, are they arriving on red or green?)

### 3.3.5 Safety-Specific Data

Additional data beyond the general geometric, operational, and observation data may be needed to support Highway Safety Manual techniques (See Section 4.4.4). Safety-specific data may include:

- Fixed object density and average distance offsets
- Intersection skew angle
- Presence/absence of centerline rumble strips, lighting, red-light cameras, and automatic speed enforcement
- Number of schools, bus stops and alcohol-selling establishments within 1000’ of an intersection.

### 3.3.6 Field Data Collection Requirements

For studies not needing simulation, the field inventory data is recommended as it can help the analysis.

For projects requiring simulation, the simulation specific field data and counts MUST be collected at a time representing the analysis time period (the 30th highest hour) as closely as possible. The simulation calibration data should be obtained by the analyst conducting/overseeing the simulation work. This effort should occur during the vehicle count collection if feasible. See the Simulation Chapter for guidance and instruction on calibrating simulations.

With some project areas, it is impractical to obtain all counts and inventory on a single day representing the 30th highest hour. When this happens, the counts and field inventory at the primary locations should be on days that closely represent the 30th highest hour. If it is not possible, then short sample counts should occur during the field inventory collection to factor the off-peak counts to the day the study area was visited. Factor the counts for seasonal influences (described in Chapter 5). If this is the case and simulation is required for the study, use the seasonal factor methodology to determine if the vehicle count day is representative of the 30th highest hour.

If the study’s primary counts occurred at a time that is more than 10% different than the 30th highest hour period (considering seasonal trend type) then short duration sample counts need to
occur during the field collection time to calibrate the “existing conditions” model. The counts need to be at critical locations (high volumes, bottlenecks, unusual conditions) to assist with representing the traffic flows. These rules are established to help ensure that calibration volumes 1) are near the 30th highest hour and 2) represent conditions that have been witnessed in the field.

3.3.7 Field Inventory Worksheet

The Field Inventory Worksheet has been designed by TPAU to be generic enough to aid in the collection of field data for all studies. The Field Inventory Worksheet, Exhibit 3-1, assists the field data collection process. The worksheet is an example of how to organize/document the information. It shows much of the suggested information, but it should be customized according the study’s needs. The worksheet can be used for projects where just geometry and observational data is required or for projects requiring simulation where all the data listed above should be addressed. Exhibit 3-1 shows a completed worksheet for a simulation project. Note that the worksheet may be printed multiple times for a given project area. The collection of worksheets can be placed in a three-ring binder providing a hard writing surface. A worksheet can be used for each intersection or area of interest in the study and all copies can be neatly organized in a single project binder.

Exhibit 3-1 Field Inventory Worksheet - Intended Setup
3.4 Vehicle Count Surveys

The data collected from vehicle count surveys is used in nearly all types of analysis procedures,
and can include information regarding volumes of vehicles, types of vehicles, vehicle speeds and directions of vehicle flow. When such information is needed, the analyst must determine the appropriate time and method of data collection to obtain the desired results.

How many counts of what type is dependent on the context of the plan or project goals and objectives. For outsourced projects and plans, a draft scope/work plan with a completed objective section is critical for efficient use of time, money and data for all involved parties. The level of count detail required will be dictated by the level of detail in the plan or project. For example, Transportation System Plans (TSP) will be less detailed than a TSP Refinement Plan.

### 3.4.1 Vehicle Count Types and Durations

**Intersection Classification Counts**

Intersection classification counts provide vital information for project development. They provide peak hourly volumes (PHV), Average Daily Traffic (ADT) and vehicle classifications such as cars, pickups, buses and trucks for each approach and movement. Additionally, the K-factor (percent of ADT in the peak hour) and the D-factor (percent of traffic in a single direction) can be derived from the intersection count data. These are then used to convert PHV to ADT. For further explanation of traffic volume characteristics, refer to the HCM – Part I: Overview.

Intersection classification counts are typically 16-hours in duration, so average daily traffic (ADT) and other relationships can be created. These counts are used at signalized intersections, intersections that may become signalized, and other important major intersections, such as interchange ramp terminals. A 16-hour count is needed when requirements exist such as multiple peak periods, truck classifications, signal warrants, pavement design, air quality and/or noise studies in environmental documents. Sixteen-hour counts can also be easily used for other purposes such as pavement design (see Chapter 6) or other plans or projects. The average cost of an ODOT-performed 16-hour Full Federal Manual Classification Count is approximately $1,100 (2012 costs). This cost is dependent on the complexity of the intersection, whether or not it’s a high-volume intersection, and other special requirements including travel.

Intersection classification counts group 13 different types of vehicles, pedestrians and bicycles. Refer to the FHWA vehicle classification descriptions in Chapter 6 and in the Environmental Traffic Data Chapter. Classification counts can either be done manually in the field or by use of video cameras. ODOT typically uses video cameras as it does not require the presence of a field technician throughout the duration of the count, may have less influence on driver behavior in some situations, allows for more flexibility in scheduling and processing counts, and provides a database that can be easily revisited if more information is desired at a later time or if an error in the count is detected. Data is recorded in the field and is then sent to the Transportation Systems Monitoring (TSM) Unit for processing.

Passenger and other two-axle vehicles are tabulated both with and without trailers. The number of axles for single-unit trucks and for all single, double and triple trailer trucks is recorded along with buses and motorcycles.

A number will be given to each count so that it can be accessed easily. A hardcopy will be stored
in TSM’s files. Counts are sent to the requestor either electronically as a spreadsheet file or hardcopy by mail. The first page of the ODOT intersection count provides a sketch of the intersection counted, the date, location, count number and the ADT for each movement. The second page provides a summary of movements broken down into 1-hour increments. Some intersection counts will break the peak periods into 15-minute intervals instead of 1-hour intervals. Specify 15-minute count intervals for any period when peak hour factors are needed. The rest of the pages show individual turning movements with the vehicle classifications, a summary of the bicycle and pedestrian counts (if originally requested) and a summary of the movement volumes. Sample Count Request and Sample ODOT Counts have been included in Appendix 3B.

**Peak Period Counts**

Peak period counts capture the individual vehicle movements at a location. These counts are typically used to capture the in/out turning movements at driveway accesses or to count all movements at minor or unsignalized intersections that are not being considered for signalization. Generally, separate truck percentages are not available. Use of turning movement counts are limited to counting in a single peak period. Typical peak periods are morning (6:00 AM – 9:00 AM), mid-day (11:00 AM – 1:00 PM), and evening (3:00 PM – 6:00 PM). A three-hour count is a typical duration to capture the peak hour. A four-hour afternoon peak period count can be obtained to capture both school and commuter peaks. Truck peak hours could be any hour outside of the typical commuter peaks so are unlikely to be captured by a peak period count. For count durations of more than four hours or when more than one peak period is needed, it is more practical to collect a 16-hour count. Count durations less than three hours make it difficult to capture the peak hour and should be avoided unless previous counts clearly identify the system peak hour in which case shorter duration counts may be acceptable. Typical ODOT count costs are variable depending on travel, duration, and other specifics, but are in the $600 (2012 costs) range.

> **Note:** Peak period counts cannot be used to create daily traffic volumes (ADT). Daily volumes are needed to support Highway Safety Manual analyses, air/noise traffic data production and any signal warrant work.

**Road Tube Counts**

Road tube counts are often employed when the details provided by intersection counts are not needed, impractical given the data needs, when certain additional data is needed that would best be collected by tubes, such as roadway speed (Section 3.5.2), or available gaps in traffic. These count individual vehicles only or can be setup to capture vehicle classifications. These counts are used to capture mid-block volumes on streets and for segment volumes on most highways and interchange ramps. Road tubes are subject to vandalism or damage, and should not be done where vehicles may stop on the tube (in congested areas or near intersections) or cross the tube at an angle (near intersections or driveways) because under or over-counting may occur. Tubes are also susceptible to be damaged on roadways with speeds at or above 40 mph, and for employee safety reasons, cannot be placed on high-volume expressways and freeways. It is also not recommended to use road tubes during winter months (November 1<sup>st</sup> – April 1<sup>st</sup>), due to the use of studded tires, which have been shown to destroy hose tubes, even at slower city speeds. Road...
tube counts are typically done in a 48-hour format so an entire 24-hour period can be obtained. A 7-day count can also be done if daily fluctuations over a week are necessary to be captured and are only done on roadway segments. Typical ODOT road tube count costs are around $200 (2012 costs).

3.4.2 Other Sources of Traffic Data Information

Frequently, existing or alternative count sources are overlooked so these should be reviewed before completing the initial count list. This can, in some cases, substantially reduce the number of new counts, save on data collection costs, and cut down the number of SOW review iterations. When searching for older traffic counts, generally the counts should only be a few years old (3-5). The longer period may be acceptable when there is little to no change in volumes or when developing a preliminary analysis. When counts are older than three years, growth rates may not reflect the growth when much change is occurring. The further the count is being interpolated, the more likely for error to be introduced. See Chapter 6 for information on forecasting.

Transportation System Monitoring (TSM) Unit Data

- Previously Collected Counts

Besides obtaining new counts there are some other sources of count information which may be used to reduce the overall new count requirement needs. ODOT has a large quantity of traffic volume data and previously collected counts. Before any new counts are ordered, the Transportation System Monitoring (TSM) Unit should be contacted to determine if any previous usable counts are available for the study area.

In general, counts in the study area should be three years old or less. Older counts between three and five years old can sometimes be used if they are the correct type and no significant changes, such as new roads or developments, have occurred to influence traffic flows. A newer count may not accurately represent the traffic flows on a roadway section even if less than the three years old if recent development has occurred within or near the study area since the count was taken.

If you have the specific count identifier of a previous count, the count can be requested from the TSM data analyst who can send either an electronic or hardcopy version of the count.

Typically, internal ODOT staff can access prior counts through the Traffic Count Management Program (TCM). This program requires approval from TSM to obtain access to the program. Also, some vendors maintain and sell traffic data from a compiled database.

- Transportation Volume Table (TVT) and Highway Performance Monitoring System (HPMS) Count Sites

The 48-hour tube counts used for the development of the TVT and at HPMS sample sites are available from TSM. These counts are collected in 15-minute intervals at a minimum. Some TVT and all HPMS counts have vehicle classification information as well. (Note: Volumes listed in the TVT are for a single point, not the entire segment).
State Highway Vehicle Classification Data

State Highway vehicle classification information is available through the TSM Unit’s Internet Traffic Volumes and Vehicle Classification webpage. Exhibit 3-3 shows an example excerpt of the State Highway Vehicle Classification Report. This report is also the source of information for highway segments AADT. With this information, the daily and hourly volumes can be obtained along with truck classifications which will substantially reduce the need for 48-hour road tube counts. Vehicle classes 4 through 13 are considered trucks for most applications, including Pavement Design and HCM analysis. However, class 3 vehicles may be considered light trucks in some software.

Note that volumes listed in the State Highway Vehicle Classification report are for segments, as shown in Exhibit 3-3. A beginning mile point is shown for the starting point of each segment. Volumes listed in the Transportation Volume Tables are for individual points, as shown in Exhibit 3-4. The mile point shown is where the traffic count was taken.

Exhibit 3-3 Excerpt from State Highway Vehicle Classification Report

Exhibit 3-4 Excerpt from Transportation Volume Tables

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• **Automatic Traffic Recorders/Automatic Vehicle Classifiers (ATR/AVC) Sites**

ATR and AVC sites record bidirectional volumes on an ongoing basis and can be used as substitutes for classification and regular road tube counts. ATR sites only include bidirectional volumes, but to understand vehicle classifications, every ATR site is also counted with a 24-hour classification count every three years which is available from the TSM Unit. AVCs continually classify data so classification data will be available throughout a given year at these locations. AVCs are gradually replacing ATRs so eventually all recorder sites will have classification abilities. ATR/AVC “Critical Hour” listings are also available which breakdown a year’s worth of data down to the hour level so a 30 HV can be easily obtained at that location.

• **Ramp Volume Diagrams**

While 16-hour counts at an interchange ramp terminal are preferable, the ramp volume diagrams in the Transportation Volume Tables and on the TSM Unit webpage can be used to substitute if a count is not available and intersection turn movements or intersection operations are not desired. Many of the interchange ramp volumes have 48-hour tube counts that were used to create these volumes, so an analyst should check for their availability. These counts are taken on a 3-year schedule. Free-flow ramp volumes (i.e. between two Interstate highways) can be obtained from the diagrams if a 48-hour tube count is not available or practical. The TVT ramp volumes are balanced and may not represent the actual count volumes. Contact the TSM Unit directly if the actual count is needed.

**Other Jurisdiction’s Counting Programs**

In addition, some counties and larger cities may have traffic counting programs in place. The TSM Unit webpage also has links to many of these jurisdiction’s Internet traffic data pages on the Traffic Counting Program webpage.

These counts are typically daily volumes and can be used to supplement the local system and can reduce the need for 48-hour road tube counts. Sometimes intersection counts are available, but differing classification breakdowns and durations from ODOT standards can make these difficult to use except for a source for local peak period counts.

**Traffic Signal Controller Counts**

The new Model-2070 and earlier Model-170 traffic signal controllers have the ability to store loop or video detection information that can be downloaded at a later date. This data is attractive to the end user as there are a large number of usable installations available. Controller count data is primarily used by Region signal timers, when preparing field refinements to signal timing plans. For traffic analysis, controller counts are useful in determining trends between weekday and weekend traffic, or in establishing relationships for side streets (i.e. seasonal adjustments). It is imperative to have a copy of the loop detector diagram for the specific intersection, when deciphering both Model-2070 and Model-170 controller count data. The Model-2070 controller stores the data in up to 32 columns or bins, depending on the complexity of the intersection, with
two loops per detector phase (standard). However, field modifications may differ from the “as-built” plans, which is why a current detector diagram is necessary. The most recent detector diagrams can be obtained from the various Region Tech Centers.

**Special Vehicle Counts (short duration)**

Frequently on projects, there is a need to collect additional peak hour data for driveways, for a check count, or other overlooked spot. Sometimes these counts are done for specific purposes such as capturing headways, weaving movements, or saturation flow rates for simulation calibration. These counts typically are collected by the project analyst rather than region or consultant counting staff. Counts longer than an hour or in many locations should be done by region staff, TSM staff or traffic count contractors.

These counts can be manually tabulated in case of a number of small adjacent driveway counts, or use of a video camera or electronic count board. Video cameras can be useful assuming that a good vantage point is available that will provide a clear view of all movements being counted. When using video cameras to collect count surveys, be sure to have an adequately charged battery and large enough media to collect the amount of data needed.

Typically, when counts are not done by video, some sort of handheld electronic count device is used. One of these is the JAMAR board which has been used by ODOT in the past to collect counts. Limitations of the JAMAR boards prevent using these to do a full 13-class count. However, the boards can be used for volume-only or limited class counts. These counters are necessary for saturation flow data capture or other simulation/operational data (see the Simulation Chapter). The JAMAR traffic count is in raw form which can be downloaded to a text file through the use of the serial cable and a communications program. Detailed instructions for this process are available on the Planning Section Technical Analysis and Tools webpage.

### 3.4.3 Vehicle Count Periods

For most traffic studies, the 30th highest hour volumes (30 HV) should be used to represent future volumes. It is recommended a top 200- to 500-hour count listing (Critical Hour) of the ATR(s) is obtained from the Transportation Systems Monitoring Unit. The 30 HV at the ATR(s) will be included in the list so that it will be possible to determine when the 30 HV occurs during the day and in the week. Manual counts can then be timed for the period when the 30 HV will likely occur, minimizing seasonal adjustments. Exhibit 3-5 illustrates the general process for identifying when the 30 HV occurs. Refer to Chapter 5 for detailed guidance on each of these steps.
To get a typical traffic mix of the 30 HV for the analysis, the counts should be taken as close to the likely 30\textsuperscript{th} highest hour as possible. This typically requires collecting counts on a weekday afternoon in most larger urban areas, but may include weekends for high recreation areas (the coast or Central Oregon), or areas experiencing lunch hour peaks or high reverse direction flows during the day. Where capturing school trips is important, counts need to be taken when school is in session. In some cases two sets of counts may be needed, during months when school is in session as well as during the summer. In fully developed portions of Metropolitan Planning Organization (MPO) areas, the 30\textsuperscript{th} highest hour is generally assumed to be represented by the
typical weekday evening commuter peak hour. Outside of fully developed MPO areas, a seasonal adjustment will be required to convert the counts to 30 HV. For access management, the peak hour is defined as the highest one-hour volume during a typical or average week in urban areas, and the 30th highest hourly volume on rural roadways.

Seasonal adjustments should not be more than 30% because the traffic flow characteristics are most likely NOT represented by the count information. A seasonal adjustment greater than 30% indicates that the count was taken at the wrong time of year. Turn movement patterns may be so different they cannot be adequately represented by a seasonal adjustment. Count timing is critical especially if the project/plan SOW will not be complete until after October. Please refer to Existing Volume Development (Chapter 5) or contact the Transportation Planning Analysis Unit (TPAU) for advice.

Counting Considerations to Minimize Seasonal Adjustments

- Coastal or summer recreational areas should be counted during the traditional summer period (Memorial Day to Labor Day). Outside of coastal/recreational areas, most areas can be counted from March to October. Larger MPO areas or commuter-based corridors can be counted most months, but should generally avoid December to February as these are the lowest traveled months, have a number of holidays, and have the most weather-related problems. Winter recreation areas (i.e. Mt. Hood area) should be counted in the December to February timeframe to capture the peak periods. Recreational areas (or routes that travel to or between recreational areas) may require counting on the weekends.
- If alternate periods/volume thresholds other than the typical summer or 30 HV like what would be used to create an alternate mobility standard, then counts need to be taken in those alternate periods so resulting seasonal factors do not exceed 30%. This might mean for certain efforts, multiple sets of count data may be required. For example, a summer recreational area that uses a non-summer standard, counts should be obtained in the non-summer (Oct-Apr) period. For areas that use an annual average, counts should be obtained in Sep-Oct and/or Apr-May periods. Winter or winter-summer recreational areas will be a variation/combination of the methods.
- Road tube count placement is limited to the April to October period because of studded tire damage potential.
- In general, days potentially influenced by state or federal holidays or other significant events (such as local festivals, sporting events, hunting season, etc.) that may alter normal traffic patterns should be avoided.
- Counts that may be influenced by nearby construction projects may be affected and such counts should be thoroughly investigated and may require adjustments.
- It is also common to avoid Monday and Friday counts when weekday data is desired, as the trip characteristics on these days generally differ from the remainder of the week.
- Consideration should be given to the presence of generators such as schools/colleges/universities because of the enrollment and events (such as spring break) can vary greatly through the year. Consideration should also be given to major employers or attractions such as regional shopping centers that experience significant peaks in generated trips that may or may not occur during the other peaks because of shift changes or event scheduling. Note: The City of Corvallis requires that counts occur
when OSU is in session because of the large percentage of the population related to school being in session.

- In agricultural areas, truck traffic may be highly seasonal and have a substantial impact on the system. Counts may have to be timed carefully to balance the overall peak months with the harvest periods.
- In the Portland Metro area, while infrequent, there may be times when additional data must be collected to capture the 2nd hour, needed to evaluate the adopted 2-hour OHP mobility target. This is generally only necessary when the mobility target for the second hour of the peak period is lower than the mobility target for the first hour of the peak period and the analysis shows the first hour does not meet its target, but satisfies the target for the second hour.

**Counting Considerations for Congested Conditions**

Counting under congested conditions (i.e. Portland Metro area) requires some additional considerations as there may be places that the actual demand is queued up and unable to flow smoothly through the system. Volumes are being reflected on the ground while demand is being reflected in the form of unserved queues (cannot pass through in a single signal cycle over a 15-minute period at least). In this case, a typical count would only measure the discharge flow through the intersection versus what would like to use the intersection. This could lead to an underestimation of demand especially under a build alternative condition. Both volume and demand should be quantified in the analysis in order to help inform the analyst on volume development steps and following analyses.

If there is a suspicion that counts may not reflect true demand...

Step 1: Check existing tube counts or automatic traffic recorders for any peak hour “M” effect where the shoulder hours on each side of the peak hour/period are higher than the peak hour/period or the shoulder hours share the same capacity as the peak hour. If this is the case, demand has likely exceeded capacity.

Step 2: Check existing manual turning movement counts to see if the 15-minute shoulder intervals of the estimated peak hour/period are higher than the peak hour/intervals.

Step 3: If easily available, check private sector vehicle probe data such as TomTom or Inrix data to see if the corridor experiences speeds lower than the posted speed for more than one hour.

Step 4: Do a field visit or have video taken to verify whether vehicles can be served before ordering counts.

Step 5: Consider collecting counts upstream from the desired count location where the roadway is not oversaturated if congestion is observed in the field, video, and/or by counts. When counting upstream, consider counting side streets between the unsaturated count location and the desire count location that may have traffic leave or enter the roadway.

Other considerations:
- If traffic is heavily favoring a single lane more than others, lane by lane utilization counts or field observations are needed. For example, this can easily occur in one lane of a dual left turn lane because of an immediate lane drop or heavy turn movement downstream.
Lane utilization counts should also be considered where a through lane is reduced downstream from a traffic signal.

- Locations need to be noted where queue spillback occurs from turn lanes blocking through lanes or vice versa. This may require additional counts upstream or field observations.

3.4.4 Vehicle Count Locations

Vehicle count locations should be identified in the project work plan/SOW, and should be determined based on the needs of the subject plan or project. For example, planning efforts that are expected to generate potential highway projects within three years will require more detailed counts than a standalone or long-range plans, such as TSPs.

For planning projects it is important to correspond with the local jurisdiction and TPAU/Region Traffic to make sure that count needs cover the system to be analyzed at the appropriate level of detail and address issues. The grant/project manager should meet with TPAU/Region Traffic staff to discuss traffic count requirements after the objective section of the SOW (or project prospectus) is completed as this section provides the context for the plan/project. For Transportation Growth Management (TGM) grants, it is usually more efficient to arrange a meeting with the appropriate TPAU/region staff to go over multiple studies at once. For construction projects, the project team or at least the region traffic engineer/manager, the environmental lead, and/or project leader should be consulted.

While differences of opinion may exist on the number and type of counts versus the available budget, remember that the ultimate goal will be to have enough data to analyze and answer the questions, address the needs, evaluate alternatives, and cover the level of detail in the plan/project as described by the project objectives and the local jurisdiction(s). Staff will need to come to an agreement whether the data collection budget and/or the number/type of counts need to change.

The following plan/project-specific count location guidelines do not cover every possibility or combination of elements, but are intended to help generate a reasonable starting point for discussion. The location guidelines are generally laid out in an increasing level of detail.

**County Transportation System Plan (TSP)**

The arterial and major collector system needs to be documented (counted). It is generally unnecessary to count lower functional class roads as these usually carry very little traffic, and possibly are unpaved unless the county government wants a specific roadway included because...
of operational issues. Analysis at the County level is more system-based with a higher emphasis on ADT rather than peak hour and many of the analysis tools require ADT as an input.

- Need to have at least ADT-level count coverage of the arterial and major collectors. Acceptable previously taken counts may exist at the state or local level.
- Major arterial intersections with other arterial and major collector intersections should be counted where operational issues exist. State highway segments (between major intersections) should use the TSM Unit’s vehicle classification data to capture volumes and truck classifications.
- The TSM Unit’s ramp volume diagrams (where available) should be used to capture any free-flow ramp connections.
- County arterials and major collectors should have at least a 48-hour classification tube count performed so truck traffic can be captured and ADT can be calculated.
- Peak period counts should be obtained at signalized intersections, unsignalized highway to highway junctions, and county arterial – highway intersections. If this is a TSP Update, refer to the old TSP to help identify the critical intersections that should be counted.

City Transportation System Plan (TSP)
The arterial and collector system needs to be documented (counted). It is generally unnecessary to count lower functional classes unless the roadway is area-significant, provides an alternate path for trips to bypass congested areas (as in a parallel local street), or the local government has previously identified operational issues. Analysis at the City level is more centered on the peak periods and individual facilities/intersections which require more detail.

- Need to have at least ADT-level count coverage of the arterial and collectors. Acceptable previously taken counts may exist at the state or local level.
- Major cities (> 50,000 pop,) generally need to have at least the arterial system counted.
- Medium cities (10,000 – 49,999 pop.) generally need to have the arterial and representative/significant collectors counted.
- Small cities (<10,000 pop.) generally need to have the arterial and significant collectors counted.
- Major arterial intersections with other arterial and significant collector intersections should be counted. Peak period counts should be obtained at minor arterial/collector signalized intersections, unsignalized highway to highway junctions, city arterial – highway intersections, and major private development accesses (i.e. regional shopping mall). If this is a TSP Update, refer to the old TSP to help identify the critical intersections that may need to be re-evaluated.
- Significant collectors extend across the city for a considerable distance, are a direct route, or extend outside the city.
- If multiple signals exist, it may not be necessary to have a count at every one, but a reasonable representation of the system needs to be counted.
- Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- Sixteen-hour counts should be obtained at interchange ramp terminals and signalized major arterial intersections. If tube classification counts are available to provide ADT and truck volumes on each leg, then shorter duration counts can be used. The TSM Unit’s
ramp volume diagrams (where available) should be used to capture any free-flow ramp connections.

- State highway segments (between major intersections) should use the TSM Unit’s vehicle classification data to capture volumes and truck classifications.
- City arterials and collectors should have at least a 48-hour tube count performed so ADT can be calculated. Larger cities may already have this count data.
- If detailed refinement plans and/or actual highway projects are expected out of the TSP within three years and plan to use the TSP data, then the counted major intersections should be 16-hour counts with the lesser unsignalized intersections or access points using peak period counts.

**Interchange Area Management Plan (IAMP)**
The roadway system needs to be counted within at least a half-mile radius of the interchange. Analysis at the IAMP level can be close to a project-level of detail (see project section) depending on whether it is standalone or not. If the IAMP is part of a project, then the IAMP should be using the project counts and volumes and no new counts should be necessary unless the counts are very old (greater than three to five years old) or development patterns in the area have changed. It may be necessary to obtain a few “check counts” to see if volumes are substantially different before replacing all or most of the counts. If the IAMP is a standalone plan but it is anticipated that a project may occur within three years, then the IAMP needs a project-level count request. If the IAMP is a standalone plan but no project is anticipated within three years:

- Major arterial intersections with other arterial and major collector/collector intersections should be counted.
- Sixteen-hour counts should be obtained at the ramp terminal intersections, other arterial/arterial intersections, or unsignalized intersections that may need to be signalized.
- Peak period counts should be obtained at other existing signalized and unsignalized intersections and unsignalized intersections.
- 48-hour road tube counts may be necessary to support HSM safety analyses.
- If multiple signals exist, it is unnecessary to have 16-hour counts at every one. Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- Most, if not all, driveway accesses should be counted with peak period counts as many of these will be rerouted to new connections.
- State highway segments (between major intersections) should use the TSM Unit’s vehicle classification data to capture volumes and truck classifications.
- The TSM Unit’s ramp volume diagrams (where available) should be used to capture any free-flow ramp connections.

**Refinement, Management or Facility Plans**
The arterial and collector system needs to be counted within the defined study area limits. It is generally not necessary to count lower functional classes unless the roadway is area-significant, provides an alternate path for trips to bypass congested areas (as in a parallel local street), or the local government has previously identified operational issues. If it is anticipated that a project may occur within three years, then a project-level count request is needed. If no project is anticipated within three years:
- Major arterial intersections with other arterial and major collector/collector intersections should be counted.
- Facilities parallel to the subject arterial should be counted.
- Longer roadway sections without intersections should use road tube counts.
- Sixteen-hour counts should be obtained at signalized intersections and major unsignalized intersections (i.e., ramp terminals, four-way stops) to capture truck traffic or where larger scale improvements may be needed.
- Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- Unsignalized intersections or major accesses should be counted with peak period counts.
- 48-hour road tube counts may be necessary to support HSM safety analyses.
- If an Interstate Highway or statewide expressway exists in the study area, the mainline shall be counted by direction between interchanges in addition to any interchange ramp terminals. Road tube counts may be necessary to capture movements on ramps or connections.

Local Street Network (LSN) or Downtown Plan
These kinds of plans are generally trying to identify new roadway or multimodal connections to control congestion on the state highway or make limited improvements in the downtown area. The arterial and collector system need to be counted. It is generally not necessary to count lower functional classes unless the roadway is the only access to a neighborhood, provides an alternate path for trips to bypass congested areas (as in a parallel local street), or the local government has previously identified operational issues. Larger numbers of peak period counts may be necessary with a few 16-hour counts at major intersections.

- Major arterial intersections with other arterial and collector intersections should be counted.
- Sixteen-hour counts should be obtained at signalized intersections and major unsignalized intersections (i.e., ramp terminals, four-way stops) to capture truck traffic or where larger scale improvements may be needed.
- If multiple signals exist, it is unnecessary to have 16-hour counts at each one. Each major roadway should have truck traffic captured on it in at least one location.
- Unsignalized intersections or major accesses should be counted with peak period counts.
- 48-hour road tube counts may be necessary to support HSM safety analyses.
- Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- State highway segments (between major intersections) should use the TSM Unit’s vehicle classification data to capture volumes and truck classifications.
- The TSM Unit’s ramp volume diagrams should be used to capture any free-flow ramp connections.

Pedestrian or Trail Plans
Generally, counts are only needed if the state highway system will be affected by removing or narrowing through travel lanes or if new crossings are to be added. Count requirements in the
lane reduction areas should follow the LSN/Downtown Plan recommendations above.

Plans with proposed mid-block trail crossings of state highways or local arterials should have a 48-hour classification road tube count performed at the crossing location. For plans with existing pedestrian crossings (formally defined or not) where the number of crossing pedestrians is desired, the crossing count should be replaced with a 16-hour video classification count with bike and pedestrians requested.

Pedestrian and/or bicycle counts are more adversely affected by weather conditions than vehicle counts, and are recommended to be taken when pedestrians and/or bikes are anticipated, such as not in the winter in many cases, or during school-in-session periods if near a school/college/university.

Traffic Impact Studies (TIS)
For TISs, the analysis area and study intersections are typically selected from estimates of anticipated impacts from added traffic based on site trip generation and distribution, and existing intersection operations. Count requests need to be developed with the guidance of the Region Access Management Engineer or appropriate region staff and the Development Review Guidelines.

- Sixteen-hour counts should be obtained at major unsignalized intersections (i.e., ramp terminals, four-way stops) to capture truck traffic; obtain the basis for signal warrants, or where larger scale improvements may be needed.
- Signalized intersections may use a 16-hour count or a peak period count depending on the particular study area.
- If multiple signals exist, it may not be necessary to have 16-hour counts at each one. Bracketing peak period counts with 16-hour counts is an acceptable practice. Each major roadway should have truck traffic captured on it in at least one location.
- Unsignalized intersections and accesses should be counted with peak period counts.
- 48-hour road tube counts may be necessary to support HSM safety analyses.
- The Interstate/expressway/highway mainline shall be counted by direction in addition to any interchange ramp terminals. Road tube counts may be necessary to capture movements on ramps or connections.

Construction Projects
For most other project types (modernization, safety, operations, etc) the analysis area and study intersections are selected by considering the problem that is being addressed by the project and the information that is required to fully assess the problem and propose appropriate solutions. Project analysis is needed to support roadway and intersection control improvements, pavement and bridge design, air quality, and noise mitigation. Larger projects, especially those with required environmental studies (such as noise and air quality) may require multiple full 16-hour classification counts.

- Sixteen-hour classification counts should be obtained at signalized intersections and major unsignalized intersections (i.e., ramp terminals, four-way stops) to capture truck traffic or where larger scale improvements may be needed.
• Truck classification data must be captured on each roadway segment in the study area.
• Minor unsignalized intersections and accesses should be counted with peak period counts.
• 48-hour road tube counts may be necessary to support HSM safety analyses.
• Significant driveway accesses should be counted as many of these will be rerouted to new connections.
• If an Interstate Highway or grade-separated highway exists in the study area, the mainline must be counted by direction between interchanges in addition to any interchange ramp terminals. Road tube counts may be necessary to capture movements on ramps or connections.

3.4.5 ODOT Internal Count Request Process

When ordering counts, the request must contain the name of the contact person (requestor), the person to whom the data will be sent, the locations, time periods, dates, types of counts and collection methods must be clearly communicated to those conducting the counts. Count requests should group different count types (classification, peak period, road tube) separately for clarity. The count request should also list any special requests, count intervals, count time windows (start and finish dates), and a charge number (Expenditure Account (EA) for internal counts). A couple examples of a special request would be counting only on a specific day or counting certain intersections or elements of intersections at the same time. Because of staffing restrictions, classification counts for 2012 and beyond will not have pedestrian and bikes counted by default. Pedestrians and bike counts will need to be specifically requested.

A map showing the count locations, durations and other special requirements should also be provided to help eliminate misunderstandings since often times the text is separated from the map. Please keep in mind that the field counting staff usually only has the map in hand so all pertinent information (count locations, durations, types, intervals, and special requests) needs to be on the map. A Sample Count Request including map have been included in Appendix 3B.

When ordering intersection counts, be sure to specify the duration and type for each location. Fifteen-minute intervals must be specified for at least the standard morning, noon and evening peak periods in 16-hour counts. Peak period counts should be done in 15-minute intervals. It is not required, but very helpful if 48-hour road tube counts are counted in 15-minute intervals as well.

Specify the latest acceptable date by which the count is needed for analysis. Keep in mind, based on scheduling and staff limitations, that it can take at least five weeks from the date of the request date to get the count scheduled (not including weather restrictions) and then another three to four weeks to have the count processed, recorded and distributed. Therefore, counts need to be requested about nine weeks ahead (or more if weather is a factor) of when they will be needed for the analysis work.

All count requests should have copies sent to both the Region Traffic Manager and to the TSM unit to alert them that they are requested and need to be scheduled. Either TSM or the region
staff will have the counts performed (in-house or with contractors) and should assure that the data is processed into an ODOT format before being released to the requestor. The TSM Unit needs know what counts are available so staff resources can be allocated. The TSM Unit coordinates the counting schedules of all Region traffic counting staff. Coordinating with the TSM Unit in the loop allows for these counts to be added to ensure the count databases are properly maintained, which can avoid unnecessary duplication and limit counting needs by others and minimize delays. ADT–capable counts performed by third parties or consultants are also encouraged to be submitted to the TSM Unit to be added to the database.

3.4.6 Using the Traffic Count Management (TCM) Program (ODOT Employees Only)

TCM is a program maintained by the TSM Unit and available for installation on ODOT staff computers. It contains recent counts (2008 forward) conducted throughout the state of Oregon. Counts performed by the TSM Unit and counts provided to the TSM Unit are entered into the program. It is important to contact the TSM Unit if you are unable to find counts in your study area or to determine if there are existing counts that have not been processed.

There are many different count types and each requires TCM to generate a different report. TCM must be installed on a computer and an individual user name and password is required. Contact the TSM Unit for access. The Traffic Count Management (TCM) Program Count Report Guide, included in Appendix 3C, provides step-by-step instructions on how to obtain traffic count information from TCM in the correct format for the most common types of counts used by the analyst. This includes intersection counts, ATR/AVC sites, TruckSum, and tube (machine) counts.

3.4.7 Count Validation

Once counts are completed and processed and are available to the analyst, the counts should be checked to make sure that everything is furnished as requested. This includes count days, time periods, 15-minute intervals, movements, and classification requirements. Missing data, intersection approaches, etc should be reported back to the TSM Unit and the appropriate region for recounting (if possible) or reprocessing (in case of a video count) as soon as possible. Do not wait until all of the counts are completed to perform these checks.

Check the counts for any “red flags.” Do the values look okay? Counts have had approaches mislabeled, or wrong orientations (i.e.flipped east to west but also can be west to north).

As counts are being assembled for volume development, additional issues may arise between adjacent counts. Compare these counts with previous counts with adding in factored historical/seasonal growth; they should be similar if nothing has changed in the field between the counts. If adjacent or a whole section of counts appear to be very low or high, then verify that no incidents (road closures on the subject or adjacent roadways, crashes, bad weather, or scheduled events nearby) occurred while the count was in progress. If the count is 18 months or older then
crash data records can be checked. Recent counts may require more investigation (contact TSM Unit, Region traffic units, local maintenance districts, or traffic operation centers).

3.5  **Travel Time, Speed and Other Data Collection**

3.5.1  **Travel Time**

Travel time surveys measure the duration of time taken for a vehicle to travel from one point to another along a designated route, and are often used to quantify congestion over a corridor. The data collected from travel time surveys works well with statistical analysis, and the results are often more easily understood by the public than other methods used for measuring congestion.

**Data Collection**

One common method used for this data collection uses a “floating car.” The elapsed time is measured from a car driven along the designated route maintaining an average travel speed relative to other cars on the road. Other methods include vehicle or license plate matching and the use of various intelligent transportation system technologies. Travel time data is collected at the beginning and end of a designated route, and can be collected between predetermined points along the route as well, depending on the level of information desired. Travel time can also be calculated from Inrix speed data using the average speed and segment length (see section on Speed below).

When collecting travel time data, all measurements should be taken under good weather conditions and during a time representative of the period of interest for the study. Except when collecting the data for simulation calibration, it is good to distribute the travel time runs over several days and over multiple weeks that are representative. To have an accurate representation of the field conditions for simulation calibration, travel times need to be taken at the same time as the operational field data collection.

It is recommended that a minimum of 10 travel time runs be collected in each direction for each hour to be simulated (and each lane where lane imbalances occur) for both freeways and arterials. The 10 travel time runs should be collected during the same time as other data collection if possible but can be collected over multiple days if necessary. The travel time runs can also be a combination of the floating car and Bluetooth data methods. For VISSIM simulations, refer to Section 3.5 in the VISSIM Protocol.

**Floating Car Data Collection with GPS**

Floating car travel time runs are conducted using a handheld GPS device that records vehicle location, speed, and direction of travel every 1 to 5 seconds. This method allows the actual roadway conditions to be analyzed as the data returned from the probe vehicles will reflect the periods of congestion and free-flow speeds experienced by other motorists. The floating car technique requires the driver to mimic or match the speed of the traffic stream for a given roadway. However, it may be difficult for test drivers to mirror the actions of the traffic stream as drivers often revert to their own driving habits instead of staying with the majority of traffic. When designing a floating car study, the goal is to have a large enough sample which is
optimally spaced for the purpose of capturing variability within the traffic stream. Some things to consider:

1. Route selection
   a. Try to include as many key intersections, segments as necessary

2. The number of floating car “probes” and the area (route) covered per run
   a. In general, increasing the number of probes sampled during the run and/or reducing the area size will increase the resolution of the samples.

3. Lane position of probe car
   a. Results are provided in fine enough detail to determine speeds based on lanes occupied. It may be difficult for the driver to determine which lane most closely represents the average vehicle speed.

4. Weather, Tree cover and %trucks along route.
   a. High instances of either will lead to signal disruption and loss of data points.

5. Start the routes at least 15 minutes ahead of recording period
   a. Establishing the route prior to the recording time minimizes driver route errors

6. Driver Notes are helpful (see Exhibit 3-5 Determining When 30 HV Occurs).
   a. Record queue position at intersections
   b. Lane position

Exhibit 3-6 Example of Notes

I hit lots of reds on OR99E. There were only a couple instances where I hit greens along the corridor. I was in the inside lane on OR99E and the outside lane on I5. I used the inside lane going northeastbound on OR99E to position myself in the appropriate ramp lane, but also because the car was delayed at driveways (Especially at Killworth) as people entered the shopping center. I used the inside lane going southwestbound on OR99E to position myself for a quick turnaround at Ermine Drive and to avoid delays due to right turning traffic. I remained in the right hand lane on I5 for all but (2) loops. The ramps are closely spaced. As long as I was following multiple vehicles, I did not feel disadvantaged by sitting in the right hand lane. During (2) loops, I was behind a semi-truck and followed other vehicles around the slow moving truck.

The queues were no more than 10 cars.
The longest queues existed for the inside lane southwestbound OR99E at Albany Airport Road and both lanes for northeastbound OR99E at Waverly.

4:30:4:45 loop - I didn’t turn left at the appropriate location: this will show in the GPS
5:10:5:20 loop - stuck behind a Hay truck turning left from Century Drive to Old Salem Road at the Murder Creek Interchange
5:20:5:33 - Used the left lane going NB on I5 to go around a semi
5:33:5:39 - Used left lane going SB on I5 to go around a semi

Upon completion of the floating car runs, the data is downloaded to an ArcGIS shapefile format for cleaning and analysis (see Exhibit 3-7). It is typical that some data cleaning will be required such as removing outliers and converting the speed to MPH. This is easily done in ArcGIS.

Exhibit 3-7 Data format
Example 3-1 Floating Car Data Collection with GPS

For a project in Albany, travel time data is needed for calibration of a simulation model for the Existing Year. See Chapter 15 for calibration procedures.

Floating car data was collected on March 31st 2010 in the peak hour between 4:45 PM and 5:45 PM. Three vehicles were equipped with GPS units and each assigned a separate travel route. In order to represent the most likely driving conditions drivers were asked to travel according to their best judgment of the traffic stream’s speed and collect as many full routes as possible during the data collection period.

Average speeds along the routes were recorded in the GPS tracklog where time/location points set to record at 1 second intervals. A greater interval period could be used in other applications such as for a rural corridor. At each 1 second interval, the GPS recorded the coordinate location, the date and time the data point was recorded and the instantaneous speed of the vehicle. Instantaneous speed and travel times along each route were averaged over the total number of completed runs and summarized based on link segments from the SYNCHRO network. The figures below display the floating car data collection route and output results. The table below summarizes the results of the data collection.
Route Description

1. Begin route south of Waverly
2. Proceed north on Waverly and turn right onto Old Salem Rd NE
3. Proceed northwest and turn right onto Albany Rd
4. Proceed southwest on Albany Rd through the intersection onto Airport Rd
5. Proceed south and turn right onto US20
6. Proceed west on US 20 through Waverly Rd. to beginning of route.
7. Repeat route in reverse “counterclockwise” direction to capture speed in both directions throughout peak hour
8. Clockwise route will be all right turns
9. Counter-clockwise will be all left turns
Floating Car Data Output Results

Route 2 Floating Car and SimTraffic Data Comparison

Analysis Procedure Manual Version 2 3-31 Last Updated 10/2014
Bluetooth
Bluetooth uses probe vehicles. Probe vehicle techniques involve direct measurement of travel time (along a route or point to point) using data from a portion of the vehicle stream. Probe

<table>
<thead>
<tr>
<th>Roadway</th>
<th>Section</th>
<th>Floating Car Data Collection</th>
<th>SimTraffic Calibration</th>
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<tr>
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<td>BETWEEN SANTIAM I5 NB RAMP TERMINAL / SPICER DR SE / US20 AND PRICE RD SE</td>
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<td></td>
<td>Travel Time (s) 14</td>
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</tr>
<tr>
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<td>BETWEEN PRICE RD SE AND TIMBER ST SE</td>
<td>Speed (mph) 46</td>
<td>Speed (mph) 37</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>Travel Time (s) 17</td>
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<tr>
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<tr>
<td>US20</td>
<td>BETWEEN TIMBER ST SE AND PRICE RD SE</td>
<td>Speed (mph) 46</td>
<td>Speed (mph) 36</td>
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<td></td>
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<tr>
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<td>Speed (mph) 27</td>
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<td></td>
<td></td>
<td>Travel Time (s) 13</td>
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<tr>
<td>US20</td>
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<td>Speed (mph) 40</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td>Travel Time (s) 42</td>
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<td>Speed (mph) 29</td>
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<td>Travel Time (s) 19</td>
<td>Travel Time (s) 20</td>
</tr>
<tr>
<td>US20</td>
<td>BETWEEN CENTER ST SE AND SANTIAM I5 SB SLIP ON-RAMP</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Travel Time (s) 53</td>
<td>Travel Time (s) 49</td>
</tr>
</tbody>
</table>
measure technology (cell phone triangulation or GPS location tracking) is based on collecting vehicle ID data and timestamps of vehicles passing a roadside reader device and checking against the last reader passed to determine the travel time between reader locations. Many computers, car radios, navigation devices, PDA’s, cell phones, headsets and other personal devices are Bluetooth enabled to allow wireless communication between devices. Both types of probe technologies provide direct travel time output. Bluetooth-based travel time measurement involves identifying and matching the MAC address of blue-tooth enabled devices. This can be used to measure arterial travel time, average running speed, and OD patterns of travelers (see sections below).

There have been several recent studies evaluating the effectiveness of the bluetooth device matching method compared to ground truck data. The results indicate that blue tooth is capable of reproducing floating car data, while providing a significantly higher number of data points than the floating car method.

3.5.2 Speed

Speed data is used in multiple areas of analysis. There are measured and calculated speeds. A measured speed is a direct “point” measurement obtained with the use of equipment such as road tubes, Radar, or Lidar. A calculated speed is derived from a combination of time and distance information (i.e. travel time over a specific length segment).

**Measured Speed**

One of the easiest ways to obtain a measured speed is through the use of road tubes with vehicle classifying counter. This method can only be used for free-flow non-congested segments where tubes can be safely placed, outside the influence of any intersections causing platooning effects. Collection of tube count data is restrained by weather and installation issues and needs to be coordinated with count program staff. Another method to obtain a measured speed is through the use of hand-held speed devices such as Radar/Lidar. See the Speed Zone Investigations Manual for procedures for measuring speeds with these devices.

Measured speeds can be used to calculate segment speeds and headways. A measured speed may also be needed to determine/verify a specific segment speed such as a turning speed around a “non-standard” radius or corner for the purpose of simulation.

Speed data can also be obtained from fee-based private sources, such as Inrix. Inrix is a private-sector provider of travel time and speed data at the link level worldwide with over 400 different sources of input data (mobile, fleet, in-pavement, etc). Inrix speed is based on GPS observations from fleets of probe vehicles (mostly commercial) which capture speed along major roadway segments. Average speed is available for every hour of the year. The travel time is calculated from the average speed and segment length.

ODOT has purchased an Inrix historical archive of real time data covering the state of Oregon. The historical data is a comprehensive database of speed statistics by day of the week. In rural or
smaller urban areas, data coverage is generally limited to state highways (which have the most probe vehicles). Larger urban areas are more likely to include data on non-state facilities.

ODOT has also purchased Inrix Analytics, a web-based tool which facilitates data extraction and reporting. The Analytics Tool is available at www.inrixtraffic.us. The Analytics Tool uses historical 1-minute or 5-minute bins of real-time data with TMC, speeds, travel times and quality scores. Quality scores indicate whether the data is based on real-time, average, or reference speeds (30, 20, or 10 respectively). Scores of “30” also have a confidence value (0-100) which indicates consistency with itself, the average, and overall trends.

Public agencies within Oregon can freely use the data for planning and analysis. ODOT can authorize contractors to do the same on ODOT’s behalf. Some limitations are that Inrix data cannot be merged or averaged with competitor’s data (i.e. Tom-Tom) and that Inrix must be given credit when the data is used. Contact the ODOT ITS Unit for more information on data availability.

**Calculated Speed**

Calculated speeds are obtained from sources that furnish point or vehicle identification with a time stamp so data matching can yield a time between known points to determine an average speed. Data may be obtained from vehicle detection equipment, historic data or private sector sources. Common uses for calculated speeds are for calibration and validation of simulation models and creation of performance measures.

Floating car and MAC address matched travel time data can be converted into “running speed”, segment or corridor travel speeds as long as distances are available.

### 3.5.3 Other Data Collection

**Origin-Destination (O-D) Surveys**

These surveys obtain route information that a vehicle takes between specific points. Project complexity can range from simple, such as a weave study, to medium focusing on select paths within a project/study area, to complex such as a city-wide network. The number of “interview” stations adds complexity to the process.

- **Direct Interview** - This process entails stopping a sample of vehicles to ask specific data collection such as point of beginning and ending, trip purpose, route choice, etc. Sometimes these are viewed as disruptive and invading privacy. These are very expensive (labor and traffic control) and require Oregon Transportation Commission (OTC) approval for state highways because of impacts to the traffic flows.
- **License Plate Surveys** – This process uses in-person or recorder images of vehicle identification (license plates) to obtain routing information without the stops associated with a direct interview process. This method can be expensive and labor intensive to match the data inputs. The more stations that are recorded, the more complex the process.
- **Mail Survey** – This process uses a sampling method to deliver/receive route information from driver input. This method requires a large distribution of requests to
get a valid sampling of information. It can have accuracy (driver reporting), privacy and timeliness issues.

- MAC Address Reader (Bluetooth) - This process uses roadside detectors (portable or permanent) to record an identifying signature of an electronic device. Using multiple detectors, the device can be tracked to a specific route. To alleviate privacy issues, only a minimal amount of characters needed to uniquely specify a device is recorded. The electronic files of data can be matched using software programs, thus reducing labor costs.

**Saturation Flow Rate Studies**

The saturation flow rate is a critical component in signalized intersection analysis. It is defined as the flow in vehicles per hour accommodated by a lane group assuming that the green phase is displayed 100 percent of the time. Saturation flow rate data is collected on an ongoing basis. Oregon saturation flow studies done to date show that the HCM 2010 value of 1750 passenger cars per hour of green per lane is appropriate for small urban areas.

Except in larger urban areas, field conditions generally do not allow the HCM saturation flow study procedures in Chapter 31 of the 2010 HCM to be met. A roadway approach may not have long enough queues during the study or intersection spacing may be so tight that long enough queues without gaps are not possible. In these cases, a default ideal unadjusted saturation flow is determined as follows:

- Outside of the Portland, Salem and Eugene MPO urban areas the unadjusted saturation flow rate is 1750 passenger cars per hour of green per lane (pcphgl).
- Inside the Portland, Salem and Eugene MPO urban growth boundaries an unadjusted saturation flow rate of 1900 pcphgl may be used, unless one or more of the following conditions is present, in which case 1750 pcphgl shall be used. Conditions indicating use of lower base saturation flow rate inside urban growth boundaries:
  - On-street parking
  - Greater than 5% trucks
  - Roadways intersect at severe skew angle (i.e., greater than 20 degrees off perpendicular)
  - One or more driveway approach(es) with a combined volume in excess of 5 vph, are present downstream of the intersection within the functional area (see Chapter 4) or upstream within the length of the standing queue
  - Poor signal spacing or observed queue spillbacks between signals during the peak hour
  - Less than 12-foot travel lanes

The ideal (unadjusted) saturation flow rate is converted to an actual flow rate by applying adjustment factors to account for the influence of lane widths, heavy vehicles, approach grades, on-street parking, frequent bus stoppages (3-4 or more per hour per direction) in the intersection vicinity or roadway segment, area type, lane utilization, turning movements and bicycle and pedestrian conflicts. Theoretically, once adjusted, the result would be equivalent to the field measured value.
Field Measurements of Saturation Flow Rates

When an analyst desires a verification of the saturation flow (conditions are outside the default conditions above or a need for simulation), an investigation should be performed. The field measurement of the saturation flow rate shall be in accordance with methodology described in Chapter 31 of the 2010 Highway Capacity Manual (HCM) and submitted on the HCM Field Saturation Flow Rate Field Study Worksheet(s).

The measurement is performed by recording the following data for each signal cycle and each desired lane. In order for a cycle to be used, it needs to have a minimum of 8 vehicles in the stopped queue at the start of green. First record the number of vehicles in the stopped queue when the signal turns green. Then record the elapsed time elapsed between when the front axle of the fourth vehicle in queue crosses the stop line and when the front axle of the last vehicle in queue crosses the stop line. Finally record the end of green. These values are used to calculate the average saturation flow headway per vehicle. Signal cycles with events such as downstream queues blocking the flow of traffic or presence of emergency vehicles should be discarded. A minimum of 15 signal cycles with a minimum of 8 vehicles in the stopped queue is needed to obtain a statistically significant value.

\[
\text{Saturation Headway} = \frac{(\text{Time of last stopped vehicle} - \text{Time of 4th vehicle})}{(\text{Vehicle position of last vehicle} - 4)}
\]

\[
\text{Saturation Flow} = \frac{3600 \text{ s/h}}{\text{saturation headway}}
\]

In order to facilitate this process, a Saturation Flow Rate Data Collection Form and a Saturation Flow Rate Calculator tool have been developed. The data collection form is arranged as one row per cycle. For each cycle, the analyst records the time of the 4th vehicle, time of last stopped vehicle, number of stopped vehicles and time at end of green. Once collected, the data from the form are directly entered into the calculator office form tab. If more than 25 cycles of data have been collected, additional cycles can be added to the calculator by pressing the “Add 25 More Cycles” button.

Once the analyst has input the field data, click the “Calculate Sat Flow” button. The calculator automatically checks to ensure there are at least 15 cycles with 8 or more vehicles in queue. Cycles with less than 8 vehicles in queue are ignored. For more specifics on the tool see the Instructions tab.

Field measured saturation flow rates are preferred over estimation and do not require further modification. Using default values and adjustment factors will not produce more accurate results. If possible, saturation flow rates should be collected at no less than one major intersection on each main study area roadway. When using these values in analysis be sure to set all of the adjustment factors to 1.0.

Once the field saturated flow rate is obtained, the ideal (unadjusted) saturation flow rate should be back-calculated by applying adjustment factors to account for the influence of lane widths,
heavy vehicles, approach grades, on-street parking, bus stops, area type, lane utilization, turning movements and bicycle and pedestrian conflicts. Heavy vehicles, parking maneuvers, turning movements, and bicycle and pedestrian conflicts must be collected during the same period as the field saturation flow study to be able to back-calculate an accurate value.

TPAU has a limited database of saturation flow rates. To find out if specific saturation flow rates are available for a specific site/area, contact TPAU analysts. Copies of saturation flow rate studies should be sent to TPAU for inclusion in appropriate studies such as verification of default values. Coordinate data collection and verification with TPAU so any acceptable saturation flow studies can be included in the database.
Appendix 3A – Field Inventory Worksheet

Appendix 3B – Sample Count Request and Sample ODOT Counts

Appendix 3C – Traffic Count Management (TCM) Program Count Report Guide

Appendix 3D – Saturation Flow Rate Data Collection Form
4 SAFETY

4.1 Purpose

This APM chapter provides some fundamental guidance on newer safety analysis methods such as those from the Highway Safety Manual. A research project currently underway will result in a complete update of APM safety analysis procedures for transportation planning and project development.

The purpose of this chapter is to identify and analyze historic and predictive safety needs and improvements to minimize the potential of crashes in a study area. A complete safety analysis should include crash analysis as well as other safety-based techniques. Existing and no-build condition analyses need to have crash analysis at a minimum. Other techniques such as functional area, conflict points, and sight distance can help the analyst to further determine crash causes. Build alternative analyses can include predictive crash analysis, but the functional area, conflict points, and other techniques needs to be included to ensure that the alternative addresses the safety issue and does not create new issues.

The APM does not address ODOT highway safety program procedures or traffic operations-level safety analysis. This includes road safety audits, collision diagrams, detailed safety investigations, and benefit-cost analyses. Contact the Traffic-Roadway Section for procedures related to those programs.

4.2 Historic Crash Analysis

Crash analysis typically involves identifying areas on facilities experiencing an over-representation of crashes or reoccurring crash patterns. The analysis also investigates the conditions that may contribute to the problem. With a general understanding of crash trends within a study, the analyst can use the information in the analysis to make recommendations. This analysis should not be confused with the operational analysis that would be done separately by Region Traffic staff. For more detailed analysis of a safety concern, refer to the ODOT Safety Investigations Manual.
4.2.1 Calculating Intersection Crash Rates

Historically, intersections have considered crash information in context of direct numbers of crashes and entering volume, without considering the differences that individual intersections may have. The general Intersection Crash Rate formula reports the number of crashes per million entering vehicles (MEV) based on the number of crashes (in millions) divided by the AADT and the time period (in days).

If existing year project volumes have been created, then derived AADTs from those counts should be used. If project volumes have not yet been created or when project counts are not ADT-capable (less than 12 hrs in duration), then it is likely that multiple years of AADT data will need to be averaged together. For state highways where count-computed AADTs are not available, use the appropriate counted year(s) (see Highway Count Schedule in the Transportation Volume Tables). Non-state highways will need to use AADTs from local jurisdictions or 48-hour tube counts. Note that count-based ADTs will need to be seasonally adjusted back to AADT levels. See Section 5.7 for procedures on use of shorter-duration counts, calculating AADTs, and converting ADT to AADT.

The old rule of thumb was that intersections with a crash rate of 1.0 per MEV or greater is generally considered to be an indication that further investigation is warranted. However, using this rule-of-thumb led to ignoring of safety issues when the crash rate was below 1.0. There are other methods that may indicate safety issues exist even when the crash rate is below 1.0. Therefore this rule-of-thumb should no longer be used.

The following example illustrates the calculation of MEV:

Example 4-1 Million Entering Vehicles (MEV)

As a part of an urban street modernization project, a safety analysis needs to be done for Main Street. This street is a congested urban corridor with a mixture of unsignalized and signalized intersections with varying numbers of lanes.

Traffic counts were taken at each intersection and crashes for the previous 5 years have been compiled. In order to calculate the HSM Critical Crash Rate the total million entering vehicles (MEV) is needed for each intersection.
Data Needs:
Directional count data is needed for each leg of each intersection. If ADT-capable counts are not available and the best data available is the TVT or a non-directional tubular count, a 50/50 directional split can be assumed. For the intersection of Main St and 3rd St, ADTs entering the intersection from each leg were developed and are shown in the diagram below. See Chapter 5 for the process to develop directional ADTs.

Step 1: Adjustment of ADTs to AADTs

The ADTs entering the intersection need to be converted to AADTs. See Chapter 5 for the process to develop the appropriate adjustment factors. NOTE: If using the TVT for volumes, this step does not apply. The volumes in the TVT have already been adjusted to AADT. In this case move directly to Step 2.

\[ AADT = ADT \times \text{Adjustment Factor} \]*

Entering AADTs at Main Street and 3rd Street

\[ AADT_{North} = 23936 \times 0.94 = 22500 \]
\[ AADT_{South} = 11489 \times 0.94 = 10800 \]
\[ AADT_{East} = 9149 \times 0.94 = 8600 \]
\[ AADT_{West} = 5000 \times 0.94 = 4700 \]

* See Chapter 5 for steps to calculate the adjustment factor.

Step 2: Million Entering Vehicles
Total Entering AADT = \sum Enter\ning \, AADTs

Total Entering AADT_{\text{Main Street at 3rd Street}} = 22500 + 10800 + 8600 + 4700 = 46,600

\[
MEV = \frac{\text{Total Entering AADT} \times 365 \times n}{1,000,000} \\
AADT = \text{Annual Average Daily Traffic} \\
n = \text{Number of Years} \\
MEV_{\text{Main Street at 3rd Street}} = \frac{46,600 \times 365 \times 5}{1,000,000} = 85.0MEV
\]

The current thinking is to consider crashes by the characteristics of the intersection, e.g., signalized versus unsignalized. This calculation (the Critical Rate method) found in Part B – Network Screening of the Highway Safety Manual (HSM) should be used. The Critical Rate method creates a performance threshold which the old rule of thumb did not provide while keeping the data requirements to a minimum.

All of the HSM network screening methods require a reference population of an adequate size. This method is useful for studies with a large number of sites to consider such as TSPs or long corridor plans which would have a large complex data set. This allows for identifying/screening down to a manageable number of critical (safety-focused) intersections for further review. A reference population is based on study area sites with similar characteristics which could be all unsignalized intersections or signalized versus unsignalized intersections. If there are enough intersections, these basic populations could be split further such as 3 versus 4-legged intersections. Signalized and unsignalized intersections should not be mixed in the same population as the crash characteristics are quite different. The more intersections in each population and the more specific populations there are better results can be obtained.

For this method to be statistically valid there needs to be at least five to ten sites in each data set (reference population). If there are less than five sites available to create a reference population, these methods do not apply (since there are not enough sites to screen). This method may also produce small crash rate variances which may overlook sites with a significant crash problem. Also, the sites within the study area reference populations may have different variances when compared to similar intersections statewide. To minimize these issues, the individual intersection crash rates need to be compared to the published statewide 90th percentile intersection crash rates in Exhibit 4-1. Any rates close to or over the 90th percentile rates need to be flagged for further analysis. In the table below, SG means signalized intersection while ST means a stop-controlled intersection, and 3 means 3-leg intersection while 4 means a 4-leg intersection. These values represent 90th percentile crash rates from a study of 500 intersections in Oregon. The crash rates are grouped by rural/urban, signalized/unsignalized, and 3-leg/4-leg intersections. Intersections with crash rates that exceed the 90th percentile values
shown in the table should be flagged for further analysis.

Exhibit 4-1 Intersection Crash Rates per MEV by Land Type and Traffic Control

<table>
<thead>
<tr>
<th></th>
<th>Rural</th>
<th></th>
<th></th>
<th></th>
<th>Rural</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>3SG</td>
<td>3ST</td>
<td>4SG</td>
<td>4ST</td>
<td>3SG</td>
<td>3ST</td>
<td>4SG</td>
<td>4ST</td>
</tr>
<tr>
<td>No. of Intersections</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>115</td>
<td>20</td>
<td>60</td>
<td>55</td>
<td>77</td>
<td>106</td>
<td>60</td>
</tr>
<tr>
<td>Mean Crash Rate</td>
<td>0.226</td>
<td>0.196</td>
<td>0.324</td>
<td>0.434</td>
<td>0.275</td>
<td>0.131</td>
<td>0.477</td>
<td>0.198</td>
</tr>
<tr>
<td>Median Crash Rate</td>
<td>0.163</td>
<td>0.092</td>
<td>0.320</td>
<td>0.267</td>
<td>0.252</td>
<td>0.105</td>
<td>0.420</td>
<td>0.145</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.185</td>
<td>0.314</td>
<td>0.223</td>
<td>0.534</td>
<td>0.155</td>
<td>0.121</td>
<td>0.273</td>
<td>0.176</td>
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<tr>
<td>Coefficient of Variation</td>
<td>0.819</td>
<td>1.602</td>
<td>0.688</td>
<td>1.230</td>
<td>0.564</td>
<td>0.924</td>
<td>0.572</td>
<td>0.889</td>
</tr>
<tr>
<td>90th Percentile Rate</td>
<td>0.464</td>
<td>0.475</td>
<td>0.579</td>
<td>1.080</td>
<td>0.509</td>
<td>0.293</td>
<td>0.860</td>
<td>0.408</td>
</tr>
</tbody>
</table>

Source: Assessment Of Statewide Intersection Safety Performance, FHWA-OR-RD-18, Portland State University and Oregon State University, June 2011, Table 4.1, p. 47.

A spreadsheet calculator has been developed that implements the critical rate calculations for intersections. For additional information see pages 4-35 through 4-39 in HSM Volume 1. Example 4-2 illustrates the use of the Critical Rate method for urban area intersections.

Example 4-2 HSM Critical Rate for Intersections

As part of an urban street modernization project, a safety analysis needs to be done for Main Street. This street is a congested urban corridor with a mixture of unsignalized and signalized intersections with varying numbers of lanes.

The project engineer has created existing year average daily traffic (ADT) volumes from available intersection counts. The ADT counts were converted into AADT using appropriate seasonal factors which are shown as daily total entering volumes in the figure below. In addition, intersection crash data for the past five years are shown in the table below.

Data Needs:
Existing Year Annual Average Daily Entering Traffic Volumes
To help save time and effort, the HSM Critical Rate screening method will be used to determine the intersections with the greatest need.

*Note: All sample calculations given at the intersection of Water St. and Main St.*

**Step 1:** At each intersection, calculate the volume on a Million Entering Vehicle (MEV) basis.

1. \[
    \text{MEV} = \frac{\text{AADT} \times 365 \times n}{1,000,000}
\]

\[\text{MEV} = \text{Million Entering Vehicles}\]

\[n = \text{Number of Years}\]

\[\text{MEV} = \frac{7,600 \times 365 \times 5}{1,000,000} = 13.9 \text{ MEV}\]

**Step 2:** Calculate the crash rate at each intersection.
(2) \[ R = \frac{\text{Crash Total}}{\text{MEV}_n} \]

\[ R = \text{Observed Crash Rate} \]

\[ R = \frac{6}{13.9} = 0.43 \frac{\text{Crashes}}{\text{MEV}} \]

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Daily Volume</th>
<th>MEV$_5$</th>
<th>Crash Total</th>
<th>Crash Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water St.</td>
<td>7,600</td>
<td>13.9</td>
<td>6</td>
<td>0.43</td>
</tr>
<tr>
<td>1st St.</td>
<td>6,700</td>
<td>12.2</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>2nd St.</td>
<td>10,900</td>
<td>19.9</td>
<td>1</td>
<td>0.05</td>
</tr>
<tr>
<td>3rd St.</td>
<td>46,600</td>
<td>85.0</td>
<td>29</td>
<td>0.34</td>
</tr>
<tr>
<td>4th St.</td>
<td>21,500</td>
<td>39.2</td>
<td>2</td>
<td>0.05</td>
</tr>
<tr>
<td>6th St.</td>
<td>22,300</td>
<td>40.7</td>
<td>14</td>
<td>0.34</td>
</tr>
<tr>
<td>7th St.</td>
<td>23,100</td>
<td>42.2</td>
<td>15</td>
<td>0.36</td>
</tr>
<tr>
<td>8th St.</td>
<td>19,800</td>
<td>36.1</td>
<td>5</td>
<td>0.14</td>
</tr>
<tr>
<td>9th St.</td>
<td>22,100</td>
<td>40.3</td>
<td>12</td>
<td>0.30</td>
</tr>
</tbody>
</table>

**Step 3: Calculate the average crash per population.**

(3a) Divide the intersections into varying populations (groups) based on operational (i.e. unsignalized/signalized/roundabouts) or geometric (i.e. four-leg/three-leg) differences. Only one reference population of sufficient size exists for this example. Six intersections fall under the unsignalized type (Type 1) reference population. There are not enough 3-leg or 4-leg unsignalized intersections to further subdivide the reference populations. The critical rate method cannot be used for the signalized intersections (Type 2) since there are only three in the reference population. Therefore the signalized intersections will be analyzed by comparing to the 90th percentile crash rates.

\[ R_a = \frac{\sum_{i=1}^{n} (N_{\text{obs},i})}{\sum_{i=1}^{n} (\text{MEV}_i)} \]

\[ R_a = \text{Average crash rate for reference population } a \]

**Average Crash Rate for Unsignalized Intersections reference population:**

\[ R_1 = \frac{6 + 0 + 1 + 2 + 14 + 5}{13.9 + 12.2 + 19.9 + 39.2 + 40.7 + 36.1} \]

\[ = 0.17 \frac{\text{Crashes}}{\text{MEV}} \]
Step 4: Calculate a critical crash rate for each intersection.

\[
R_c = R_a + \text{Confidence Level} \times \frac{R_a}{\sqrt{MEV_n}} + \frac{1}{2 \times MEV_n}
\]

- \(R_c\) = Critical crash rate
- \(R_a\) = Weighted average crash rate for reference population

\[
R_c = 0.17 + 1.645 \times \frac{0.17}{\sqrt{13.9}} + \frac{1}{2 \times 13.9} = 0.39 \text{Crashes/MEV}
\]

Table 4-9 in the HSM (page 4-36) gives P-levels to correspond to differing confidence levels. Typical use would be 95% confidence (P=1.645).

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Intersection Population Type (3a)</th>
<th>Crash Rate (2)</th>
<th>Critical Crash Rate (4)</th>
<th>Over Critical (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water St.</td>
<td>1</td>
<td>0.43</td>
<td>0.39</td>
<td>Over</td>
</tr>
<tr>
<td>1st St.</td>
<td>1</td>
<td>0.00</td>
<td>0.41</td>
<td>Under</td>
</tr>
<tr>
<td>2nd St.</td>
<td>1</td>
<td>0.05</td>
<td>0.35</td>
<td>Under</td>
</tr>
<tr>
<td>4th St.</td>
<td>1</td>
<td>0.05</td>
<td>0.29</td>
<td>Under</td>
</tr>
<tr>
<td>6th St.</td>
<td>1</td>
<td>0.34</td>
<td>0.29</td>
<td>Over</td>
</tr>
<tr>
<td>8th St.</td>
<td>1</td>
<td>0.14</td>
<td>0.30</td>
<td>Under</td>
</tr>
</tbody>
</table>

Step 6: Compare observed crash rate with critical crash rate.

Compare the critical crash rate with the crash rate for each intersection. Any intersection with a crash rate that exceeds its critical rate should be flagged for further review.

In the above example, the following intersections were flagged for further analysis:
- Water St. and Main St.
- 6th St. and Main St.

Step 7: Compare observed crash rate with 90th percentile published rate.

From Exhibit 4-1, the 90th percentile crash rates are as follows:
- 4-leg signalized intersections in an urban area (4SG) = 0.86
- 3-leg unsignalized intersections in an urban area (3ST) = 0.29
- 4-leg unsignalized intersections in an urban area (4ST) = 0.41
In this example, all of the intersections in the study area have crash rates below the published 90th percentile rates.

**Step 8: Conclusions**

From the analysis, the intersections of Main St. and Water St. and Main St. and 6th exceed the critical rate. These intersections are “safety focus” locations that need to be reviewed more in depth. At a minimum, crashes and patterns need to be identified and potential countermeasures indicated. More in-depth HSM predictive analysis could be done for the existing conditions and any later future conditions which could also include finding the most cost-effective countermeasures.

### 4.2.2 Calculating Segment Crash Rates

Crash rates are commonly used to determine if the frequency of crashes experienced at a given intersection or segment of roadway is above average. The total number of crashes experienced on a segment is related to the number of vehicles using that facility, so rates are often calculated to allow for comparisons of different facilities. The most common comparison is to calculate the number of crashes experienced per million users. Specifically, for roadway segments, the number of crashes per million vehicle miles of travel (MVM) is calculated. These rates can also be calculated using only specific crash types (rear-end or fixed object, etc.) or severity (fatal, injury or property damage only crashes). The corresponding formulas for these calculations are shown in Exhibit 4-2.

<table>
<thead>
<tr>
<th>Description</th>
<th>Expression</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment Crash Rate (crashes per million vehicle miles of travel, MVM)</td>
<td>Annual number of crashes times one million, divided by the annual vehicle-miles of travel.</td>
<td>( \frac{\text{Annual number of crashes} \times 10^6}{\left(\text{AADT} \times (365 \text{ days/year}) \times \text{segment length in miles}\right)} )</td>
</tr>
</tbody>
</table>

One of the inherent limitations of using crash rates for safety analysis is that comparisons cannot be made across segments that vary greatly in length or have significantly different traffic volumes or major characteristics. Identifying the segment needs to consider the general road and roadside characteristics such as lanes, topography (mountainous vs. flat), development (urban/rural/suburban), traffic volumes (no more than a 10% variation), and other features that will significantly influence the outcome. When roadside characteristics and/or traffic volume prevent full one-mile sections (or greater) to be created, then the segment crash rate should not be used. Segment crash rates are acceptable for rural areas or areas that are relatively homogeneous over long stretches of a mile or longer. Segments with only a few crashes should not have crash rates computed as the results would be inflated and relatively meaningless. Any segment, urban or rural, may minimize an intersection with a significant crash rate, therefore it is important to calculate both intersection and segment crash rates.

However, in urban areas, conditions and volumes can change frequently and mile-long
segments can be difficult to find. Sections that are short in length will often end up showing an over-estimated segment crash rate. If a short segment focuses on a cluster of crashes it will have a substantially higher crash rate than if the segment length were longer. In addition, in urban areas, most crashes occur at intersections and a segment crash rate can minimize a crash problem at an intersection so much that the overall segment crash rate does not pass the ODOT Crash Rate Table II threshold for further investigation. Generally, in urban areas, the intersection crash rate methodology should be used. Urban area segment crash rates may be used to identify driveway crash issues, or for urban grade-separated free-flow facilities which generally have longer segment lengths.

It is recommended that the Critical Rate methodology for segments, described later, be used for both rural areas and urban grade separated facilities in addition to comparisons to a published crash rate. Use of this method would involve creating groupings (reference populations) of segment geometric characteristics (lanes, terrain, etc). Any crash rate in excess of the critical rate or the rates in the ODOT Crash Table II should be flagged for further analysis.

For reporting crash rates on state highways, ODOT uses the segment crash rate. The ODOT CAR Unit publishes an annual document called the Oregon State Highway Crash Rate Tables. In this document, crash rates for given segments of all state highways are calculated and listed for each of the last five years. The individual highways segments listed in this book are categorized by the urban/rural classification, so it can be used as a quick check of crash rates for comparison to the summary table. Care has to be taken if the reported segment is less than 1-mile for the same reason as noted above. The crash rate book also contains a variety of summaries of crash rates for state highways considering fatalities and different highway types and information about the data used in the calculations.

Table II is the primary table used in segment crash rate analysis. It shows statewide average crash rates for each of the last five years, by urban and rural area, and by roadway classifications for state and non-state roadways. Federal functional classifications can be found on the ODOT Federal Functional Classification (FC) webpage. This table is often used to compare a specific (study) calculated segment crash rate to the statewide average rate for a comparable roadway type.

For example, to select the appropriate highway type for comparison, the analyst must determine the study segment functional classification (freeway or non-freeway and arterial/collector/local) and jurisdiction (urban or rural area).

If existing year project volumes have been created, then derived AADTs from those counts should be used. If project volumes have not yet been created or when project counts are not ADT-capable (less than 12 hrs in duration), then it is likely that multiple years of AADT data will need to be averaged together. For state highways where count-computed AADTs are not available, use the appropriate counted year(s) (see Highway Count Schedule in Section I of the Transportation Volume Tables). Non-state highways
will need to use AADTs from local jurisdictions or 48-hour tube counts. Note that count-based ADTs will need to be seasonally adjusted back to AADT levels. See Chapter 5 for more information on calculating AADTs and converting ADT to AADT.

Example 4-3 Segment Crash Rate Calculation and Comparison

A 1.6 mile principal highway segment in a rural area has experienced 22 reported crashes over the last 3 years. The segment AADT from the State Highway Vehicle Classification Data Report is 23,000.

\[
\text{Rate} = \frac{\text{Number of Crashes \times 1,000,000}}{\text{Length (in miles) \times \text{AADT} \times (\text{Yrs} \times 365)}}
\]

\[
= \frac{22 \times 1,000,000}{1.6 \times 23,000 \times 3 \times 365}
\]

\[
= 0.55 \text{ Crashes per Million Vehicle Miles (MVM)}
\]

As shown in the table below, the statewide average crash rates are as follows:

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.67</td>
<td>0.69</td>
<td>0.68</td>
<td>0.68</td>
</tr>
</tbody>
</table>

The segment crash rate of 0.55 is less than the average statewide rate of 0.68.
A segment crash rate that exceeds the statewide average crash rate may be an indication that further investigation is necessary, although it is possible that upon further investigation it may be determined that no improvements are necessary. Likewise, cost effective improvements to reduce crashes could still be identified even with a segment crash rate lower than the statewide average.

The HSM critical rate method can also be applied to segments, such as in rural areas or along a highway corridor. Segments should not include intersections that have crashes since the intersections will be analyzed separately. Reference populations can be created by number of lanes (4-lane versus 2 lane, passing/climbing lanes), divided/undivided, terrain type (level, rolling, or mountainous), or other geometric feature. Reference populations still need to have at least five segments in each with more recommended. Screening can be done with a couple reference populations to maximize the number of segments in each population. Screening can be done multiple times with different variables each time to see if generally the same segments are being flagged. Care should be taken not to assume that multiple reference populations create a greater precision level than the data can support for this screening tool.

### Statewide Crash Rate Table

#### TABLE II: FIVE-YEAR COMPARISON OF STATE HIGHWAY CRASH RATES

Table II presents a comparison of state highway crash rates for the past five years, for urban and rural areas, by functional classification. Mileage is shown for the current data year only.

See Table IV for information on official highway mileage and VMT data.

<table>
<thead>
<tr>
<th>JURISDICTION AND FUNCTIONAL CLASSIFICATION</th>
<th>MILES*</th>
<th>2007 Rate</th>
<th>2006 Rate</th>
<th>2005 Rate</th>
<th>2004 Rate</th>
<th>2003 Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL STATE HWY SYSTEM</td>
<td>7,455.23</td>
<td>0.85</td>
<td>0.85</td>
<td>0.87</td>
<td>0.79</td>
<td>0.98</td>
</tr>
<tr>
<td>Interstate Freeways</td>
<td>729.57</td>
<td>0.38</td>
<td>0.39</td>
<td>0.41</td>
<td>0.38</td>
<td>0.42</td>
</tr>
<tr>
<td>Other Freeways/Expressways</td>
<td>52.26</td>
<td>0.73</td>
<td>0.78</td>
<td>0.90</td>
<td>0.78</td>
<td>0.67</td>
</tr>
<tr>
<td>Non-Freeways (combined)</td>
<td>6,673.40</td>
<td>1.27</td>
<td>1.26</td>
<td>1.25</td>
<td>1.13</td>
<td>1.45</td>
</tr>
<tr>
<td>Other Principal Arterials</td>
<td>3,281.04</td>
<td>1.28</td>
<td>1.29</td>
<td>1.28</td>
<td>1.16</td>
<td>1.52</td>
</tr>
<tr>
<td>Minor Arterials</td>
<td>1,964.61</td>
<td>1.20</td>
<td>1.14</td>
<td>1.14</td>
<td>1.02</td>
<td>1.20</td>
</tr>
<tr>
<td>Urban Collectors</td>
<td>8.69</td>
<td>1.00</td>
<td>0.68</td>
<td>1.19</td>
<td>1.23</td>
<td>2.08</td>
</tr>
<tr>
<td>Rural Major Collectors</td>
<td>1,332.20</td>
<td>1.25</td>
<td>1.11</td>
<td>1.14</td>
<td>0.93</td>
<td>1.25</td>
</tr>
<tr>
<td>Rural Minor Collectors</td>
<td>36.86</td>
<td>0.64</td>
<td>0.66</td>
<td>1.30</td>
<td>0.32</td>
<td>1.30</td>
</tr>
<tr>
<td>Rural Local</td>
<td>0.00</td>
<td>0.00</td>
<td>16.52</td>
<td>4.23</td>
<td>2.68</td>
<td>8.06</td>
</tr>
</tbody>
</table>

| Rural Areas                              | 6,414.01| 0.58      | 0.58      | 0.59      | 0.51      | 0.59      |
| Interstate Freeways (combined)           | 539.37  | 0.28      | 0.30      | 0.31      | 0.25      | 0.26      |
| Non-Freeways (combined)                  | 5,874.64| 0.79      | 0.77      | 0.80      | 0.68      | 0.80      |
| Other Principal Arterials                | 2,658.39| 0.68      | 0.69      | 0.67      | 0.61      | 0.71      |
| Minor Arterials                          | 1,839.04| 0.99      | 0.93      | 0.98      | 0.83      | 0.97      |
| Rural Major Collectors                   | 1,340.60| 1.24      | 1.08      | 1.10      | 0.92      | 1.20      |
| Rural Minor Collectors                   | 36.61   | 0.69      | 0.36      | 1.40      | 0.35      | 1.40      |
| Rural Local                              | 0.00    | 0.00      | 16.52     | 4.23      | 2.68      | 8.06      |

* Coupeit and Roadway 3 data are included. Frontage road and connection data are excluded.
A spreadsheet calculator has been developed that implements the critical rate calculations for segments. Example 4-4 shows the critical rate method applied to a rural highway corridor.

**Example 4-4 HSM Critical Rate for Segments**

A screening level safety analysis is to be performed on North Santiam Highway, a rural state highway corridor. The route is approximately 80 miles in length and has both level and rolling terrain. It contains multilane, 2-lane, passing and climbing lane sections. It is desired to identify segments for further safety analysis. The HSM Critical rate method will be applied to segments within the corridor. The study area is shown below.

**Study Area**

![Study Area Diagram](image)

All sample calculations given are for the reference population 4-lane highway, and for Segment 5.

**Step 1: Obtain comprehensive (PRC) crash report in Excel format for corridor**

Five years of crash data should be obtained using the PRC crash report, available for both state highways and local roads on the ODOT [Internal Crash Reports website](#) or the [External Crash Reports website](#). The PRC report contains multiple records per crash. Only the crash level record (first record) is needed. The vehicle and participant level records should be filtered out so that only the crash level record remains for each crash.

**Step 2: Filter out Urban areas and Rural intersections**
The PRC report identifies intersection crashes using the RD_CHAR_SHORT_DESC field. Filter out these crashes. Intersection crashes can generally be assumed to be those identified as at an intersection with at least one crash, plus 0.01 miles on either side of the intersection milepoint, as well as those coded as intersection-related. Segments are subdivided at intersections with at least one crash. Intersections with no crashes can be included within segments. The intersections with crashes can be analyzed separately using the Intersection Critical Rate method described previously.

**Step 3: Obtain AADTs from the State Highway Vehicle Classification Report**

Each segment is assigned an AADT. For state highways, AADTS are obtained from the State Highway Vehicle Classification Report. For non-state highways AADTs will need to be calculated following procedures in Chapter 5.

**Step 4: Segmenting**

Segments are developed based on reference populations. Segment boundaries should be placed where the reference population changes, at intersections which have crashes, and at other logical breakpoints in order for segments not to exceed two or three miles in length. For some very long corridors such as in rural eastern Oregon, segments could be up to five miles in length.

A variety of potential reference populations could be considered, including
- Urban/rural
- Freeways/arterials
- Number of travel lanes (2, 3, 4, 5, etc)
- Divided/undivided
- Presence of auxiliary lanes (passing lanes, climbing lanes)
- Terrain (level, rolling and mountainous)
- Geographic area or elevation
- AADT level

Data sources for determining reference population boundaries include TransGIS, Transviewer, the digital video log, and the State Highway Vehicle Classification Report.

At least five segments are needed for each reference population. If there are enough segments it may be possible to have sub-groupings, such as initially by number of lanes and then by terrain. It may also be desirable to separately analyze more than one reference population. This may help to further identify crash trends. Specific types of crashes could be examined as well, such as those involving snow and ice, or fatal and injury crashes.

Freeway reference populations could include basic freeway lane sections, weave sections, and ramp merge or diverge sections.
Each segment is assigned a Begin and End Milepoint. Segment lengths need to be adjusted if they contain a milepoint equation. Milepoint equations can be found from the Equations and Milepoint Range Report.

**Step 5: Identify the number of crashes in each segment**

Each segment is assigned the total number of crashes within that segment. This process can be automated using the PRC crash data from Step 1 as a lookup table to sum the number of crashes in each segment between begin and end milepoints.

In this example, five segments were identified within the reference population of 4 lane divided highway segments, as show in the following table.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Reference Population Type</th>
<th>Begin Milepoint</th>
<th>End Milepoint</th>
<th>5 Year Crash Total</th>
<th>AADT</th>
<th>Crash Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4 Lane Divided</td>
<td>4.10</td>
<td>6.84</td>
<td>21</td>
<td>24400</td>
<td>0.17</td>
</tr>
<tr>
<td>2</td>
<td>4 Lane Divided</td>
<td>6.88</td>
<td>8.89</td>
<td>7</td>
<td>19100</td>
<td>0.10</td>
</tr>
<tr>
<td>3</td>
<td>4 Lane Divided</td>
<td>8.93</td>
<td>11.53</td>
<td>8</td>
<td>19100</td>
<td>0.09</td>
</tr>
<tr>
<td>4</td>
<td>4 Lane Divided</td>
<td>11.54</td>
<td>13.23</td>
<td>8</td>
<td>13100</td>
<td>0.20</td>
</tr>
<tr>
<td>5</td>
<td>4 Lane Divided</td>
<td>13.24</td>
<td>13.80</td>
<td>5</td>
<td>8900</td>
<td>0.55</td>
</tr>
</tbody>
</table>

**Step 6: Calculate the crash rate for each segment**

The remaining steps can be automated using the Critical Rate Calculator. It is convenient if the data previously developed is formatted to paste directly into the calculator input cells.

\[
MVMT = \frac{AADT \times L \times 365 \times n}{1,000,000}
\]

\[
MVMT = \text{Million Vehicle – Miles of Travel}
\]

\[
L = \text{Segment Length}
\]

\[
n = \text{Number of Years}
\]

\[
R = \text{Crash Rate} = \frac{\text{Number of Crashes}}{MVMT}
\]

The MVMT for Segment 5 is calculated as follows:
\[ MVMT = \frac{8900 \times (13.80 - 13.24) \times 365 \times 5}{1,000,000} = 9.10 \]

The crash rate for Segment 5 is calculated as follows:
\[ R = \frac{5}{9.10} = 0.55 \]

**Step 7: Calculate the average crash rate for each reference population**

\[
(2) \quad R_a = \frac{\sum_{i=1}^{n} (N_{obs,i})}{\sum_{i=1}^{n} (MVMT_i)}
\]

\[ R_a = \text{Average segment crash rate for reference population } a \]

For the reference population of 4-lane divided highway segments, the average crash rate is calculated as follows:

\[
R_1 = \frac{21+7+8+8+5}{122.01+70.06+90.63+40.40+9.10} = 0.15 \text{ Crashes / MVMT}
\]

**Step 8: Calculate a critical crash rate for each segment**

\[
(3) \quad R_c = R_a + \text{Confidence Level} \times \sqrt{\frac{R_a}{MVMT_n}} + \frac{1}{2 \times MVMT_n}
\]

\[ R_c = \text{Critical crash rate} \]
\[ R_a = \text{Weighted average crash rate for reference population} \]

The segment 5 critical crash rate is calculated as follows:

\[
R_c = 0.15 + 1.645 \times \sqrt{\frac{0.15}{9.10}} + \frac{1}{2 \times 9.10} = 0.41 \text{ Crashes / MVMT}
\]

**Step 9: Compare observed crash rate with critical crash rate.**

Segments can be ranked and prioritized by the amount the segment crash rate exceeds its
critical rate. Mapping the safety priority locations may be desirable for visualization.

Segments identified for further analysis can then be analyzed in more detailed by identifying specific crash types, causes and locations within the segment. For example, for a climbing lane segment, each portion of the climbing lane can be examined; the uphill, crest, and downhill sides.

For Segment 5, the observed crash rate is 0.55, which exceeds Segment 5’s critical crash rate of 0.41.

**Step 10: Conclusions**

From the analysis, Segment 5 exceeds the critical rate and is a “safety focus” location that needs to be reviewed in more detail. At a minimum, crashes and patterns need to be identified and potential countermeasures indicated. More in-depth HSM predictive analysis could be done for the existing conditions and any later future conditions which could also include finding the most cost-effective countermeasures. A variation of this method could be to calculate fatal and injury only crash rates. This could help to identify segments with potential crash severity issues.

### 4.3 Excess Proportion of Specific Crash Types

*Excess Proportion of Specific Crash Types* is an HSM method that expands on the *Probability of Specific Crash Types Exceeding Threshold Proportion* method and is used to quantify the extent that a specific crash type is overrepresented. Its measure allows for network screening of a study area without relying on the need for intersection volumes. This method should be used if there are not enough ADT-capable (12 hours or greater) counts to support the HSM Critical Rate or other HSM Part B method. It can also be used to supplement the Critical Rate method as it screens by crash type rather than a crash rate.

Like critical crash rates, a reference population must be available to calculate a statistical variance between intersections. This method relies purely on a total number of crashes and does not require information regarding volume. It is calculated using total crashes for a user-chosen number of years. Without reliance on a time frame, this method is not affected by the regression to the mean bias.

Each intersection is subcategorized, similarly to critical crash rates at intersections, into reference populations. For example, 3-leg stop controlled is one reference population, and 3-leg signalized is another. It is important to have a large enough project area that the number of sites in each reference population is sufficient to be statistically relevant. The larger the reference population for an intersection type, the higher the precision level is for that population. Although this method is not reliant on volumes, care should be taken to not place significantly different intersections into the same reference population. For
example, intersections with significantly different volumes or driver characteristics but
the same layout should not be placed in the same reference population, for comparative
purposes.

Threshold proportions must be calculated for each crash type for each reference
population. These threshold proportions are compared to the observed proportion of crash
types at each type of intersection. The probability of a crash type exceeding the threshold
proportion is then calculated.

The probability and proportions for each crash type must be calculated for each reference
population. Due to the intensity of the statistical calculations, a spreadsheet was
developed to aid in the implementation of this method and is discussed in Example 4-5.
The spreadsheet is available at
http://www.oregon.gov/ODOT/TD/TP/APM/ProbabilityofCrash_v102.xlt. For more
detailed instructions on using the tool, see the instructions tab within the spreadsheet. For
more information on this method see pages 4-52 to 4-58 in the Highway Safety Manual
Volume 1.

**Example 4-5 HSM Excess Proportions at Intersections**

As a part of a corridor safety project, a safety analysis needs to be completed for 25
intersections along Salem Highway (#072). The focus of this study is to increase safety
by reducing angle crashes. The project is to reduce crashes at five intersections along the
corridor. There are no ADT-capable counts along the corridor and the budget does not
allow for new counts to be taken.

The intersection breakdown of total crashes and intersection characteristics is obtained
from the Excel version of the PRC listing report and pasted into the spreadsheet. See the
Instructions tab in the spreadsheet for more detailed directions on how to organize the
sites.
Step 1: Organize Sites into Reference Populations

After using the spreadsheet to summarize PRC crash data, organizing the sites is necessary. There may be multiple rows of crashes pertaining to the same intersection. Crashes that are intersection and intersection related need to be combined into a single row per intersection. This difference can be because of crashes occurring due to the intersection but were not in the intersection proper, due to the number of people working to electronically code the crashes, or due to inconsistencies in the reported data. Engineering judgment must be used when combining multiple rows of crashes.

The next 6 Steps are all done within the spreadsheet. Once the sites have been organized the spreadsheet is able to calculate the following steps.

Step 2: Calculate Observed Proportions

\[ p_i = \frac{N_{observed,i}}{N_{observed,i,\text{total}}} \]

Where: \( p_i \) = Observed proportion at site i
\( N_{observed,i} \) = number of observed target crashes at i.
\( N_{observed,i,\text{total}} \) = Total number of crashes at i.

Step 3: Calculate a Threshold Proportion

\[ p^* = \frac{\sum N_{observed,i}}{\sum N_{observed,i,\text{total}}} \]
Where: \( P_i = \) Threshold proportion  
\[ \sum N_{\text{observed},i} = \text{Sum of observed target crash frequency within the population.} \]  
\[ \sum N_{\text{observed},i(\text{total})} = \text{Sum of total observed crash frequency within population.} \]

**Step 4: Calculate Sample Variance**

\[
Var(N) = \left( \frac{1}{n_{\text{sites}} - 1} \right) \times \left[ \sum_{i=1}^{n} \left( \frac{N_{\text{observed},i}^2 - N_{\text{observed},i}}{N_{\text{observed},i(\text{total})}^2 - N_{\text{observed},i(\text{total})}} \right) - \left( \frac{1}{n_{\text{sites}}} \right) \times \left( \sum_{i=1}^{n} \frac{N_{\text{observed},i}}{N_{\text{observed},i(\text{total})}} \right)^2 \right]
\]

For \( N_{\text{observed},i} \geq 2 \)

Where:

\[ n_{\text{sites}} = \text{Total number of sites being analyzed} \]
\[ N_{\text{observed},i} = \text{Observed target crashes for site } i \]
\[ N_{\text{observed},i(\text{total})} = \text{Total number of crashes for site } i \]

Note: If the number of sites with more than two type ‘i’ crashes is not greater than one, the variance is zero. If the variance is zero, the probability cannot be calculated because there is nothing to compare.

**Step 5: Calculate the Alpha and Beta Parameters**

\[ \alpha = p_{i}^* - p_{i}^{*2} - s^2 \left( p_{i}^{*2} \right) \]

\[ \beta = \frac{\alpha}{p_{i}^*} - \alpha \]

Where:

\[ n_{\text{sites}} = \]
\[ p_{i}^* = \]
\[ p_i = \]
\[ Var(N) = s^2 \]

**Step 6: Use the excel function to calculate the beta distribution.**

\[
Var(N) = \left( \frac{1}{n_{\text{sites}} - 1} \right) \times \left[ \sum_{i=1}^{n} \left( \frac{N_{\text{observed},i}^2 - N_{\text{observed},i}}{N_{\text{observed},i(\text{total})}^2 - N_{\text{observed},i(\text{total})}} \right) - \left( \frac{1}{n_{\text{sites}}} \right) \times \left( \sum_{i=1}^{n} \frac{N_{\text{observed},i}}{N_{\text{observed},i(\text{total})}} \right)^2 \right]
\]
Where:
\[ p^*_i = \]
\[ p_i = \]
\[ N_{\text{observed\,(total)}} = \]
\[ N_{\text{observed\,}_i} = \]

The number that comes out of this calculation is the probability of a specific crash type being greater than the long-term expected proportion of that crash type at the specified intersection type.

**Step 7: Calculate the Excess Proportion**

\[ p_{\text{diff}} = p_i - p^*_i \]

Where:

\[ p^*_i = \text{Threshold proportion} \]
\[ p_i = \text{Observed proportion} \]

The spreadsheet calculates both the probability of exceeding the long-term expected crash rate as well as the excess proportion of the specific crash type. The calculated probability can be interpreted as the likelihood that the long-term expected proportion of a crash type at the intersection is greater than the threshold proportion. The excess proportion that is calculated is simply the difference in the observed crash proportion and the threshold proportion for the reference population. The data output and a short explanation of the output for this example can be seen below. The spreadsheet places the output onto the results and the Excess Proportions tabs.
The cells that appear as pink are automatically highlighted by the spreadsheet because their probability is greater than 60%. For example, the 0.706 in smaller box should be read as; there is a 70.6% chance that the long-term expected proportion of angle crashes at Commercial Street and Hickory Street will be greater than the long-term expected proportion of angle crashes at other 3-leg stop controlled intersections in this population.

On the excess proportion tab is where to find the excess proportion of the crash type. According to the HSM, the greater this difference is, “the greater the likelihood that the site will benefit from a countermeasure targeted at the collision type under consideration.” Using the same intersection from above, the 0.274 means that there are 27% more observed angle crashes than the calculated threshold for 3-leg stop controlled intersections in this population.

For this population of intersections, a total of 14 intersections have a greater than 60% chance of having a greater proportion of angle crashes than expected. Using the excess proportion calculation, the five intersections that would respond best to countermeasures for angle crashes could be chosen. The five intersections that would benefit most from...
countermeasures aimed at angle crashes are listed below.

<table>
<thead>
<tr>
<th>Intersection</th>
<th>INT Type</th>
<th>Road Characteristic</th>
<th># of Legs</th>
<th>Street 1</th>
<th>Street 2</th>
<th>Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.62</td>
<td>ONE-WAY</td>
<td>INTER</td>
<td></td>
<td>LIBERTY ST NE</td>
<td>PINE ST NE</td>
<td>0.542</td>
</tr>
<tr>
<td>5.30</td>
<td>TRF SIGNAL</td>
<td>INTER</td>
<td>3-LEG</td>
<td>COMMERCIAL ST PERRY ST SE</td>
<td>0.349</td>
<td></td>
</tr>
<tr>
<td>6.32</td>
<td>ONE-WAY</td>
<td>INTER</td>
<td></td>
<td>LIBERTY ST SE</td>
<td>TRADE ST SE</td>
<td>0.297</td>
</tr>
<tr>
<td>3.62</td>
<td>ONE-WAY</td>
<td>INTER</td>
<td></td>
<td>COMMERCIAL ST THICKORY ST NE</td>
<td>0.274</td>
<td></td>
</tr>
<tr>
<td>4.84</td>
<td>TRF SIGNAL</td>
<td>INTER</td>
<td>CROSS</td>
<td>FRONT ST PKY UNION ST NE</td>
<td>0.223</td>
<td></td>
</tr>
</tbody>
</table>

### 4.4 Predictive Crash Analysis

The Highway Safety Manual (HSM) has introduced a new way of evaluating safety performance of a roadway segment based on substantive safety. This new predictive method, detailed in Part C, was created from extensive research and analysis rather than relying on design standards (nominal safety). The overall method predicts crashes per year and severity depending on specific local conditions.

The HSM makes a distinction between the crashes based only on characteristics (Predicted Crashes) versus characteristics plus local crash history (Expected Crashes). Predicted Crash Frequency is based on the geometric design, traffic control and traffic volumes of the local conditions. The Expected Crash Frequency is the combination of the predicted crash frequency with the historical crash frequency (using the Empirical-Bayes methods). The benefit of the Empirical-Bayes (EB) method is that it accounts for the regression-to-the-mean (RTM) error which is the natural fluctuation of crashes that occur over the years independently of the contributing factors the analysis is trying to review.

The HSM predictive equation is located in Section C.4 of the HSM but is generalized to:

\[
P\text{Predicted Crashes} = \text{Safety Performance Function} \times \text{Crash Modification Factor(s)} \times \text{Calibration Factor}
\]

#### 4.4.1 Safety Performance Functions (SPF)

HSM Safety Performance Functions (SPF) are mathematical models based on national data including crash data, geometric features, and operational data. SPFs use a generic base-condition that needs to be adjusted to local conditions using Crash Modification Factors (CMFs). There are different SPF’s for rural highways, urban streets, intersections, and bike/pedestrians. Currently, there are specific HSM SPFs for the following:

- Freeways (In final AASHTO review and should be available soon)
- Interchanges (In final AASHTO review and should be available soon)
Rural Two-Way, Two-lane
Rural Multi-lane (up to 2 through lanes in each direction)
Urban/Suburban Arterials
Divided or Undivided
Three or Four-legged Intersections
Traffic Control (Signalized or 2-way Stop Controlled)

SPFs account for the non-linearity of crash rates. Crash rates incorrectly assume a linear relationship between observed number of crashes and traffic volumes. SPF’s correct for relationships other than traffic volumes, i.e., type of roadway, number of lanes, etc. An example non-linear SPF plot is shown in Exhibit 4-3.

Exhibit 4-3 Rural Multilane SPF 4-Leg Signalized Intersections (4SG)*

* Fig 11-7 on p 11-23 in Ch 11 of Volume 2, Part C, 1st Edition HSM

Note there are separate factors (not SPFs) for pedestrians and bicycles. There are currently no HSM SPFs for the following facilities:
  - All-Way Stop
  - Yield Control (including Roundabouts)
  - Rural 3-legged Signal
  - One-Way Streets and Intersections with One-Way Streets
  - Six-Lane Arterials

Study roadways are broken into segments and intersections based on HSM defined functional area definitions. The SPF’s are then applied to determine the crashes for each
segment or intersection. Totaling the intersection and segment crashes determines the overall number of facility crashes.

### 4.4.2 Crash Modification Factors (CMFs)

Crash Modification Factors (CMFs) are used to “modify” SPF’s to account for the local conditions present in the study area. SPF’s are “base” models, based on a set of base conditions. For example a base model SPF may have four foot shoulders but the actual area has eight foot shoulders. A CMF is multiplied with the crash frequency predicted by the SPF to account for change in predicted crashes from the base condition. As in the above example, if the roadway has eight foot shoulders but the base condition of the SPF is four foot shoulders one would expect a CMF of less than 1.0. A CMF equal to 1.0 means no change is expected. A CMF greater than 1.0 implies an increase in crashes, while a CMF less than 1.0 would have a decrease in crashes. In the above example, one would expect a crash reduction from having a wider shoulder, but the reduction will vary depending on the facility type.

A summary of CMF’s used in Part C are:
- Site specific
- Developed from research database from which SPF’s were developed
- Unique to the Part C Predictive Method

CMFs are also used to predict the crashes after application of a countermeasure or change in conditions and are found in Part D or the CMF Clearinghouse.

A summary of CMF’s used in Part D/CMF Clearinghouse are:
- Treatment or countermeasure specific
- Based on independent research; reviewed and approved by HSM Task Force
- Applicable to any site analysis

The term Crash Reduction Factors (CRFs) was part of the early discussions of predictive crash methods (and is still frequently used in other literature), but was dropped in preference to the modification factors. CRFs relate to CMFs in the following way:

\[
\text{CMF} = 1 - \left( \frac{\text{CRF}}{100} \right)
\]

so a CMF of 0.2 is a CRF of 80%. .

Listed below are some, but not all of the factors, which can be included:

---

Part C CMF’s were developed in conjunction with the model development whereas Part D CMF’S are based on actual countermeasures. CMF’s in Part C should only be used with Part C SPF’s. CMF’s in Part D should not be used with Part C unless they were originally from Part C.

---

Analysis Procedure Manual Version 2  4-25  Last Updated 10/2014
Segment:
Shoulder Width
Roadside Object Density (poles, trees)
Median Widths
Parking
Lighting
Automatic Speed Enforcement

Intersection:
Turn Lanes
Signal Phasing
Lighting
Red Light Camera Enforcement

Other:
Alcohol Establishments
Schools
Transit Stops

The FHWA Crash Modification Factors Clearinghouse contains a Web-based database of CMFs along with supporting documentation to help analysts identify the most appropriate countermeasure. The ODOT CMF Instructions web page provides guidance on how best to use the FHWA CMF Clearinghouse site.

Note that the ODOT CMF standard is to use CMFs with quality ratings of three stars or better (star rating is a rating of the type of research and more stars indicate better, more reliable results). For many countermeasures, there may be multiple CMFs available with different levels of crash reduction. Care should be taken to not just pick the highest reduction at first. A particular CMF may apply to all crashes, or just severe crashes, or for a particular crash type. The CMF study parameters may limit it to a particular roadway configuration or to a specific volume range. The CMF AADT range should be no more than +/- 10% away from the countermeasure location AADT. Values greater than this indicate that the subject roadway likely does not have the same characteristics as the one in the CMF study.

4.4.3 Calibration Coefficients

Because each state has different crash reporting and enforcement requirements, the HSM states that calibration to local conditions should be performed. In Oregon, crash reporting is a driver responsibility with some enhancement for enforcement. This means that it is more likely to have a police report if there was a serious injury than a property damage only crash. Oregon’s required reporting threshold is typically higher than many other states (at $1500) so many minor crashes do not have to be reported. Because of these reporting requirements, Oregon conditions data should not be directly related to adjacent states (i.e. Washington) which have different reporting thresholds. ODOT has created Oregon Calibration Factors for use in the predictive equations for most facility
types in the report, *Calibrating The Future Highway Safety Manual Predictive Methods For Oregon State Highways*, February, 2012. Where an Oregon calibration factor does not exist, the results of the predictive analysis should only be used for relative comparisons. An example of this is the new freeway and interchange SPF's that will soon be released.

### 4.4.4 Data Needs

For the predictive method of safety evaluation, the evaluation should be based on the study area characteristics regardless of the specific HSM definition of rural/urban. There are some areas within urban growth boundaries which by the HSM would be classified as urban but are rural in nature. There are also areas that would be classified as rural (UGB with less than 5,000 population) that are distinctly urban i.e. Sisters, Canyonville, Depoe Bay, Joseph, etc.) Please see guidance on creating AADT’s from Section 5.7.

For rural 2-lane segments with traffic in each direction (rural 2-way, 2-lane) the following data is needed to perform predictive safety evaluations - geometrics and traffic volumes as well as specific information about driveways, roadside hazard rating and other specific features.

**Rural, 2-lane, 2-way Segments**
- Segment length
- AADT (major)
- Lane and Shoulder Widths
- Shoulder Types
- Horizontal Curve Data
- Grades
- Driveway Density
- Roadside Hazard Rating (general characteristics for a scale of 1-7)
- Presence or Absence of:
  - Centerline Rumble Strips
  - Passing Lanes
  - Short 4-lane sections (side-by side passing lanes)
  - TWLTL
  - Lighting
  - Automated Speed Enforcement

Rural multi-lane segments needs the same types of data as rural 2-lane with specific information about medians and side-slopes.

**Rural, Multi-lane Segments**
- Segment length
- AADT (major)
- Lane and Shoulder Widths
- Presence of Median (and width) if divided
- Side slope (if undivided)
Presence or Absence of:
Lighting
Automated Speed Enforcement

Rural intersections need data related to the individual approaches (volumes, lanes, control, skew) and other features.
Rural 2-lane 2-way and Multi-lane Intersections
AADT (major and minor)
No. on approaches (legs)
Traffic Control
Skewed Angle on Approaches
No. of approaches with left or right turn lanes
Presence or Absence of Lighting

On urban and suburban arterial segments, the data required roadway geometrics and characteristics, and other specific features.

Urban / Suburban Arterial Segments
Segment length
AADT (major)
No. of Through Lanes
No. of driveways for each driveway type
Roadside Fixed Object Density (see HSM page 12-10)
Average Offset to Roadside Fixed Objects
Speed Category (Actual or Posted)
Presence or Absence of:
Median Type
Parking Type
Lighting
Automated Speed Enforcement

Urban and suburban intersections need data related to the individual approaches (volumes, lanes, control, skew) and other features.

Urban / Suburban Arterial (All) Intersections
AADT (major and minor)
No. on approaches (legs)
Traffic Control
No. of approaches with left or right turn lanes
No. of major road approaches with left turn phasing
No. of approaches with Right Turn on Red prohibited
Maximum number of lanes to be crossed by a pedestrian
Proportion of nighttime crashes (if unlit)
Presence or Absence of Lighting

In addition to the general intersection information above, signalized intersections need
other specific information to perform predictive safety evaluation.

Urban / Suburban Arterial Signalized Intersections (all of the above) plus:
  - No. of bus stops within 1000 feet of the intersections
  - Presence of school grounds within 1000 feet of the intersections
  - No. of alcohol sales establishments within 1000 feet of the intersections
  - Presence of Red-Light Cameras
  - No. of approaches where Right Turn on Red is allowed

4.4.5 HSM-based Tools

There are a variety of Highway Safety Manual-based tools available to help streamline project-level analysis to segments and intersections. These tools mostly implement the Part C predictive analysis.

Interactive Highway Safety Design Model (IHSDM)
The IHSDM software is a group of different software modules used for evaluating the safety and operational effects of geometric design. More information can be found on the [IHSDM software download website](#).

IHSDM is a free application approved for installation on ODOT computers. This software package focuses on geometric design, so it requires a high level of detail. Roadway geometric data can be hard-coded or AutoCAD-compatible drawings can be directly loaded into the software. The software is too data intensive to be used practically for extended sections of highway. IHSDM is typically used for:

- Rural segments that have little change over the length
- Urban arterials—short sections
- Design exception evaluation
- Can also be used in smaller sections or issues on large projects

HiSafe

HiSafe is a commercial software program that implements the HSM Part C predictive method. This software allows for a quick way to analyze a number of different alternatives with varying countermeasures. The program has been designed to facilitate easy input and navigation between segments and intersections and their results (see Exhibit 4-4). HiSafe allows for the quick addition or removal of intersections, segments, and analysis years. The analysis results are available in multiple pages showing the results by individual segment, intersection, or by the entire project area. Similarly, they can be viewed by individual year or over the entire analysis study period. The results can also be further divided into single vehicle crashes, multiple vehicles crashes, crashes by severity level, and crashes by collision type. The program allows for the default crash proportions to be overridden with local values. It also has the ability to calculate the
expected crash rates using the Empirical Bayes (EB) Method. HiSafe is a “small” cost program which has been approved for installation on ODOT computers. Data needs are consistent with the normal HSM Part C requirements.

Exhibit 4-4 HiSafe Screenshot

More information is available on the HiSafe website.

Highway Safety Manual Spreadsheets
The HSM spreadsheets were developed as part of NCHRP Project 17-38, Highway Safety Manual Implementation and Training Materials, to aid in training the HSM Part C predictive method (see Exhibit 4-5). The spreadsheets themselves are designed with a set number of sheets, which means only two segments and two intersections for one year can be analyzed within one spreadsheet without modifying the spreadsheet. The user can copy worksheets in the spreadsheet and modify the results page to add segment and intersection capacity. However, adding additional worksheets to increase the amount of segments and intersections in an analysis can be moderately time consuming. The basic NCHRP spreadsheets have the ability to utilize the EB Method. The spreadsheet displays results by segments and intersections and also separates the results into single-vehicle, multiple-vehicle non-driveway, and multiple-vehicle driveway-related crashes. The worksheets are free to download but do not have any technical support at this time for any changes or updates to the HSM. Data needs are consistent with the normal HSM Part
The spreadsheets containing Oregon-specific calibration factors and crash proportions can be downloaded from the [ODOT HSM Webpage](http://www.odot.state.or.us/hsm).

**Highway Safety Investigations Manual**

The Highway Safety Investigations Manual is a resource to assist ODOT traffic investigators and analysts with detailed highway safety project screening and evaluations. The manual includes checklists and analysis procedures suitable for a variety of field and office safety investigations and assessments. A set of worksheets is available containing tools and forms to facilitate the analysis. The manual and spreadsheets are available on the [ODOT Highway Safety Webpage](http://www.odot.state.or.us/hsm).

### 4.5 HSM Applications

In general, study areas should be screened using the HSM Part B Critical rate method and comparison to published (Table II) segment crash rates to determine the priority safety intersections and segments. For each of these priority locations, the causes and patterns...
need to be determined and potential countermeasures identified. Each of the potential countermeasures or safety improvements need to be screened using HSM Part D Crash Modification Factors (CMFs) or the FHWA CMF Clearinghouse site. Each CMF can indicate a potential percentile reduction in crashes. Judgment needs to be applied to see if the measures are practical or cost-effective. The analyst should also coordinate with Region Traffic during this phase. Final alternatives or operational improvements can report out specific predicted crash reductions as determined using Parts C/D of the HSM.

For TSPs and other higher-level corridor plans, the HSM Part B Critical Rate screening method should be used to narrow down the safety needs. Safety improvements should be only identified by potential percentile crash reduction using CMFs. Predictive analysis is not used at this level.

For more detailed plans and projects, once the study area has been screened down to safety priority locations, then HSM Part C predictive analysis should be used (where applicable) to establish the existing condition and future no-build expected crashes. Causes and patterns need to be identified and potential countermeasures/safety improvements evaluated using Parts C/D. Analysis of multiple future build alternatives in the alternative development process can be done using CMFs, unless the alternative changes are great enough for another SPF to be applicable, instead of the predictive methods. Larger projects such as ones under National Environmental Policy Act (NEPA) requirements will require predictive analysis on the final alternatives at least leading up to the preferred alternative. In addition, evaluation criteria may also require other alternatives to be evaluated with CMFs or the predictive methods as applicable.

**Example 4-6 CMF & Predictive Analysis**

A corridor was selected for a safety analysis to determine if any safety improvements were possible. Traffic counts were done in 2010 to find the Average Daily Traffic (ADT) on each street segment adjacent to or in the area in question. The area chosen for analysis contains a combination of five signalized intersections (Type 1) and two stop-controlled intersections (Type 2).

The safety study will be conducted from 2006 to 2010. The crash data was found online through the Oregon Department of Transportation’s Crash Data System. For your convenience, the crash data has been recorded in the table below.
Average Daily Traffic

Crash Data

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>126th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>127th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>128th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>129th SE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>129th NE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>130th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>131st</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To be able to use the Critical Rate method and the Predictive method, bi-directional ADTs need to be converted to approach (directional) ADTs. To complete this step, simply multiply the ADT by the appropriate directional factor (D). The ADTs were computed and are shown below in the diagram.
From these results, we can see that the intersection of 128th St and Adams St needs to be scrutinized further to determine the cause for the high rate of crashes. This brings us to the predictive method.

From Exhibit 4-1, the 90th percentile crash rates are as follows
- 4-leg signalized intersections in an urban area (4SG) = 0.86
- 3-leg unsignalized intersections in an urban area (3ST) = 0.29
- 3-leg signalized intersections in an urban area (3SG) = 0.51

In this example, none of the intersections exceed the 90th percentile published rates.

Predictive Method for Urban and Suburban Arterial Intersections

Note: The predictive method example is based on Adams St and 128th St, which is a 4-leg signalized intersection.
Step 1: Determine the limits of the roadway and facility types that will be included in the study network, facility, or site.
  ▪ The critical rate method flagged the intersection of Adams St and 128th St with an unusually high crash rate. We will study this intersection further using the predictive method.

Step 2: Define the time period of interest.
  ▪ The time period for this study is 2006 – 2010.

Step 3: Determine AADT and availability of crash data for each year in the period of interest.
  ▪ This data was originally collected through the critical rate method and will be reused in the predictive method. Throughout the analysis, the AADTs will need to be adjusted for the years of study.

Step 4: Determine geometric design features, traffic control features, and site characteristics for all sites in the study network.
  ▪ Data for the intersection of Adams St and 128th St are shown in the following table.
### Data Requirement | Intersection of Adams St and 128th St
--- | ---
AADT (Vehicles/day) | The AADTs were found through the local agency’s traffic counts information page.
Pedestrian volumes | The pedestrian volume was estimated to be 50 pedestrians per day. Table 12-15 of the 1st edition Highway Safety Manual, Volume 2, Chapter 12 gives estimates of pedestrian crossing volumes based on the general level of pedestrian activity.
Number of intersection legs | The intersection has 4 legs.
Type of traffic control | The intersection is signalized.
Number of approaches with a left-turn lane | All 4 of the approaches to the intersection have left-turn lanes.
Number of approaches with left-turn signal phasing and type of left-turn signal phasing for each movement | All four of the left-turn lanes have protected/permited phasing.
Number of approaches with a right turn lane | None of the approaches to the intersection have right-turn lanes.
Number of approaches with right-turn-on-red operation prohibited | None of the approaches have prohibited right-turn-on-red movements.
Presence/absence of intersection lighting | There is intersection lighting.
Maximum number of traffic lanes to be crossed by a pedestrian in any crossing maneuver at the intersection considering the presence of refuge islands | The maximum number of lanes to be crossed by a pedestrian is 5 lanes.
Number of bus stops within 1,000 feet of the intersection | There are four bus stops located within 1,000 feet of the intersection.
Presence of schools within 1,000 feet of the intersection | There are no schools located within 1,000 feet of the intersection.
Number of alcohol sales establishments that sell alcohol within 1,000 feet if the intersection | There are four different establishments that sell alcohol within 1,000 feet of the intersection.

Step 5: Divide roadway into individual roadway segments and intersections.
- The example study area is only one intersection, therefore this step is unnecessary.

Step 6: Assign observed crashes to individual sites.
- This step is also completed in the Critical Rate method and that data will be reused.

Step 7: Select a roadway segment or intersection.
- The intersection of Adams St and 128th has been selected for further study.

Step 8: Select first or next year of the evaluation period.
- The example will start in year 2010 and work to year 2006 with the calculations. A table of Calculations has been included below for your convenience.
Step 9: Select and apply Safety Performance Functions (SPF). SPFs relevant to Urban and Suburban Arterial Intersections are found in Section 12.6.2 of the 1st edition, Highway Safety Manual, Volume 2. The results of these calculations are shown below.

- **Multiple-Vehicle Collisions;** \( N_{\text{binv}} \)
  \[ N_{\text{binv}} = \exp(a + b \times \ln(AADT_{\text{Maj}}) + c \times \ln(AADT_{\text{Min}})) \]
  Where:
  - \( AADT_{\text{Maj}} \) = average daily traffic volume (vehicles/day) for major road (both directions of travel combined).
  - \( AADT_{\text{Min}} \) = average daily traffic volume (vehicles/day) for minor road (both directions of travel combined).
  - \( a, b, c \) = regression coefficients (Table 12-2 in the 1st edition, Highway Safety Manual, Volume 2, Chapter 12)

- **Single-Vehicle Crashes;** \( N_{\text{bisv}} \)
  \[ N_{\text{bisv}} = \exp(a + b \times \ln(AADT_{\text{Maj}}) + c \times \ln(AADT_{\text{Min}})) \]
  Where:
  - \( AADT_{\text{Maj}} \) = average daily traffic volume (vehicles/day) for major road (both directions of travel combined).
  - \( AADT_{\text{Min}} \) = average daily traffic volume (vehicles/day) for minor road (both directions of travel combined).
  - \( a, b, c \) = regression coefficients (Table 12-12 in the 1st edition, Highway Safety Manual, Volume 2, Chapter 12)

- **Vehicle-Pedestrian Collisions;** \( N_{\text{pedi}} \)
  \[ N_{\text{pedi}} = N_{\text{pedbase}} \times \text{CMF}_1 \times \text{CMF}_2 \times \text{CMF}_3 \]
  Where:
  - \( N_{\text{pedbase}} \) = predicted number of vehicle-pedestrian collisions per year for base conditions at signalized intersections.
  - \( \text{CMF}_1 \ldots \text{CMF}_3 \) = crash modification factors for vehicle-pedestrian collisions at signalized intersections (See step 10)

**\( N_{\text{pedbase}} \) Calculation**

\[ N_{\text{pedbase}} = \exp\left(a + b \times \ln(AADT_{\text{total}}) + c \times \ln\left(\frac{AADT_{\text{Maj}}}{AADT_{\text{Min}}}\right) + d \times \ln(PedVol) + e \times n_{\text{lanex}}\right) \]

Where:
- \( AADT_{\text{total}} \) = sum of the average daily traffic volumes (vehicles/day) for the major and minor roads (\( = \frac{AADT_{\text{Maj}} + AADT_{\text{Min}}}{2} \)).
- \( n_{\text{lanex}} \) = maximum number of traffic lanes crossed by a pedestrian in any crossing maneuver at the intersection considering the presence of refuge islands.
a, b, c, d, e = regression coefficients (Table 12-14 in the 1st edition, Highway Safety Manual, Volume 2, Chapter 12)

- **Vehicle-Bicycle Collisions;** $N_{\text{bikei}}$

  $$N_{\text{bikei}} = N_{\text{nti}} \times f_{\text{bikei}}$$

  $$N_{\text{hi}} = N_{\text{spf\text{int}}} \times \left( CMF_{1i} \times CMF_{2i} \times \ldots \times CMF_{6i} \right) \times C$$

  $N_{\text{hi}}$ = predicted average crash frequency of an intersection (excluding vehicle-pedestrian and vehicle-bicycle collisions).

  $f_{\text{bikei}}$ = bicycle crash adjustment factor (Table 12-17 in the 1st edition, Highway Safety Manual, Volume 2, Chapter 12)

  $N_{\text{spf\text{int}}}$ = predicted total average crash frequency of intersection-related crashes for base conditions (excluding vehicle-pedestrian and vehicle-bicycle collisions)

  $CMF_{1i}, \ldots, CMF_{6i}$ = crash modification factors for intersections (See step 10)

  $C$ = Calibration Factor

**Step 10: Apply CMFs**

- **Intersection Left-Turn Lanes:** $CMF_{1i}$ (Table 12-24 in the 1st edition, HSM, Volume 2, Chapter 12)
  - For the intersection of Adams St and 128th, $CMF_{1i} = 0.66$

- **Intersection Left-Turn Signal Phasing:** $CMF_{2i}$ (Table 12-25 in the 1st edition, HSM, Volume 2, Chapter 12)
  - For the intersection of Adams St and 128th, $CMF_{2i} = 0.96$

- **Intersection Right-Turn Lanes:** $CMF_{3i}$ (Table 12-26 in the 1st edition, HSM, Volume 2, Chapter 12)
  - For the intersection of Adams St and 128th, $CMF_{3i} = 1.00$

- **Right-Turn-on-Red:** $CMF_{4i}$
  - $CMF_{4i} = 0.98^n_{\text{proh}}$

  Where:

  $CMF_{4i}$ = crash modification factor for the effect of prohibiting right turns on red on total crashes

  $n_{\text{proh}}$ = number of signalized intersection approaches for which right-turn-on-red is prohibited.

  - For the intersection of Adams St and 128th, $CMF_{4i} = 1.00$

- **Lighting:** $CMF_{5i}$
  - $CMF_{5i} = 1 - 0.38 \times p_{ni}$
Where:

\(CMF_{5i}\) = crash modification factor for the effect of intersection lighting on total crashes

\(p_{ni}\) = proportion of total crashes for unlighted intersections that occur at night.

Default values for \(p_{ni}\) can be found in Table 12-27 in the 1st edition HSM, Volume 2, Chapter 12. It is recommended to replace the default values with locally derived values.

- For the intersection of Adams St and 128th, \(CMF_{5i} = 0.94\) using a locally-derived value \((p_{ni} = 0.154)\).

### Red-Light Cameras: \(CMF_{6i}\)

- \(CMF_{6i}\) is based on the presence of red-light cameras. The base condition is their absence. There are no red-light cameras at the intersection of Adams St and 128th, so for the example \(CMF_{6i} = 1.00\). The formula for \(CMF_{6i}\) is (12-37) found in the 1st edition HSM, Volume 2, Chapter 12.

### Bus Stops: \(CMF_{1p}\) (Table 12-28 in the 1st edition, HSM, Volume 2, Chapter 12)

- There are more than 3 (2 bus stops at 128th and Adams St, 1 a block North on 128th, and 1 half a block west on Adams St) bus stops within 1,000 feet of Adams St and 128th, so \(CMF_{1p} = 4.15\).

### Schools: \(CMF_{2p}\) (Table 12-29 in the 1st edition, HSM, Volume 2, Chapter 12)

- There are no schools within 1,000 feet of Adams St and 128th, so \(CMF_{2p} = 1.00\).

### Alcohol Sales Establishments: \(CMF_{3p}\) (Table 12-30 in the 1st edition, HSM, Volume 2, Chapter 12)

- There are 4 (2 stores, 1 restaurant, and 1 gas station) alcohol sales establishments within 1,000 feet of Adams St and 128th, so \(CMF_{3p} = 1.12\).

<table>
<thead>
<tr>
<th>(CMF_{1i})</th>
<th>(CMF_{2i})</th>
<th>(CMF_{3i})</th>
<th>(CMF_{4i})</th>
<th>(CMF_{5i})</th>
<th>(CMF_{6i})</th>
<th>(CMF_{i})</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.66</td>
<td>0.96</td>
<td>1.00</td>
<td>1.00</td>
<td>0.94</td>
<td>1.00</td>
<td>0.58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(CMF_{1p})</th>
<th>(CMF_{2p})</th>
<th>(CMF_{3p})</th>
<th>(CMF_{p})</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.15</td>
<td>1.00</td>
<td>1.12</td>
<td>4.65</td>
</tr>
</tbody>
</table>

Step 11: Apply a calibration factor. (location specific)

- The recommended Oregon Highway Safety Manual Calibration factor is 1.05.

Step 12: Is there another year? If yes, return to step 8. (there are five years in this example)
Step 13: Apply site-specific EB method. (this step is not included in this example)

Step 14: Is there another site? If yes, return to step 7. (this step is not included in this example)

Step 15: Apply project-level EB method. (this step is not included in this example)

Step 16: Sum all sites and years.
- The sum of the individual years is shown in the table below.

<table>
<thead>
<tr>
<th>Year</th>
<th>AADT (Maj)</th>
<th>AADT (Min)</th>
<th>N_bimv</th>
<th>N_bisv</th>
<th>N_spf int</th>
<th>N_bi</th>
<th>N_bikei</th>
<th>N_pedbase</th>
<th>N_pedi</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>23,150</td>
<td>12,300</td>
<td>6.88</td>
<td>0.43</td>
<td>7.32</td>
<td>4.59</td>
<td>0.07</td>
<td>0.029</td>
<td>0.13</td>
<td>4.84</td>
</tr>
<tr>
<td>2009</td>
<td>22,868</td>
<td>12,150</td>
<td>6.78</td>
<td>0.43</td>
<td>7.20</td>
<td>4.52</td>
<td>0.07</td>
<td>0.029</td>
<td>0.13</td>
<td>4.76</td>
</tr>
<tr>
<td>2008</td>
<td>22,589</td>
<td>12,002</td>
<td>6.67</td>
<td>0.42</td>
<td>7.09</td>
<td>4.45</td>
<td>0.07</td>
<td>0.029</td>
<td>0.13</td>
<td>4.69</td>
</tr>
<tr>
<td>2007</td>
<td>22,314</td>
<td>11,856</td>
<td>6.56</td>
<td>0.42</td>
<td>6.98</td>
<td>4.38</td>
<td>0.07</td>
<td>0.028</td>
<td>0.13</td>
<td>4.62</td>
</tr>
<tr>
<td>2006</td>
<td>22,042</td>
<td>11,711</td>
<td>6.46</td>
<td>0.41</td>
<td>6.87</td>
<td>4.31</td>
<td>0.06</td>
<td>0.028</td>
<td>0.13</td>
<td>4.55</td>
</tr>
<tr>
<td></td>
<td>Predicted</td>
<td></td>
<td>22.2</td>
<td>0.33</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23.45</td>
</tr>
<tr>
<td></td>
<td>Actual</td>
<td></td>
<td>46</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>47</td>
</tr>
</tbody>
</table>

Where:
- \( N_{\text{bimv}} \) = Multiple Vehicle Crashes / Year
- \( N_{\text{bisv}} \) = Single Vehicle Crashes / Year
- \( N_{\text{spf \ int}} \) = Vehicle Crashes / Year
- \( N_{\text{bi}} \) = Predicted Vehicle Crashes / Year
- \( N_{\text{bikei}} \) = Vehicle-Bicycle Crashes / Year
- \( N_{\text{pedbase}} \) = Vehicle-Pedestrian Crash Factor
- \( N_{\text{pedi}} \) = Vehicle-Pedestrian Crashes / Year

*Note: The sample calculations below are for year 2010.*

\[
\begin{align*}
N_{\text{bimv}} &= e^{-10.99 + 1.07 \times \ln(23,150) + 0.23 \times \ln(12,300)} = 6.88 \text{ crashes / year} \\
N_{\text{bisv}} &= e^{-10.21 + 0.68 \times \ln(23,150) + 0.27 \times \ln(12,300)} = 0.43 \text{ crashes / year} \\
N_{\text{spf \ int}} &= 6.88 + 0.43 = 7.32 \text{ crashes / year} \\
N_{\text{bi}} &= 7.32 \times (0.66 \times 0.96 \times 1.00 \times 1.00 \times 0.94 \times 1.00) \times 1.05 = 4.59 \text{ crashes / year} \\
N_{\text{bikei}} &= 4.59 \times 0.015 = 0.07 \\
N_{\text{pedbase}} &= e^{-9.53 + 0.4 \times \ln(23,150 + 12,300) + 0.26 \times \ln(12,300)} + 0.26 \times \ln(50) + 0.04 \times 5 = 0.029 \text{ crashes / year} \\
N_{\text{pedi}} &= 0.029 \times 4.15 \times 1.00 \times 1.12 = 0.13 \text{ crashes / year} \\
\text{Total Predicted Crashes / 5-year period} &= 4.84 + 4.76 + 4.69 + 4.62 + 4.55 \\
\text{Total Predicted Crashes / 5-year period} &= 23.45 \text{ crashes / 5-year period}
\end{align*}
\]

Step 17: Is there an alternative design, treatment, or forecast AADT to be evaluated? If yes, return to step 3.
- The intersection of Adams St and 128th St exhibits more crashes than anticipated. After field inspection, three possible mitigations were identified.
  - Implement automated red light running enforcement cameras
    - The FHWA CMF Clearinghouse was used to determine the CMF for this mitigation.
    - A Multi-Jurisdictional Safety Evaluation of Red Light Cameras; Persaud et al., 2005
- Angle CMF = 0.75
- Rear End CMF = 1.15
- 5 Stars

- Change left turn phasing from protected/permitted to protected
  - The CMF clearing house was used to determine the CMF for this mitigation.
  - Evaluation of the Safety Effectiveness of Selected Treatments at Urban Signalized Intersections; Srinivasan et al.
    - Angle (Left Turn only) CMF = 0.00
    - All CMF = 1.02
    - 3 stars
    - Because the angle CMF of this mitigation applies to left turns only, the CMF is multiplied by the number of left turn crashes only. In this example 11 of the angle crashes were left turn involved.

- Implement automated speed enforcement cameras (this only applies to certain cities under ORS 810.438 and 810.439)
  - The CMF clearing house was used to determine the CMF for this mitigation.
  - Evaluation of the Scottsdale Loop 101 automated speed enforcement demonstration program; Shin et al.
    - All CMF = 0.46
    - 4 stars

  Note: The CMF Clearing House does not distinguish specific angle crash types. Be sure to check the appropriate CMF documentation to determine which specific angle crashes the chosen mitigation applies to.

- After making each of these adjustments the following reductions in predicted crash percentages were determined:

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Red-Light Running</th>
<th>Protected Left Turn</th>
<th>Speed Enforcement</th>
<th>All Mitigations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear End</td>
<td>-15%</td>
<td>-2%</td>
<td>54%</td>
<td>46%</td>
</tr>
<tr>
<td>Angle</td>
<td>25%</td>
<td>48%</td>
<td>54%</td>
<td>82%</td>
</tr>
<tr>
<td>Sideswipe</td>
<td>0%</td>
<td>0%</td>
<td>54%</td>
<td>53%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5%</strong></td>
<td><strong>22%</strong></td>
<td><strong>54%</strong></td>
<td><strong>64%</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Red-light running with protected left turn</th>
<th>Red-light running with speed enforcement</th>
<th>Protected left turn with speed enforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear End</td>
<td>-17%</td>
<td>47%</td>
<td>53%</td>
</tr>
<tr>
<td>Angle</td>
<td>61%</td>
<td>66%</td>
<td>76%</td>
</tr>
<tr>
<td>Sideswipe</td>
<td>-2%</td>
<td>54%</td>
<td>53%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21%</strong></td>
<td><strong>56%</strong></td>
<td><strong>64%</strong></td>
</tr>
</tbody>
</table>

A negative result indicates a predictive increase in accidents of this type for the specific countermeasure.
Step 18: Compare and evaluate results.

- The total predicted vehicle crashes (22 crashes/5-year period) is about 25 less than the actual vehicle crashes (46 crashes/5-year period). The tables above show three possible mitigations and combinations of their effects. The automated speed enforcement cameras have the greatest effect on the predicted crashes, reducing the value from 46 crashes/5-years to 22 crashes/5-years. When the automated speed enforcement cameras are combined with protected left turns, the predicted crashes/5-years lowers even further to 17 crashes/5-years.
- These potential countermeasures are recommended for more detailed investigation by Region Traffic.
- *Note: Although the steps seem quite lengthy, the calculations can be expedited through the use of spreadsheets or other tools. Examples of these tools include the NCRHP spreadsheets and HiSafe, which are discussed in Chapter 4 of the Analysis Procedures Manual.*

4.6 **Countermeasure Selection**

While crash patterns identified should be considered during the alternatives analysis, specific countermeasure selection is generally not addressed in most transportation analysis projects. Most analysis projects will specify general or potential ranges of countermeasures. A separate effort should be initiated by Region Traffic for a detailed consideration of the crash patterns in the project report. Certain countermeasures may need specific review and approval by the Region or State Traffic Engineer (see list of [ODOT Traffic Engineering Authorities](#)).

There are many resources that provide potential countermeasures (HSM, etc) to select from for a given crash pattern. For example, FHWA has developed a list of proven systemic countermeasures ([FHWA Nine Proven Crash Countermeasures](#)). When selecting countermeasures, the analyst should coordinate with the ODOT TRS. Information on countermeasures is included in the ODOT Safety Investigations Manual. Certain countermeasure analysis for plans and projects may require economic analysis (i.e. HSM Chapter 7). Countermeasures can generally be grouped into three categories: education, enforcement and engineering.

- **Education** - a variety of public information campaigns using a broad range of media to reach a target audience. These can be effective in reducing driver error by making motorists aware of the risks and consequences of certain driving behaviors and environments encountered. These can be handled by the Region Public Information office (for a specific area) or by the Traffic Safety Division (for programmatic issues).
- **Enforcement** - involves increased policing activity to encourage compliance with existing traffic controls and regulations. Increased enforcement is often implemented due to frequent driver violations. The application of enforcement countermeasures is typically coordinated by Region Traffic Sections.
• Engineering - a broad range of improvements to the transportation system to improve roadway safety. These may include geometric improvements, ITS applications, changes to traffic controls (signing, striping, signals, etc.), changes to roadway surfacing, or operational enhancements.

Specific investigation into countermeasures should be at the appropriate level for the analysis being conducted. A system plan or alternative concepts should be screened using relative safety improvement which would report expected ranges of crash reduction. This reduction can be determined using HSM Part D Crash Modification Factors (CMFs) applied to historic crash values. Final alternatives or operational improvements can report out specific predicted crash reductions as determined using Parts C/D of the HSM.

4.7 Crash Data Reporting

4.7.1 Safety Priority Index System (SPIS)

Another analysis tool that ODOT uses is the Safety Priority Index System (SPIS) which provides an alternative method of ranking for intersections and segments of roadways on State Highways. SPIS All-Roads covers all local roadways that have traffic volume data available in addition to state highways (typically these include all functionally classed public roads in Oregon). SPIS incorporates crash rate, frequency and severity components to provide a single index to compare a roadway or intersection. Every section of a state highway may have an assigned SPIS number. Cutoff values of the top 5% and 10% are determined for each year of data. Sites with SPIS numbers less than the 10% cutoff are not likely relevant to the analysis at hand. Detailed documentation on SPIS can be found on the Safety Priority Index System website.

As part of a complete safety analysis, the analyst needs to locate and report any top 5 or 10% sites in their study area. These sites may be are areas with safety issues that need to be identified and addressed. These may or may not be previously identified in HSM screening methods. Plan or project alternatives need to address any Top 5 or 10% SPIS locations within the study area. The analyst should diagnose the crash causes to see that safety issues have been addressed with improvements or countermeasures.

The top 5% SPIS ranking requires the Region Traffic offices to conduct a safety investigation each year to determine if there is an appropriate safety improvement fix to the problem. The SPIS ranking can be determined by contacting the appropriate Region Traffic Office for assistance or on the SPIS webpage.

4.7.2 Trends and Patterns

The commonly used procedure to identify crash patterns is categorizing crashes by characteristics such as types, time of day, weather conditions and locations. In this form it may be easier for the analyst to identify crash trends such as a high number of a certain type of crash
or a location or movement that experiences a disproportionate amount of the total crashes. Impaired drivers are generally not included in identification of crash patterns for engineering countermeasures (could be for enforcement or education-based countermeasures). Other contributing factors/causes should be noted such as driving too fast for conditions, following too closely, or failure to yield, etc. All of the detail in a particular crash record can be used to help determine the actual issues and point to the appropriate countermeasures.

Caution should be exercised when identifying actual crash locations from reported data. Crashes may be reported at the nearest integer milepoint even if they occurred hundreds of feet away, i.e., a crash reported at milepoint 12 even though it actually occurred at milepoint 12.34. This can be evidenced by clusters of crashes reported at even milepoints. Crash data should be checked for discrepancies such as where a crash occurred on a curve, but the reported milepoint is located on a straightaway section.

The crash summaries from the CAR Unit are heavily code-dependent. A code key is necessary to determine the crash details. However, there are a number of tools available to decode the reports and offer a quicker way to analyze the information. Two such examples of tools are listed below under Tools.

**What Data to Report**

An analysis report should contain summarized information about crashes within the study area. The summary should contain trends, crash rates and a general discussion of the crashes. A table showing the crashes by year and type needs to be included. A bulleted list showing major crash summaries (weather, lighting conditions, types, locations, etc) is very helpful. Fatal crashes and pedestrian/bike crashes should be individually mentioned. The use of graphics to show trends is encouraged. The intersection and segment crash rates and comparisons to the critical crash rate or other HSM network screening options should also be included. The full crash analysis and the summarized crash data listings (date, type, severity, and cause) are typically appendices in the final traffic technical memorandum/narrative.

**Example 4-7 Crash Analysis Reporting**

This is an example of a typical crash analysis reporting at the project development level included in a technical report appendix.

The majority of the crashes were rear end collisions at intersections. The table below shows the crash and year summary for US97 between 2006 and 2011. The crashes on US 97 were mainly rear-end, turning, or fixed object type. These crashes mainly occurred in dry, daytime conditions. About 56% of the crashes occurred at one of three intersections: Cooley Road (MP 134.07 to MP 134.39), Robal Road (MP 134.48 to MP 134.70) and Empire Avenue (MP 135.03 to 135.76). Crashes were highest on this roadway in 2006 with 44 being reported. The six year average is about 36 crashes per year.

**US 97 Crash Type and Year**

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Analysis Procedure Manual Version 2 4-44 Last Updated 10/2014
There were a total of 214 crashes in this area between 2006 and 2011:

- Three fatal crashes
- 5% (11) injury A crashes
- 41% (88) injury crashes (including A)
- 57% (123) Property Damage Only (PDO) crashes
- 75% (160) occurred in daylight conditions
- 56% (120) were rear-end collisions
- 13% (28) were turn movement related
- 10% (21) were fixed object collisions
- 10% (22) were side-swipe collisions
- 56% (119) were intersection or intersection-related crashes
- 21% (44) were located at or near Cooley Road
- 25% (54) were located at or near Robal Road
- 10% (21) were located at or near Empire Avenue

There were three fatal crashes in this section during the six year period. In November 2006, there was a fatal rear-end collision (driver error) located at the US97 and Robal Road traffic signal. The crash occurred in clear dry illuminated conditions in the early evening. A southbound vehicle was traveling too fast for conditions (but not exceeding the posted speed) failed to avoid a vehicle stopped in a queue at the signal. The second vehicle was forced into a third vehicle in front of it. The driver of the errant vehicle was the fatality. The second fatal crash was on a clear, dry December day in 2010. A 19 year old male driver with two passengers was southbound and for an unknown reason, crossed the centerline striking a northbound vehicle. The driver in the southbound vehicle was the fatality. The last crash happened in May of 2011 on a dry, cold Saturday afternoon. A southbound motorcycle was traveling too fast for conditions, and lost control resulting in a fatality.

The number of crashes has generally remained constant over time from 2006 to 2011, decreasing slightly after a high in 2006. The number of severe injury or fatal crashes has also remained
relatively constant, with a spike in 2008 of injury A crashes. The crash rates were reviewed based on two segments, the first segment, from the UGB (MP 132.19) to Robal Road (134.60) has an overall 2011 crash rate of 1.09 crashes per million vehicle miles as compared to the comparable statewide rate of 2.52 for urban principal arterials. The second segment from Robal Road to the south end of the project has a 2011 segment crash rate of 0.40 crashes per million vehicle miles compared to 0.87 for comparable urban expressways statewide.

While the segment crash rates can seem to minimize safety issues, almost half of the crashes on US97 are concentrated at the Cooley and Robal intersections which mean a closer look is needed. The 2011 intersection crash rates at Cooley Road and Robal Road are 0.64 and 0.75 crashes per million entering vehicles. The Robal intersection is close to the published statewide 90th percentile rate of 0.860 crashes per million entering vehicles for signalized four-leg urban intersections.

In addition, a segment and intersection analysis from the Highway Safety Manual (HSM) was completed for 3rd Street/US97 from Cooley to Robal Road for the 2011 existing, 2036 no-build, and 2036 build conditions. For comparison, a similar-length section of US97 from the future 3rd Street extension south in the preferred alternative was also completed. This kind of safety analysis allows for predicting crash frequency instead of just relying on historical patterns. This analysis used the freely available spreadsheets and included Oregon-derived data and calibration factors which account for the citizen reporting requirements. The next three tables show the HSM input data for the intersection and segment analysis.
# HSM 3rd Street Intersection Input Data

<table>
<thead>
<tr>
<th>Input Data</th>
<th>3rd/Ribal Rd</th>
<th>3rd/Cooley Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection Type</td>
<td>4-legged signal</td>
<td>4-legged signal</td>
</tr>
<tr>
<td>AADT Major Street(^1)</td>
<td>40,800/53,000/25,900</td>
<td>37,800/52,500/19,800</td>
</tr>
<tr>
<td>AADT Minor Street(^1)</td>
<td>6,400/10,700/9,300</td>
<td>6,900/20,800/20,800</td>
</tr>
<tr>
<td>Intersection Lighting</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Calibration Factor</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>Approaches w/left turn lanes</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Approaches w/ right turn lanes</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Approaches with left-turn signal phasing</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Left turn signal phasing – Leg #1</td>
<td>Protected</td>
<td>Protected</td>
</tr>
<tr>
<td>Left turn signal phasing – Leg #2</td>
<td>Protected</td>
<td>Protected</td>
</tr>
<tr>
<td>Left turn signal phasing – Leg #3</td>
<td>Protected</td>
<td>Protected</td>
</tr>
<tr>
<td>Left turn signal phasing – Leg #4</td>
<td>Protected</td>
<td>Protected</td>
</tr>
<tr>
<td>Approaches w/RTOR prohibited</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Red-light cameras</td>
<td>Not present</td>
<td>Not present</td>
</tr>
<tr>
<td>Pedestrian volume sum</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Max lanes crossed by a pedestrian</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Bus stops within 1000’</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Schools within 1000’</td>
<td>Not present</td>
<td>Not present</td>
</tr>
<tr>
<td>Alcohol establishments within 1000’</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^1\) AADT is shown as 2011 no-build/ 2036 No-build/ 2036 build
## HSM Preferred Alternative US97 Intersection Data

<table>
<thead>
<tr>
<th>Input Data</th>
<th>3rd/US97</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection Type</td>
<td>3-legged signal</td>
</tr>
<tr>
<td>AADT Major Street</td>
<td>42,200</td>
</tr>
<tr>
<td>AADT Minor Street</td>
<td>12,600</td>
</tr>
<tr>
<td>Intersection Lighting</td>
<td>Present</td>
</tr>
<tr>
<td>Calibration Factor</td>
<td>0.73</td>
</tr>
<tr>
<td>Approaches w/left turn lanes</td>
<td>2</td>
</tr>
<tr>
<td>Approaches w/ right turn lanes</td>
<td>2</td>
</tr>
<tr>
<td>Approaches with left-turn signal phasing</td>
<td>2</td>
</tr>
<tr>
<td>Left turn signal phasing – Leg #1</td>
<td>Protected</td>
</tr>
<tr>
<td>Left turn signal phasing – Leg #2</td>
<td>Protected</td>
</tr>
<tr>
<td>Approaches w/RTOR prohibited</td>
<td>0</td>
</tr>
<tr>
<td>Red-light cameras</td>
<td>Not present</td>
</tr>
<tr>
<td>Pedestrian volume sum</td>
<td>5</td>
</tr>
<tr>
<td>Max lanes crossed by a pedestrian</td>
<td>6</td>
</tr>
<tr>
<td>Bus stops within 1000’</td>
<td>0</td>
</tr>
<tr>
<td>Schools within 1000’</td>
<td>Not present</td>
</tr>
<tr>
<td>Alcohol establishments within 1000’</td>
<td>1</td>
</tr>
</tbody>
</table>
### HSM Segment Input Data

<table>
<thead>
<tr>
<th>Input Data</th>
<th>3rd/Rabal-Cooley</th>
<th>US97 (Preferred Alt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Type</td>
<td>4-lane divided</td>
<td>4-lane divided</td>
</tr>
<tr>
<td>Segment length</td>
<td>0.49 mi</td>
<td>0.49 mi</td>
</tr>
<tr>
<td>AADT(^1)</td>
<td>31,600/50,700/23,100</td>
<td>42,000</td>
</tr>
<tr>
<td>Parking Type</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Parking Proportion</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Median Width</td>
<td>15 feet</td>
<td>15 feet</td>
</tr>
<tr>
<td>Lighting</td>
<td>Not Present</td>
<td>Not Present</td>
</tr>
<tr>
<td>Auto Speed enforcement</td>
<td>Not Present</td>
<td>Not Present</td>
</tr>
<tr>
<td>Major Commercial Driveways</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Minor Commercial Driveways</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Major Industrial Driveways</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minor Industrial Driveways</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Major Residential Driveways</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minor Residential Driveways</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other Driveways</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Speed Category</td>
<td>Greater than 30 mph</td>
<td>Greater than 30 mph</td>
</tr>
<tr>
<td>Roadside fixed object density</td>
<td>Average 37 per mile</td>
<td>Estimate 4 per mile</td>
</tr>
<tr>
<td>Offset to roadside fixed objects</td>
<td>Average 15 feet</td>
<td>Average 15 feet</td>
</tr>
<tr>
<td>Calibration Factor</td>
<td>0.64(^2)</td>
<td>0.64</td>
</tr>
</tbody>
</table>

\(^1\)Shown as 2011 / 2036 no-build / 2036 build for 3rd Street between Robal and Cooley Roads. US97 is shown for the 2036 preferred alternative alignment only.

\(^2\)National calibration factor used versus Oregon’s at 1.41 as the small Oregon sample set and the higher assumed designs for four-lane divided facilities in the HSM has skewed the value high. Future four-lane divided facilities need to use the 0.64 factor so the existing case needs to match to avoid just comparing safety impacts on a calibration factor difference.

Using the predictive equations and the actual observed crashes at these intersections in 2011 resulted in 7.4 and 7.2 expected crashes per year at Robal and Cooley Road, respectively as seen in the table below. The 2011 observed crashes was eight at both intersections. Since the observed crashes are greater than the expected crashes, this indicates a potential safety issue at both intersections. The observed crashes are greater than what would be expected at a four-leg signalized intersection, with the 2011 volumes, and other major parameters such as turn lanes, left-turn phasing, lighting, etc. and taking past crashes into account.
### 2011 Observed, Predicted & Expected Crashes

<table>
<thead>
<tr>
<th></th>
<th>US97 &amp; Robal (crash/yr)</th>
<th>US97 &amp; Cooley (crash/yr)</th>
<th>Robal – Cooley Segment (crash/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011 Observed Crashes</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Predicted Crashes</td>
<td>5.6</td>
<td>5.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Expected Crashes</td>
<td>7.4</td>
<td>7.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Total 2011 Observed Crashes per year for Section</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total 2011 Predicted Crashes per year for Section</td>
<td>13.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total 2011 Expected Crashes per year for Section</td>
<td>15.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Even when adding in the half-mile segment between the two intersections which did not have any non-intersection related crashes, the total observed crashes are still occurring at a faster rate than what would be expected for this section of 3rd Street.

Based on the HSM analysis done for the 2011 existing conditions, the same Robal – Cooley Road segment was analyzed under the 2036 no-build and build (preferred alternative) conditions. The only change to the section over 2011 is the volumes so all other contributing geometric/operational elements remaining constant. This shows the potential reduction in crashes on 3rd Street with the preferred alternative over the no-build in the next table. Under 2036 no-build conditions, predicted section crash rates would be over 22 crashes per year. Note that the Cooley Road intersection crash rate has outpaced the Robal Road rate by 2036 because of the large future volume increases on Cooley Road.

With the preferred alternative re-routing longer distance trips off of 3rd Street and to the new US97 alignment, the predicted crash rates drop to nine crashes per year. This indicates that about 12 intersection and segment crashes per year would be reduced on this section of 3rd Street when the new US97 alignment is constructed. Taking past crashes into account reduces the crash savings to about six expected crashes per year. Even though there is a crash savings from reducing volumes, the geometric and operational factors remain the same which still contribute to expected crash rates being significantly higher than predicted crash rates for this roadway type.
2036 3rd Street Predicted & Expected Crashes

<table>
<thead>
<tr>
<th></th>
<th>US97 &amp; Robal (crash/yr)</th>
<th>US97 &amp; Cooley (crash/yr)</th>
<th>Robal – Cooley Segment (crash/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2036 No-build</td>
<td>2036 Build</td>
<td>2036 No-build</td>
</tr>
<tr>
<td>Predicted Crashes</td>
<td>8.3</td>
<td>3.8</td>
<td>9.6</td>
</tr>
<tr>
<td>Expected Crashes</td>
<td>8.4</td>
<td>6.3</td>
<td>8.7</td>
</tr>
<tr>
<td>Total 2036 No-build Predicted Crashes per year for Section</td>
<td>22.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total 2036 No-build Expected Crashes per year for Section</td>
<td>18.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total 2036 Build (East DS2 Modified) Predicted Crashes per year for Section</td>
<td>9.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total 2036 Build (East DS2 Modified) Expected Crashes per year for Section</td>
<td>12.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Since the preferred alternative adds a signal at the north end of 3rd Street, this three-leg signalized intersection was analyzed along with a comparative segment of the new US97 alignment. The overall predicted crash rate is about seven crashes per year as shown in the table below. Expected crashes cannot be calculated as this is a future route with no crash history. The overall result between the 2036 no-build and the 2036 preferred alternative on the US97 existing and new alignments is a net reduction of over 14 crashes per year at and around signalized intersections on US97 in the project area. This is about a 66% reduction in overall crashes (fatal, injury and property damage only severities).

2036 US97 Preferred Alternative Predicted Crashes

<table>
<thead>
<tr>
<th></th>
<th>US97 &amp; 3rd</th>
<th>US97 Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted Crashes\1</td>
<td>4.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Total 2036 Build (East DS2 Modified) Predicted Crashes per year for Section</td>
<td>7.4</td>
<td></td>
</tr>
</tbody>
</table>

\1 No expected crashes can be calculated as this is a future alignment with no crash history.

SPIS Reporting

There is one Top 5% 2012 SPIS (Safety Priority Index System) site in the study area located at the US97 & Robal Road intersection. However, over the past five years shows multiple intersections on US97 and US20 in the project area have been recorded on the Top 5% or 10% SPIS lists. For all of the past five years, Robal Road has been a Top 5% SPIS site (See table below). In addition, US97 and Cooley Road has been a Top 5% or 10% SPIS site from 2008-2011. Both US20 at Robal Road and at Empire Avenue have had two or three Top 10% SPIS list inclusions over the past five year period as well.
### US97 & US20 Top 5 % and 10% SPIS Sites 2008-2012


<table>
<thead>
<tr>
<th>Route No.</th>
<th>BMP</th>
<th>EMP</th>
<th>Intersection (if appropriate)</th>
<th># of Crashes</th>
<th>Fatal Crashes</th>
<th>SPIS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>US97</td>
<td>134.08</td>
<td>134.17</td>
<td>Cooley Road</td>
<td>26</td>
<td>0</td>
<td>44.73</td>
</tr>
<tr>
<td></td>
<td>134.51</td>
<td>134.69</td>
<td>Robal Road</td>
<td>28</td>
<td>1</td>
<td>72.99¹</td>
</tr>
<tr>
<td>US20</td>
<td>17.82</td>
<td>17.95</td>
<td>Robal Road</td>
<td>7</td>
<td>1</td>
<td>52.74</td>
</tr>
</tbody>
</table>

#### 2009 (2006-2008 data)

<table>
<thead>
<tr>
<th>Route No.</th>
<th>BMP</th>
<th>EMP</th>
<th>Intersection (if appropriate)</th>
<th># of Crashes</th>
<th>Fatal Crashes</th>
<th>SPIS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>US97</td>
<td>134.06</td>
<td>134.19</td>
<td>Cooley Road</td>
<td>19</td>
<td>0</td>
<td>46.45</td>
</tr>
<tr>
<td></td>
<td>134.51</td>
<td>134.69</td>
<td>Robal Road</td>
<td>24</td>
<td>1</td>
<td>71.77¹</td>
</tr>
<tr>
<td>US20</td>
<td>17.82</td>
<td>17.95</td>
<td>Robal Road</td>
<td>5</td>
<td>1</td>
<td>46.98</td>
</tr>
<tr>
<td></td>
<td>18.71</td>
<td>18.88</td>
<td>Empire Avenue</td>
<td>16</td>
<td>0</td>
<td>47.09</td>
</tr>
</tbody>
</table>

#### 2010 (2007-2009 data)

<table>
<thead>
<tr>
<th>Route No.</th>
<th>BMP</th>
<th>EMP</th>
<th>Intersection (if appropriate)</th>
<th># of Crashes</th>
<th>Fatal Crashes</th>
<th>SPIS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>US97</td>
<td>134.02</td>
<td>134.20</td>
<td>Cooley Road</td>
<td>22</td>
<td>0</td>
<td>54.78¹</td>
</tr>
<tr>
<td></td>
<td>134.47</td>
<td>134.57</td>
<td></td>
<td>5</td>
<td>0</td>
<td>45.86</td>
</tr>
<tr>
<td></td>
<td>134.51</td>
<td>134.65</td>
<td>Robal Road</td>
<td>19</td>
<td>0</td>
<td>54.81¹</td>
</tr>
<tr>
<td>US20</td>
<td>18.71</td>
<td>18.89</td>
<td>Empire Avenue</td>
<td>13</td>
<td>0</td>
<td>46.36</td>
</tr>
</tbody>
</table>

#### 2011 (2008-2010 data)

<table>
<thead>
<tr>
<th>Route No.</th>
<th>BMP</th>
<th>EMP</th>
<th>Intersection (if appropriate)</th>
<th># of Crashes</th>
<th>Fatal Crashes</th>
<th>SPIS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>US97</td>
<td>134.02</td>
<td>134.20</td>
<td>Cooley Road</td>
<td>19</td>
<td>0</td>
<td>54.48¹</td>
</tr>
<tr>
<td></td>
<td>134.47</td>
<td>134.57</td>
<td></td>
<td>5</td>
<td>0</td>
<td>46.29</td>
</tr>
<tr>
<td></td>
<td>134.51</td>
<td>134.65</td>
<td>Robal Road</td>
<td>22</td>
<td>0</td>
<td>59.78¹</td>
</tr>
<tr>
<td>US20</td>
<td>18.71</td>
<td>18.89</td>
<td>Empire Avenue</td>
<td>11</td>
<td>0</td>
<td>43.00</td>
</tr>
</tbody>
</table>

#### 2012 (2009-2011 data)

<table>
<thead>
<tr>
<th>Route No.</th>
<th>BMP</th>
<th>EMP</th>
<th>Intersection (if appropriate)</th>
<th># of Crashes</th>
<th>Fatal Crashes</th>
<th>SPIS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>US97</td>
<td>134.51</td>
<td>134.65</td>
<td>Robal Road</td>
<td>23</td>
<td>0</td>
<td>60.36¹</td>
</tr>
</tbody>
</table>

¹ Top 5% SPIS site

This shows a continuing safety need along US97 and US20 in the project area, regardless of any single year look, so cost-effective safety improvements will still need to be identified for these intersections. The data in the above table is based on a three-year average of the recorded SPIS site and is used as a flagging tool to indicate locations with potential safety issues. Every year the top 10% of SPIS sites are listed and the top 5% require investigations and solutions identified to be incorporated into projects.
4.7.3 Tools

Crash Decoder Tool
The Crash Decoder Tool is an excel-based spreadsheet with macros that uses a PRC output (in excel format) that using look-up tables to translate the information. Once the sheet has decoded the information, filters can be applied to the data set to investigate specific locations or issues. It is available on the ODOT Highway Safety Webpage.

Crash Graphing Tool (ODOT Employees Only)
The Crash Graphing Tool summarizes crash information of the “Direction” listing (in an Excel format) report from the State Highway Crash Reports and presents the information in standard graphs and charts. Only ODOT employees can get this internal tool by contacting Information Services.

Oregon Adjustable Safety Index System (OASIS) (ODOT Employees Only)
This was developed as an online safety analysis tool that is capable of performing “SPIS like” safety analysis and allows users to vary the SPIS calculations. Specific types of crashes can be analyzed and parameters can be changed including segment length, number of crash data years, and SPIS formula defaults like the weightings of the formulas. The OASIS tool allows the user to create custom safety analyses of the data within the system. This program is available to Traffic Roadway staff and ODOT Region Staff.

Crash Summary Database (ODOT Employees Only)
The Crash Summary Database, produced annually since 1990, is useful to generate quick summary reports that are often sufficient to answer questions when there is not time to do a detailed analysis. This software must be installed by an IS field technician. The crash summary database is a product of the most current SPIS run so it uses the same three years of data. The crash summary gives an estimated crash rate based on the number of crashes, the average of the AADTs at the beginning and ending mile points of the segment and the numeric difference in the same mile points. This summary does not account for interruptions in the mile point distance (equations) or variation in the volumes when crossing multiple segments. The output reports only an estimated value along with the highest and number of SPIS sites within the section. It should not be used to report a formal crash rate unless all the above items have been accounted for.

Crash Magic is a tool to create collision diagrams. These are created by the CAR Unit or region safety investigators for a very detailed look at a specific location. An analyst should understand the contents of the diagram but should not be creating them. An analyst rarely needs this level of detail for planning or project studies.

4.8 Other Safety Analysis Tools

Unlike the other tools previously mentioned in this chapter, there are a couple of macroscopic
and microscopic tools that an analyst can use to evaluate a study area. These tools are not HSM-based.

PlanSafe is a free macroscopic/GIS-based tool that uses inputs from a travel demand model that can be used to evaluate relative safety across an entire study area, neighborhoods/districts, a city or a region. More information about PlanSafe is available on the PlanSafe TRB webpage.

SSAM (Surrogate Safety Analysis Method/Model) is based on a micro-simulation input trajectory file. These trajectory files include headways, speeds, and paths/conflicts to determine the likelihood of a crash. VISSIM and Synchro 8 can both create the trajectory files. This tool may be useful for analyzing new designs that have no historical traffic data or that do not fit within current HSM methodologies. SSAM is a free application and there is ongoing research to refine the tool. SSAM can be used to determine comparisons of relative safety for project alternatives. More information on SSAM is available on the FHWA SSAM webpage.

4.9 Other Safety-related Techniques

The techniques listed in this section allow a full analysis of a safety issue or proposed build alternative or safety mitigation. The application of these techniques incorporates necessary human factors into the analysis. Functional area, sight distance, conflict points and other techniques focus the need to spread apart necessary driver information processing points. Issues can occur when driveways, intersections, and other elements are too closely spaced leading to confusion and looking too far ahead which can lead to increased crashes. Driving is a visual experience and the driver should not be overloaded by too much information too quickly. In addition, as the driving population ages, the importance of these techniques cannot be overstated. The analyst is strongly encouraged to be familiar with Chapter 2 of the HSM.

4.9.1 Functional Area of an Intersection

A functional area analysis should be done if there are closely-spaced intersections, accesses, or any combination of intersections and accesses. This can be for either existing or proposed (alternative) conditions. Areas with long queues should also be reviewed for functional area impacts. The analysis should also be done when adding new connections to a roadway to verify functional area overlap does not occur and vehicle maneuvers can be performed lawfully.

The functional area of an intersection is the area in which an intersection affects vehicle paths. The intersection functional area influences driver decisions, vehicle movements, and vehicle queues. The influence of the intersection extends beyond the actual intersection area, including auxiliary lanes, to incorporate roadway sections immediately upstream and downstream. Exhibit 4-6 shows the functional area of an intersection.
The intersection area is the physical area where two roads overlap. The sections beyond the intersection area are composed of upstream and downstream functional areas. The upstream functional area for vehicles moving toward the intersection has four maneuvering elements. The downstream functional area for vehicles traveling away from the intersection has one maneuvering element, the stopping sight distance. Each element is unique in its contribution to the functional area.

Exhibit 4-6 Components of the Functional Area

Both upstream and downstream functional areas may need to be studied for an intersection improvement or any project with access in the immediate intersection area. However, only the upstream functional area needs to be studied if an access is opened upstream of an intersection and only the downstream functional area needs to be studied if an access is opened downstream of an intersection. Functional area analysis may determine the placement of an access, the

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1 Data referenced through exhibits in this section were obtained from the Discussion Papers presented to the Oregon Department of Transportation by the Transportation Research Institute (TRI) of Oregon State University.
provision of turn movements, or the number of travel lanes.

**Upstream Functional Area**

There are four elements that make up the distance a vehicle travels as it approaches an intersection: the distance traveled during the perception-reaction time ($d_1$), the distance traveled while the driver decelerates and moves laterally ($d_2$), the distance traveled during full deceleration ($d_3$), and the storage length ($d_4$). Exhibit 4-7 depicts the succession of these movements.

**Exhibit 4-7 Upstream Functional Area, $d_1$, $d_2$, $d_3$, and $d_4$**

Turn lanes may be installed at unsignalized intersections to improve safety and at signalized intersections to expand the roadway capacity. The minimum length for a turn bay (including the taper) is the deceleration and lateral move distance and the full deceleration distance, plus the storage length ($d_2 + d_3 + d_4$). The upstream functional area increases/decreases with the number of lanes (related to $d_2$), the rate of deceleration (related to $d_3$), and the queue ($d_4$). Vehicles that change lanes at an intersection expand the influence area of the intersection and the intersection functional area.

The components of functional area are as follows:

- **The upstream intersection functional area includes the distance traveled during the perception–reaction time, $d_1$, as the driver approaches the intersection.** The perception-reaction time has four phases: perception, intellection, emotion, and volition (PIEV). This section of highway involves the driver seeing the intersection, thinking about his options, making a decision, and initiating his response. The perception-reaction time is 2.0 seconds for desirable conditions and 1.0 seconds for limiting conditions as set by the Transportation Research Institute (TRI) of Oregon State University in *Discussion Paper No. 7, Functional Intersection Area* (January 1996). *Discussion Paper No. 7* was prepared for the Oregon Department of Transportation to support ODOT’s policies, practices, and procedures. A table of perception-reaction distances for varying time intervals is shown in Exhibit 4-8.
Exhibit 4-8 Perception-Reaction Time, d₁

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Perception-Reaction Time (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>45</td>
<td>65</td>
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<tr>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>70</td>
<td>105</td>
</tr>
</tbody>
</table>

(1) Rounded to 5 feet  
(2) US Customary: distance (feet) = 1.47*(speed in mph)*t  
(3) Distance traveled in t-seconds

- **The area d₂ is the distance traveled while braking and moving laterally into a turn bay.** The limiting condition for a vehicle traveling laterally over a 12 foot lane is three seconds in urban areas with an assumed lateral movement at four feet per second (fps). For each 12 foot lane, three seconds of travel time should be added. Four seconds of travel time per 12 foot lane should be assumed for rural conditions, with an assumed lateral movement at three fps.

- **Full deceleration, d₃, is the distance traveled to the end of the storage queue.** The maneuver distances are based on a 6.7 fps² deceleration rate accommodating 85% of drivers. The limiting condition accommodates 50% of drivers with a deceleration rate of 9.2 fps² or higher. The distances of d₁, d₂, and d₃ are dependent on vehicle speed. Maneuver distances (d₂ + d₃) and PIEV plus maneuver distance (d₁ + d₂ + d₃) are based on the intersection functional area approaches from the Access Management Manual (February 2002). Values for just the maneuver distance and PIEV plus maneuver distance are developed from the uniform acceleration formulas and are listed in the table in Exhibit 4-9. Note that storage length, d₄, is not included in the values of Exhibit 4-8. Perception-reaction time may not always be included in an upstream functional area analysis if decisions are made prior to the driver’s approach to the intersection.
### Exhibit 4-9 Upstream Functional Intersection Area, $d_1 + d_2 + d_3$

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Desirable Conditions</th>
<th>Limiting Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maneuver Distance</td>
<td>PIEV Plus Maneuver</td>
</tr>
<tr>
<td></td>
<td>(ft)</td>
<td>Distance (ft)</td>
</tr>
<tr>
<td></td>
<td>$d_2 + d_3$</td>
<td>$d_1 + d_2 + d_3$</td>
</tr>
<tr>
<td></td>
<td>$d_1 + d_2 + d_3$</td>
<td>$d_2 + d_3$</td>
</tr>
<tr>
<td></td>
<td>$d_1 + d_2 + d_3$</td>
<td>$d_1 + d_2 + d_3$</td>
</tr>
<tr>
<td>20</td>
<td>70</td>
<td>130</td>
</tr>
<tr>
<td>25</td>
<td>110</td>
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<tr>
<td>30</td>
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<tr>
<td>35</td>
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<td>395</td>
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<td>45</td>
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<td>50</td>
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<td>55</td>
<td>510</td>
<td>670</td>
</tr>
<tr>
<td>60</td>
<td>605</td>
<td>780</td>
</tr>
<tr>
<td>65</td>
<td>710</td>
<td>900</td>
</tr>
</tbody>
</table>

1. Rounded to 5 feet
2. 10 mph speed differentials, 5.8 fps² deceleration while moving from the through lane into the turn lane; 6.7 fps² average deceleration after completing lateral shift into the turn lane
3. 2.0 second perception-reaction-time
4. 10 mph speed differential; 5.8 fps² deceleration while moving from through lane into the turn lane; 9.2 fps² average deceleration after completing lateral shift into the turn lane
5. 1.0 second perception-reaction time
6. Assumes turning vehicle has “cleared the through lane” (a following through vehicle can pass without physically encroaching on the adjacent through lane when the turning vehicle has moved laterally 10 ft. Also assumes a 12 ft. lateral movement will be completed in 3.0 seconds

- **The length required to store turning vehicles, $d_4$, is calculated by the 95th percentile queue for turning or through traffic, whichever is greater. Turn bays on major roadways are designed for a 95% probability of storing the entire queue during the peak hour. Turn lanes remove turning vehicles from the general flow of traffic allowing through vehicles to proceed.**
without significant slowing or stopping. Research indicates that the crash potential between turning vehicles and through traffic increases exponentially as the speed differential increases. It is desirable to have no more than a 10 mph speed differential between vehicles in the through lanes and vehicles entering turn bays. Providing a turn lane with adequate deceleration distance significantly lowers the speed differential between turning vehicles and through traffic.

Turn lanes at a signalized intersection serve as capacity expanders and are constructed where demand approaches or exceeds capacity. Turn lanes on the major roadway at unsignalized intersections are generally constructed for safety reasons and serve as safety refuges. The typical urban turn bay is 100 feet unless capacity or speeds require it to be longer, while the typical rural turn bay is 150 feet. The 95th percentile queue is generally calculated by traffic analysis software for signalized intersections. Chapter 13 contains the procedures to consider turn bays for intersections and estimating the length for right turn and left turn vehicle queues.

It is important to determine driver familiarity to the area by the type of development impacting the area. A driver who uses a road often may have a perception-reaction time as little as one second or less, but an unfamiliar driver may require several seconds to make a decision. A familiar driver will choose the appropriate lane in anticipation of a turn and may reduce speed at the intersection approach. An unfamiliar driver may take quick lane changes or may decelerate abruptly. The length of the vehicle paths also depends on whether the development will attract familiar drivers (a grocery store) or unfamiliar drivers (a vacation destination).

An extended perception-reaction time benefits other types of drivers in addition to the unfamiliar driver. The perception-reaction time is used to account for roadway user demographics. Older drivers may have significantly longer perception-reaction times than the typical two seconds because of physical or medical conditions. Younger drivers may have longer perception-reaction times while developing decision making skills. Reviewing type of development and roadway users helps build roads that best serve the community.

A functional area analysis has four possible values: The unfamiliar path under desirable conditions, the unfamiliar path under limiting conditions, the familiar path under desirable conditions, and the familiar path under limiting conditions. Limiting conditions are used for projects that have design constraints. A project using limiting conditions must justify the reason for using limiting conditions and provide appropriate documentation. Anywhere from one to all of these scenarios may need to be checked depending on driver types and roadway conditions.

The Oregon Vehicle Code states that an unlawful or unsignaled turn occurs if “The person fails to give an appropriate signal continuously during not less than the last 100 feet traveled by the vehicle before turning.” The code mandates a minimum 100’ signaling distance for all turn movements and lane changes. This is an addition to the four elements, $d_1$ through $d_4$, to determine if driveways and access points are a safe distance from an intersection and accommodate traffic turning at both locations.

Note that the upstream functional area analysis is a check for adequacy in safety and legality.
Further analysis will be necessary to ensure the adequacy of the design.

Example 4-8 Upstream Functional Area
A development proposes to access the roadway upstream of a signalized intersection. The intersection shown has a volume of 100 vph using the left turn lane. The road has a posted speed of 35 mph. How close to the intersection can a proposed driveway be placed?

Assume the signal has a 120 second cycle length.

Upstream Functional Area Example

Solution:

PIEV Plus Maneuver Distance \((d_1 + d_2 + d_3)\)
Check values from Exhibit 4-9:

Limiting Condition
\[ d_{L1} = d_1 + d_2 + d_3 = 240 \text{ feet} \]

Desirable Condition
\[ d_{D1} = d_1 + d_2 + d_3 = 320 \text{ feet} \]

Storage Length \((d_4)\)

For this signalized intersection, the Left Turn Movement Queue Estimate Technique from Chapter 14 was used.

Assume each cycle is 120 seconds (30 per hour)
Assume the constant, \(t\), is 1.85 to find the 95\textsuperscript{th} percentile queue. (See Chapter 7 for background information)
Length = \( \frac{\text{volume}}{\# \text{of cycles/hour}} \times 25 \text{feet} \)

\[
\frac{100 \text{vph}}{30 \text{cycles/hour}} \times 1.85 \times 25 \text{feet} = 154.17 \text{feet} = 154 \text{ feet (rounded)}
\]

**Turn Signal Length**

Another 100 feet must be added to provide distance for the turn signal to be used.

**Total Functional Area Length**

**Limiting Condition**

\[
d_{L_{\text{Total}}} = d_1 + d_2 + d_3 + d_4 + \text{Signal Distance} = 240' + 154' + 100' = 494 \text{ feet}
\]

**Desirable Condition**

\[
d_{D_{\text{Total}}} = d_1 + d_2 + d_3 + d_4 + \text{Signal Distance} = 320' + 154' + 100' = 574 \text{ feet}
\]

**Upstream Functional Area Desirable Condition**

Using the values for a 35 mph speed in Exhibit 4-9, the desirable conditions path is 575 feet long and the limiting conditions path is 495 feet long. The desirable condition calculated using the value from Exhibit 4-9 is the greatest distance and is the closest location to access the highway with respect to the intersection. The driveway should be no less than 575 feet from the intersection.

**Downstream Functional Area**

As a vehicle travels away from an intersection the driver needs a minimum stopping sight distance (\(d_5\)) before approaching another intersection or driveway. The stopping sight distance is the distance traveled while braking to avoid an unexpected obstacle. Stopping sight distance is determined by the American Association of State Highway and Transportation Officials.
(AASHTO) by the speed, brake reaction time, and the deceleration rate. A table developed from the following AASHTO equation is shown in Exhibit 4-10:

\[
d = 1.47 \cdot V \cdot t + 1.075 \cdot \left( \frac{V^2}{a} \right)
\]

Where:  
- \( V \) – speed, mph  
- \( t \) – brake reaction time, 2.5s  
- \( a \) – deceleration, ft/s²

If an acceleration lane is present, the stopping sight distance is measured from the end of the taper. The downstream intersection functional area includes the distance traveled during acceleration before merging into the general traffic flow. Acceleration lanes are rarely provided for at-grade arterials. Lane drops that have an auxiliary lane longer than the distance traveled during acceleration before merging will not be included in the functional area analysis.

**Exhibit 4-10: Downstream Functional Area**

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>AASHTO Stopping Sight Distance (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>115</td>
</tr>
<tr>
<td>25</td>
<td>155</td>
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<td>30</td>
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</tr>
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</tr>
<tr>
<td>50</td>
<td>425</td>
</tr>
<tr>
<td>55</td>
<td>495</td>
</tr>
<tr>
<td>60</td>
<td>570</td>
</tr>
</tbody>
</table>

Note that the downstream functional area analysis is a check for adequacy in safety and legality. Further analysis will be necessary to ensure the adequacy of the design.

Functional Intersection area is detailed in the ODOT Access Management Manual and further information is contained in Discussion Paper No. 7, Functional Intersection Area, Transportation Research Institute (TRI) of Oregon State University (January 1996).

**Example 4-9 Downstream Functional Area**

There is a driveway located 350 feet downstream of the intersection shown. The main street has no traffic control and a speed of 35 mph.
Is there adequate spacing between the intersection and the driveway? What is the stopping sight distance \((d_5)\) for this intersection? The following figure shows a general diagram of the intersection area.

**Downstream Functional Area Example**

Solution:

**Stopping Sight Distance, \(d_5\)**

Check values from Exhibit 4-10: AASHTO Stopping Sight Distance at 35 mph

\[ d_5 = 250 \text{ feet} \]

The driveway must be at least 250 feet from the next downstream intersection to avoid a stopping sight distance conflict. Keep in mind that the downstream functional area analysis is a check for adequacy in safety and legality. Further analysis will be necessary to ensure the adequacy of the design.
**Functional Area Application**

The principles of functional area can be used to test geometric and operational adequacy before detailed analysis starts. The primary objective is to check vehicle paths for adequate length to perform safe and legal maneuvers. For example, a path that connects a right turn onto a roadway to a turn left at the next intersection, or two paths come from two roadways merging together and terminating at a signal, may require lane changes that have safety and legal constraints. Although a functional area analysis may reveal potential conflicts, simulation is used to ensure the adequacy of design in the detailed analysis. Generally, functional area overlaps will appear in simulation results as slowdowns or bottlenecks.

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**Example 4-10 Functional Area Application – Geometric Adequacy**

There is a two lane ramp transitioning from a freeway to an arterial and has geometry similar to an interchange. A development proposes a driveway to intersect the arterial near this ramp as shown in the following figure. The queue at a speed limit of 45 mph is estimated at 400 feet.

Test the adequacy of the design for a driver in either lane of the exit ramp to turn left into the driveway. Can movements from the off ramp to northbound driveway occur safely in this design? Check both the familiar path and the unfamiliar path.

---

**Upstream Functional Area Application Example Paths**

![Diagram of functional area example paths](image-url)
Solution:

Familiar drivers will generally use the familiar path, the lane closest to the turn bay, in anticipation of the left turn. Unfamiliar drivers may take the unfamiliar path which starts from the furthest lane or the “wrong lane” and must change lanes into the turn bay. The maneuver distance over one lane is 198 feet when a 3.0 s maneuver time is assumed.

At Speed Maneuver Distance:
\[
\left( \frac{45 \text{ miles}}{\text{hr}} \right) \times \left( \frac{1 \text{ hr}}{3600 \text{ s}} \right) \times \left( \frac{5280 \text{ ft}}{1 \text{ mile}} \right) \times 3 \text{ s} = 198 \text{ ft} \quad (200 \text{ feet})
\]

Perception-reaction (PIEV) distances are found in Exhibit 4-8. Assume a two second PIEV (130 feet) for desirable conditions and a one second PIEV (65 feet) for limiting conditions as set by the TRI.

The maneuver distances for the turn bay includes the deceleration and lateral move distance along with the full deceleration distance. The maneuver distances are found in Exhibit 4-9. For a speed of 45 mph, there should be 300 feet of distance to meet the limiting conditions and 345 feet is desirable.

Lane changes and turn movements should be signaled for 100 feet prior to the action. If an unfamiliar driver follows the unfamiliar path, a lane change must be signaled to move laterally into the near lane and the turn bay separately. The following figures show the components of the unfamiliar path and familiar path for desirable and limiting conditions.

**Unfamiliar path (desirable conditions)**
\[
d_{UD} = 130' \text{ (PIEV)} + 100' \text{ (turn signal)} + 200' \text{ (at speed maneuver)} + 100' \text{ (turn signal)} + 345' \text{ (desirable distance into the turn bay)} + 400' \text{ (queue)} \\
d_{UD} = 1,275'
\]

**Unfamiliar path (limiting conditions)**
\[
d_{UL} = 65' \text{ (PIEV)} + 100' \text{ (turn signal)} + 200' \text{ (at speed maneuver)} + 100' \text{ (turn signal)} + 300' \text{ (limiting distance into the turn bay)} + 400' \text{ (queue)} \\
d_{UL} = 1,165'
\]
Familiar path (desirable conditions)
\[ d_{FD} = 130' \text{ (PIEV)} + 100' \text{ (turn signal)} + 345' \text{ (desirable distance into the turn bay)} + 400' \text{ (queue)} \]
\[ d_{FD} = 975' \]

Familiar path (limiting conditions)
\[ d_{FL} = 65' \text{ (PIEV)} + 100' \text{ (turn signal)} + 300' \text{ (limiting distance into the turn bay)} + 400' \text{ (queue)} \]
\[ d_{FL} = 865' \]
Unfamiliar path (desirable conditions): \( d_{UD} = 1,275' \)

Unfamiliar path (limiting conditions): \( d_{UL} = 1,165' \)

Familiar path (desirable condition): \( d_{FD} = 975' \)

Familiar path (limiting condition): \( d_{FL} = 865' \)

The design would need to ideally allow 1,185’ feet between the stop bar at the intersection back to the gore point. If the distance available was between 865 and 1,185’ then drivers using the unfamiliar path would be subject to high speed differentials.

4.9.2 Sight Distance

The length of roadway ahead that is visible to a driver is often referred to as “sight distance.”
The amount of visible roadway needed by a driver at any given time depends on the maneuvers or decisions that must be made at that moment. The four basic categories of sight distance are:

1. Intersection Sight Distance (Desirable)
2. Stopping Sight Distance (Minimum)
3. Decision Sight Distance
4. Passing Sight Distance

Note: Some portions of the access management process use different sight distance methods than what would be normally used for operations and project development. See OAR 734-051 for more information.

While each of these is briefly described below, intersection and stopping sight distance are most frequently examined in traffic analysis. For additional information on sight distance refer to ODOT’s Highway Design Manual.

- **Intersection sight distance (desirable)** is considered adequate when drivers at or approaching an intersection have an unobstructed view of the entire intersection and of sufficient lengths of the intersecting highways to permit the drivers to anticipate and avoid potential collisions. Sight distance must be unobstructed along both approaches at an intersection and across the corners to allow the vehicles simultaneously approaching to see each other and react in time to prevent a collision. Intersection sight distance should be obtained at every road approach, whether it is a signalized intersection or private driveway. In no case should the sight distance be lower than safe stopping sight distance (minimum).

- **Stopping sight distance (minimum)** is the minimum distance required for a vehicle traveling at a particular design speed to come to a complete stop after an obstacle on the road becomes visible. Stopping sight distance is normally sufficient to allow an alert and prudent driver to come to a hurried stop under normal circumstances. This is used frequently for fatal-flaw screening in project analysis.

- **Decision sight distance** should be provided at locations where multiple information processing, decision making and corrective actions are needed. Sample locations where decision sight distance is needed include unusual intersection or interchange configuration and lane drops.

- **Passing sight distance** is the minimum distance required for a vehicle to safely and comfortably pass another vehicle. If adequate passing sight distance opportunities cannot be accommodated in the project design, passing lanes or climbing lanes should be considered.
4.9.3 Conflict Points

Introduction
It is good practice to determine the conflict points at intersections and major accesses in the study area for most analysis work other than TSPs. Areas that have functional area overlaps or have identified safety issues need to have the conflict points quantified. Number of conflict points can also be a good alternative screening evaluation criteria.

Every roadway access creates conflict points for drivers, pedestrians, and bicyclists. Conflict points are locations where one vehicle path impacts another. Each conflict point is a possible crash location. Crashes occur at conflict points when one roadway user fails to yield to another. The crash potential associated with each conflict point varies depending on the complexity and volume of the movements. Multi-lane highways increase the number of conflict points as well as the crash potential because of the increased exposure area, exposure time, and potential for obstructed sight distance by vehicles in adjacent lanes. Reducing conflict points decreases crash potential. Conflict points are classified as diverging, merging, weaving, turning, and crossing.

Crossing paths are major conflicts. Diverging, merging, and weaving paths are minor conflict points. Diverging conflicts occur where one path separates into two. Merging conflicts occur where two paths come together. Weaving conflicts involve vehicles changing paths. Both major and minor conflict points may occur at high speeds, but minor conflicts typically involve vehicles traveling in the same direction. Vehicles crossing paths at high speeds may not have the sight distance or ability to minimize the severity of the crash.

Turning and crossing conflicts can also involve pedestrians and bicyclists. A crossing conflict point, which includes pedestrians and bicyclists, occurs where a vehicle path passes through a crosswalk or bike path; a turning conflict point occurs where the turning vehicle path passes through a crosswalk or bike path. Pedestrian crashes are not limited by locations. The pedestrian - vehicle conflicts are counted separately from vehicle - vehicle conflict points.

This section is a reference only. Every intersection is unique and must be analyzed appropriately. The analysis should consider geometry, permitted turn movements, the level of control of non-permitted movements, and the number of lanes for each movement. Reducing conflict points allows drivers to move through an area with less distraction so that traffic flows smoothly at constant speeds. With fewer conflict points, drivers can better maintain their attention on roadway conditions.

Conflict points can be reduced through three measures:

1. Limit the number and/or type of access points
2. Install medians, channelization, and other control devices (e.g., roundabouts) to restrict or control turning movements
3. Grade separate traffic flows
Limit the Number and/or Type of Access Points

Limiting driveways or access points should be considered at locations with poor sight distance, high crash rates, high volume-to-capacity ratios, or poor access to facilities.

Sight distance can be improved by clearing signs and foliage or directing traffic to one access point where drivers have adequate sight distance. Improving the sight distance serves both the general traffic flow and vehicles entering the general traffic flow. The access point may funnel entering traffic to one location, so that drivers passing by the access are aware of entering traffic.

Combining driveways is another way to reduce accesses and conflict points. Closely spaced driveways can cause traffic to slow and increase the crash potential. Accommodating entering traffic at one location simplifies driver tasks. Combining multiple driveways into one joint-use driveway directs traffic more safely, clearly, and efficiently.

Exhibit 4-11 shows the relationship between access density and accident rates in Lincoln City and Lincoln Beach. The crash rates increase as the density of access points increases. The area labeled City Limit in Exhibit 4-11 is Lincoln City on US101, which has a high density of access points. The area labeled Parkway is in Lincoln Beach where a non-traversable landscaped median limits access to driveways and side streets. Crash rates in the Parkway section are greatly reduced.

Exhibit 4-11 Access Points Per Mile vs. Crashes Per Mile
Locating driveways on lower classification roadways or backage/frontage roads also reduces the number of conflict points along the roadway. Removing driveways from an arterial or a collector decreases delay caused by turning vehicles. Diverting traffic to local roads directs traffic to one access point and simplifies conditions.

Refer to the Oregon Administrative Rule (OAR) 734, Division 51 for information concerning signal spacing, backage/frontage roads, or access rights. Sometimes access rights to individual parcels are obtained. Rules regarding obtaining property access rights to state highways, signal spacing, and backage/frontage roads are found in OAR 734, Division 51 and on the ODOT Access Management website.

Non-traversable Median or Traffic Control Devices to Restrict Turning Movements
Medians are a highway element sometimes provided to separate traffic traveling in opposite directions. A median can be traversable or non-traversable. A traversable median may be a painted or concrete mountable median which allows traffic over it. A non-traversable median is a physical barrier (examples include the Jersey barrier, landscaped, or grassy median) that separates opposing traffic and prohibits movement across the median. Installing a non-traversable median restricts turning and crossing movements at roadway accesses. Non-traversable medians reduce conflict points by eliminating turn movements that impact the general traffic flow. More information about median types can be found in Chapter 5.5 of the Highway Design Manual (HDM).

A median that impacts the State Highway Freight System must comply with the ORS 366.215 which states that the Oregon Transportation Commission (OTC) may not permanently reduce the vehicle-carrying capacity of an identified freight route when altering, relocating, changing, or realigning a state highway unless safety or access considerations require the reduction.

According to the Transportation Research Board, Access Management Manual 2003, 47% of crashes involve left turn ingress movements and 27% of crashes involve left turn egress movements, shown in Exhibit 4-12 Controlling turn movements can sometimes allow one turn direction and divert others elsewhere.

Exhibit 4-12 Percent of Driveway Crashes by Movement

Non-traversable medians reduce overall crash rates, improve pedestrian safety, and enhance
visuals. They restrict traffic from making complex left turns and provide median openings at designated locations. They may provide a pedestrian refuge between directions of traffic and decrease pedestrian clearance intervals. A Georgia study\(^2\) reports that a highway with a non-traversable median has 78% less pedestrian fatalities per 100 miles of road than a highway with a two-way left-turn lane. Landscaping large medians improves the aesthetics of the roadway. Although medians improve the roadway, they are costly and may require the acquisition of right-of-way.

**Grade-Separated Roadways**

Grade-separated roadways are where one roadway crosses over the other. Grade separation should be considered for safety or where an at-grade signal cannot accommodate traffic capacity. Conflict points are decreased by removing major flow grade crossings and by re-routing turning traffic. Interchanges are grade-separated connections of two or more roads. Interchanges reduce conflict points and the severity of crashes, increasing safety. Although interchanges occupy a large amount of space and require costly structural work, they reduce delay and improve the safety and efficiency of a corridor.

It can be difficult to accommodate pedestrians at interchanges because of the separation of paths. For more information about accommodating pedestrians or bicyclists, refer to the [Oregon Bicycle and Pedestrian Plan](#) and the related [Bicycle & Pedestrian Design Guide](#).

**Weaving Segments**

Weaving segments, where vehicles traveling in the same direction cross paths, create several conflict points. Exhibit 4-13 and Exhibit 4-14 show two examples of weaving vehicle paths entering and exiting the roadway. A single lane change weaving segment has five minor conflict points. A lane-balanced two-lane change weaving segment has seven minor conflict points. More information about weaving segments can be found in Chapter 12.

**Exhibit 4-13 Conflict Points for a Weave with One Lane Change**

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Unchannelized Intersections
Unchannelized intersections are located where two roadways with traversable medians and no turn restrictions intersect. Unchannelized intersections allow full access to traffic. Every intersection should be analyzed as a unique situation. Unchannelized intersections may have other forms of traffic control such as a traffic signal. A traffic signal does not reduce the number of conflict points, but increases driver communication and awareness. For movements that operate with separate signal phases the exposure to conflicts is significantly reduced when compared to movements that operate with unsignalized control or permissive signal phasing.

NOTE: The intersections analyzed and illustrated in the figures are typical configurations however, for clarity, turn lanes are not included. The addition of single turn lanes should not increase the number of conflict points. Any additional through or dual turn lanes must be included in the analysis.

T-Intersection
A T-intersection is where one roadway ends at its intersection with another roadway. The T-intersection shown in Exhibit 4-15 permits turns in all directions. The intersection in the figure has nine conflict points, three of which are major.
Exhibit 4-15 Conflict Points for the T-Intersection

Exhibit 4-16 Conflict Points by Lane for a Four-Leg Intersection of Two One-Way Roads

Four-Leg Intersection of a Two-Way Road and a One-Way Road
A four-leg intersection of a two-way road and a one-way road is shown in Exhibit 4-17. The one-way road may be part of a couplet. The one-way road limits turns and reduces conflict points.
Four-Leg Intersection
The four-leg intersection with no medians, shown in Exhibit 4-17, has the most conflict points of all intersections. The four-leg intersection allows movement in all directions and is the most familiar to drivers.

Channelized Intersections
A channelized intersection has restricted turn movements by signs, pavement markings, medians or some other type of traffic control. Channelized intersections include, but are not exclusive to
right-in/right-out intersection; non-traversable median separated four leg intersection, left turn ingress intersection, left turn egress intersection, and roundabout. Both ends of the non-traversable median should be analyzed for the required traffic control to meet traffic needs safely.

Intersections and driveways that are restricted to right-in/right-out have two conflict points, but complex channelized intersections may have up to eleven conflict points.

Right-In/Right-Out (RIRO) Intersection
The right-in/right-out geometry shown in Exhibit 4-19 restricts traffic to right turn movements only and forces roadway users to complete a left turn at another location either in a permitted u-turn or at a completely different intersection or roadway. Additional lane changing/weaving may also be necessary. This improves safety at the location of the RIRO intersection, but requires left turning vehicles to travel further to get to their destination. The analyst needs to address where the left turning vehicles will end up so potential safety issues are not created elsewhere.

Non-Traversable Median Separated Four-Leg Intersection
Installing a non-traversable median changes the traffic flows of the typical four-leg intersection by effectively creating two right-in/right-out intersections as shown in Exhibit 4-20. Left turning or crossing vehicles must complete that maneuver at another location, eliminating the major conflict points. This reduces the conflict points from the typical 32 to just four. The intersection is restricted to right turns, improving safety and operations, but does add out of direction travel.
**Roundabout**

Roundabouts are considered at locations where speeds and volumes may not require a traffic signal for smooth operations. The roundabout, shown in Exhibit 4-21, directs all traffic to move in a counter-clockwise direction allowing movements in all directions. This limits conflict points to merging and diverging movements. Bypass lanes would produce additional conflict points at their respective merge and diverge locations. Chapter 13 contains capacity analysis procedures for roundabouts and bypass lanes.
Exhibit 4-21 Conflict Points for the Single Lane Roundabout

Exhibit 4-22 Conflict Points for the Multilane Roundabout

**Left Turn Ingress Intersection**

The left turn ingress intersection shown in Exhibit 4-23 permits one direction of traffic to turn left, from a turn bay, while the opposing left and crossing movements are prohibited. The permitted left turn may have significantly higher volumes or may service a critical access.
Exhibit 4-23 Conflict Points for a Median with One Left Turn Ingress Intersection

**Two Left Turn Ingresses Intersection**
Exhibit 4-24 shows the geometry for two left turn ingresses. Only the traffic turning left into the access street is permitted through the median. Vehicles can remain in the median until there is a sufficient gap to complete the turn. More left turn egress and left turn ingress examples are shown in Exhibit 4-25 through Exhibit 4-27. Locations that provide a median restricting egress or ingress turns require median openings for vehicles to make U-turns. The median openings add a merge and a diverge point to the segment or intersection. Any intersection along a median that permits U-turns must be analyzed for conflict points, with the inclusion of the merge and diverge conflict points caused by the U-turn.
Exhibit 4-24 Conflict Points for a Median with Two Left Turn Ingresses Intersection

Exhibit 4-25 Conflict Points for a Median with a Left Turn Ingress and Egress Intersection

Other Ingress and Egress Examples
Exhibit 4-26 Conflict Points for a Median with One Left Turn Egress Intersection

8 Conflicts
3 – Merging
3 – Diverging
2 - Crossing

8 Conflicts

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Indirect Left Turns
Some intersections require creative accommodations for left turning vehicles. The treatment of left turns must be considered at intersections with restricted turns, high volumes or high speeds to achieve the greatest capacity and safety for traffic.

J-Turn
The J-turn provides an opportunity for larger vehicles to turn left on either side of a non-traversable median. The median restricts intersections and driveways to right-in/right-out which reduces the conflict points. Vehicles can turn left at median openings which may be accompanied by a stand alone J-turn, a J-turn intersection, or a signalized J-turn intersection. The J-turn intersection shown in Exhibit 4-28 has thirteen conflict points. Locations where the J-Turn does not meet a crossing roadway or driveway have three conflict points: one diverge, one crossing, and one merge conflict point.

The J-turn intersection also provides turning vehicles an opportunity to join traffic moving in its desired direction. An add-lane at the J-turn will eliminate the merge conflict point, shown in Exhibit 4-28, and increase the capacity of the segment. The J-turn reduces the congestion and improves the safety of median openings. A J-turn intersection may or may not have pedestrian...
crossings.

Exhibit 4-28 Conflict Points for a J-Turn Intersection

Note: The J-Turn is sometimes located at an intersection.
**Jug handle Intersection**

This jug handle intersection, shown in Exhibit 4-29, is commonly used when there are high left turn volumes which cannot be accommodated by a signalized intersection. The left turning traffic passes through the intersection as a through movement both before and after diverging onto a loop ramp to complete the left turn. This reduces the congestion by removing phases from the traffic signal and improves the safety of the intersection by reducing the number of conflict points. The jug handle can be located in various quadrants of the intersection depending on the restricted turn movements.

Note: Jug handle configurations are not always installed as pairs and are not always accompanied with right turn bypass lanes.

**Exhibit 4-29 Conflict Points for a Jug handle Intersection**
**Pedestrian Conflict Points**

Pedestrian conflict points are counted separately from vehicle-vehicle conflict points. Pedestrian conflict points are located at the intersection crosswalks. Turning vehicles and crossing vehicles are counted separately. Sometimes pedestrian movements need to be furnished away from the intersection. Locations where no crosswalk is located, such as the main line of an intersection with two left turn ingresses, may be serviced by an overpass or pedestrians may cross further down the road at a designated pedestrian crossing or signal. Intersections with wide cross sections, such as a median separated four-way intersection, are more attractive to pedestrians when it has a non-traversable landscaped median. The median serves as a pedestrian refuge and can decrease the pedestrian clearance intervals. Exhibit 4-30 through Exhibit 4-32 show various examples of pedestrian conflict points from two one-way roads to a four-way intersection with restricted left turn ingresses.

**Exhibit 4-30 Pedestrian Conflict Points for a Four-Leg Intersection**

![Diagram of pedestrian conflict points](image)

- □ 16 – Turning
- ▲ 8 – Crossing
- 24 Pedestrian Conflicts
Exhibit 4-31 Pedestrian Conflict Points for a Median Separated Four-Leg Intersection

Exhibit 4-32 Pedestrian Conflict Points for a Median with One Left Turn Ingress Intersection
**Grade-Separated Access**
High speed and high volume junctions may need grade-separated access to meet traffic capacity and safety. Interchanges remove major flow grade crossings increasing capacity and reducing conflict points. Interchanges may have as few as six conflict points (directional interchange) or as many as twenty-eight conflict points (left turn flyover).

**Directional Interchange**
The directional interchange has all free flow ramps with only six (three diverging and three merging) minor conflict points in the system as seen in Exhibit 4-33. It is similar to a T-intersection with large volumes and high speeds. Traffic does not cross paths due to the grade separation. Each free flow connection has a merge and diverge conflict point. Due to the high volumes and speed, pedestrian crossing does not occur at the street level.

The full directional interchange, shown in Exhibit 4-33 has three levels of grade separation. A partial directional interchange is a junction where one leg has lower speeds and is accommodated by a loop ramp. A partial directional interchange has only two levels of grade separation. Since each free flow ramp has one merge and one diverge conflict point, the partial directional interchange has the same conflict points as the full directional interchange. Likewise, a four way directional interchange would have eight conflict points, four merge and four diverge. Additional conflict points could be introduced if ramps are closely spaced.

**Exhibit 4-33 Conflict Points for a Directional Interchange**
**Left-Turn Flyover Intersection**
The left-turn flyover intersection, shown in Exhibit 4-34, is commonly used when one direction has high left turn volumes which cannot be accommodated by a signalized intersection. The left turning traffic is grade-separated as it crosses over the opposing traffic, reducing conflict points and congestion. Pedestrian crossings may or may not be modified from the standard intersection.

**Exhibit 4-34 Conflict Points for a Left-Turn Flyover Intersection**
**Diamond Interchange**
The diamond interchange has four ramps and may have traffic control at the minor road. Traffic is directed to turn on or off each ramp creating conflict points. There is potential for weaving conflicts if this interchange has two or more lanes in each direction. Conventional, compressed, and tight diamond interchanges all travel the same paths and the conflict points are the same. Exhibit 4-35 shows the conflict point configuration for a conventional diamond interchange.

Pedestrian crossings are generally not provided at locations along the major, free-flowing movement.

**Exhibit 4-35 Conflict Points for a Diamond Interchange**

![Conflict Points for a Diamond Interchange](image)

**Split Diamond Interchange**
A split diamond interchange, shown in Exhibit 4-36, has only four ramps which connect to each other with segments that travel parallel to the major roadway. This type of interchange is appropriate where minor roads are one-way streets and will most likely be accompanied with traffic signals at the ramp terminals. It may be furnished on a regular grid system where the minor streets are two-way as well.
Single Point Urban Interchange (SPUI)
The single point urban interchange has four ramps that converge to one point which is controlled by a traffic signal. All minor movement vehicles must travel through the same grade-separated intersection. This type of interchange conserves space and provides large capacity, since the signal operates with fewer phases. These conflict points are shown in Exhibit 4-37.
Divergent Diamond Interchange

The divergent diamond interchange has four ramps where vehicles that want to turn right may get on or off the roadway as shown in Exhibit 4-38. The divergent diamond is designed so that as traffic on the minor roadway approaches the interchange intersections, the opposing lanes change which side of the road is being used. This allows turn conflicts to be merge/ diverge rather than crossing. Vehicles that want to turn left follow the appropriate traffic flow and merge into the receiving lane without interference of opposing traffic. The divergent diamond overlap allows vehicles to turn left at the designated signalized intersections reducing crossing paths and conflict points. This configuration also allows the use of fewer phases in the traffic signal operation.

Due to high speeds and high volumes, the divergent diamond must consider appropriate pedestrian crossings. There have been designs that show pedestrian crossings over the ramps and down the middle of the minor leg.
Partial Cloverleaf Interchange
The partial cloverleaf, shown in Exhibit 4-39, reduces conflict points by providing elevated ramps to maneuver on and off the roadway. The on-ramps are free flow but the off ramps are controlled by traffic signs or signals. Vehicle paths cross only for left turning traffic from the ramps. There is potential for weaving conflicts if this interchange has two or more lanes in each direction.

Although a full cloverleaf configuration is a possible design, Oregon and many other states no longer use them because of the short distance between the merging/diverging paths of the ramps.

If pedestrian crossings were present, they would direct people over the ramps where the speeds are lowest and drivers have adequate sight distance.
4.9.4 Access Management

Access management is the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway. Good access management promotes the safe and efficient use of the transportation network while providing access to adjacent land uses. Access management can often be a low cost solution to safety and congestion problems.

In 1948, the Oregon State Highway Department was tasked with policing access to Oregon’s state highways. The state highway approach permitting process was created to regulate the number of private driveways or public approaches onto a state highway. The Highway Division was also required to regulate the design of driveways, in order to ensure they met with current design standards. When the Oregon Department of Transportation was established in 1973, access management remained a department duty with processes specified in Oregon Administrative Rules (OARs). The goal of this policy was and is to protect viability of the State’s highway infrastructure, and to provide the motoring public with safe and reasonable access.
Effects of Access Management Implementation

Good access management techniques improve both the roadway and adjacent land use. Details and research citations on the safety, operational, economic and other effects of access management as noted below are documented in the Access Management Manual, TRB, 2003.

Safety Effects
- Reduction of crashes involving vehicles as well as pedestrians and bicyclists
- Limit number of traffic conflict points
- Separate conflict areas
- Preserve functional area of intersections
- Increased driver response time to potential conflicts
- Fewer conflicts for bicyclists
- Medians reduce crashes as well as provide pedestrian dwelling areas for two stage crossings
- Reduced speed differentials
- Improved sight distance

Operational Effects
- Proper spacing of access points and intersections improves the flow of traffic. Poor spacing, design and location of driveways may reduce average travel speeds by up to 5 to 10 mph from desired speeds³.
- Reduced access density improves free-flow speed and reduces delay and congestion
- Up to 40% less vehicle hours of delay on access controlled roadways as compared to uncontrolled roadways
- Preserve integrity of the roadway system.
- Extend functional life of the roadway.

Economic Effects
- Access improvements on corridors have been shown to result in increased property values by decreasing travel time.
- Predictable travel times benefit service industries and manufacturing facilities operating under “just in time” delivery contracts
- Combining driveways creates more room for parking and landscaping and may result in lower maintenance. Providing cross-access between retail parking lots often encourages multi-stop business trips by customers who otherwise may not have stopped.
- Non traversable median projects generally have little or no overall adverse impact on business activity.

Other Effects
- Improved traffic flow resulting from access management reduces vehicle emissions and fuel consumption.

³ Access Management and the Relationship to Highway Capacity and Level of Service, Florida DOT, 1996
Rules, Policies and Guidance

Laws pertaining to the control of access to public highways in Oregon are found in Oregon Revised Statutes (ORS) Chapter 374.

Administrative rules for highway approaches, access control, spacing standards and medians are found in Oregon Administrative Rules (OAR) Chapter 734, Division 51 (OAR 734-051). Division 51 establishes procedures, standards, and approval criteria used by ODOT to govern highway approaches, access control, spacing standards, medians and restriction of turning movements.

The Oregon Highway Plan (OHP) serves as the policy basis for implementing OAR 734-051 through three goals:

Goal 1: System Definition
To maintain and improve the safe and efficient movement of people and goods and contribute to the health of Oregon’s local, regional, and statewide economies and livability of its communities.

Goal 2: System Management
To work with local jurisdictions and federal agencies to create an increasingly seamless transportation system with respect to the development, operation, and maintenance of the highway and road system that:
• Safeguards the state highway system by maintaining functionality and integrity;
• Ensures that local mobility and accessibility needs are met; and
• Enhances system efficiency and safety.

Goal 3: Access Management
To employ access management strategies to ensure safe and efficient highways consistent with their determined function, ensure the statewide movement of goods and services, enhance community livability and support planned development patterns, while recognizing the needs of motor vehicles, transit, pedestrians and bicyclists.

The ODOT Access Management program website provides guidance on access management.

Types of Access Management Efforts

Access management encompasses a variety of different activities. The following is a brief description of each area. Detailed guidance on these efforts can be found on the ODOT access management website. It is important to coordinate with the Region Access Management Engineer (RAME) and other access management staff early in planning and project development processes.

Standards

Section 4020 of Division 51 contains standards for approval of private approaches, including the Analysis Procedure Manual Version 2
access spacing tables for roadways and interchanges. The spacing standards are also contained in OHP Appendix C. In addition, Table 12 of OHP Appendix C contains standards for spacing between interchanges.

Planning

Access management is one of the principal goals of the OHP (Goals 1, 2 & 3). Plans involving public road connections to the highway should be coordinated with the RAME as they are not subject to the approach permitting process. A resource for more information on access management in planning is NCHRP Report 548, *A Guidebook for Including Access Management in Transportation Planning*.

ODOT encourages the development of access management plans and interchange area management plans to maintain and improve highway performance and safety by improving system efficiency and management before adding capacity. Division 51 includes requirements and criteria for Access Management Plans and Interchange Area Management Plans in section 734-051-7010.

An Access Management Plan (AMP) is a plan adopted by the OTC for managing access on a designated section of highway or the influence area of an interchange to maintain and improve highway performance and safety. Detailed guidance on AMPs can be found on the ODOT access management website.

An Interchange Area Management Plan (IAMP) is a plan to determine transportation solutions or land use/policy actions needed in an interchange area and how best to balance and manage transportation and land use issues over time. It is an important tool in protecting the function and operations of state highway interchanges and the supporting local street network. Assistance in the preparation of IAMPs is available in the ODOT Interchange Area Management (IAMP) Guidelines.

Project Development

Access Management in project delivery is addressed in Division 51 Section 734-051-5120. ODOT encourages the development of access management strategies and access management plans during project delivery to maintain and improve highway performance and safety by improving system efficiency and management before adding capacity.

An Access Management Strategy (AMStrat) is a product developed by the project team that identifies the location and type of approaches and other necessary improvements that will occur as part of the project. The strategy may range from general statements on a preservation project to maps showing specific access closures in a modernization project. Division 51 requires access management strategies (AMStrat) for modernization projects, projects within an influence area of an interchange where the project includes work along the crossroad, or projects on an expressway. Access management strategies may be developed for other highway projects.

The goal of an AMStrat is to improve safety and operations through measures taken during...
Operational notices provide requirements and guidance on access management in project development and delivery. **PDLT Notice 03** addresses access management in project development. **PDLT Notice 03(A)** addresses access management specifically for pavement preservation projects.

A tabular evaluation of spacing standards should be done as part of existing conditions, future no-build, and alternative analyses and documented in the appropriate technical memorandums and narratives. This should cover all applicable roadway segments in the study area. Local jurisdiction’s spacing standards shall be used for non-state roadways.

### Example 4-11 Access Spacing Standards Reporting

This is an example of a typical access spacing standards reporting at the project development level included in a technical report.

The spacing and location of intersections and driveways affect traffic safety and operations. These access points introduce conflicts and are frequently the causes of slowing or stopping vehicles that can significantly degrade the flow of traffic and reduce the efficiency of the transportation system. Appendix C in the OHP has spacing standards for public road approaches and private access to be used in the planning process. The following spacing standards apply to this project:

- **Interchange to Interchange**: six miles for rural interstate and non-interstate freeways
- **Next intersection adjacent to ramp terminal**: 1320 feet for a two-lane crossroad in a rural area next to a full or right-in/out intersection.
- **Street Spacing**: 990 feet for a rural statewide highway and 500 feet for a rural district highway. There is no standard for private accesses as they are discouraged on state highways.

The table below shows the comparison between roadway segments and their appropriate spacing standard. Existing street, ramp and interchange spacing is well below standards for all segments in the project area. On I84 the distance between the Biggs-Junction and Rufus interchange is approximately 5 miles, this is below the standard but not a major concern as both interchanges are in rural areas with relatively low interstate volumes. Additionally, Bargeway Lane directly accesses the I84 westbound on-ramp acceleration lane. The access point is less than 300 feet downsteam of the I84 westbound ramp terminal intersection and approximately 600 feet upstream of the freeway entrance. Extending the length of the on-ramp, so that the acceleration lane begins west of the Bargeway Lane, will reduce the potential for accelerating vehicles to crash with slow moving and/or turning vehicles entering/exiting Bargeway Lane.

On US97, the distance between the I84 EB ramp terminal and the Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection is less than half the spacing standard. Queuing and blocking...
on this segment will become an issue as volumes grow however, because of the topography and waterway constraints, meeting the spacing standards for this segment will not be possible even under the best conditions. On the segment south of the Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection there are two driveways for the Shell Gas and Travel Stop, the first (for cars) is approximately 550 feet south of the intersection and the second (for trucks) is approximately 900 feet south of the intersection.

On the Celilo-Wasco Spur, there are multiple driveways on both sides of the highway. The first, for McDonalds and the Grand Central Travel stop on the opposite side of the road, is approximately 150 feet west of the Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection. The second, for both locations, is approximately 300 feet west of the intersection.

### Spacing Standard Summary

<table>
<thead>
<tr>
<th>Access Management Classification</th>
<th>Roadway</th>
<th>Segment</th>
<th>Spacing Standard</th>
<th>Existing Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interchange to Interchange</td>
<td>I84</td>
<td>Between Biggs Junction and Rufus Interchange</td>
<td>6 miles</td>
<td>5 miles</td>
</tr>
<tr>
<td>Next intersection adjacent to ramp terminal</td>
<td>US97</td>
<td>Between I84 EB ramp terminal and Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection</td>
<td>1320 feet</td>
<td>600 feet</td>
</tr>
<tr>
<td>Street Spacing: Statewide Highways</td>
<td>US97</td>
<td>Between Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection and entrance to Shell Gas and Travel Stop</td>
<td>990 feet</td>
<td>550 feet</td>
</tr>
<tr>
<td>Street Spacing: District Highways</td>
<td>Celilo-Wasco Spur</td>
<td>Between Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection and the entrance to McDonalds / Travel Stop</td>
<td>500 feet</td>
<td>150 feet</td>
</tr>
</tbody>
</table>

1. OHP Spacing Standards
2. Approximate approach spacing
3. Black-shaded cells indicate that the spacing standard is not met

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Permits

An Application for State Highway Approach is required for new approaches and in other circumstances. The outcome of the permitting process is issuance of a Permit to construct the approach. Once construction is approved, a final Permit to Operate, Maintain and Use the Approach is issued. Details on the permitting process are found in Division 51 as well as Chapter 4 of the Access Management Manual.

Access Management Techniques

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A variety of administrative and design techniques can be applied to preserve and enhance the safety and operational character of a roadway segment and to mitigate the traffic problems at many types of locations. The appropriate technique depends on the context of the roadway, traffic, land use and environmental characteristics. There is not one-size-fits-all solution. The following is not an exhaustive list. HDM Section 8.2 contains additional information on the design of road approaches.

- Minimize – Relocate driveways to farthest edge of property, consolidate driveways to increase separation, close, acquire access rights, joint and cross access, provide secondary access
- Administrative - Access policies and codes, subdivision and partition review, vehicle use limitations, purchase of access control, Division 51, spacing tables.
- Alternate Access – Backage or Frontage Roads
- Restrictions – Painted/Non Traversable Medians, porkchops to preclude direct left turns. Raised medians remove major conflict points from direct left turns. Studies indicate significant crash reductions from installation of raised medians. Raised medians also significantly benefit pedestrian safety.
- Location – sight distance, spacing, corner clearance, signal spacing
- Design – width reduction, definition, throats vs. aprons, curb radius, directional median openings, shoulder bypass, jug handles, frontage roads, service roads, illumination, visual cues at driveways. Indirect turns such as U-turns and J-turns or roundabouts are safer than direct left turns. Frontage and backage roads facilitate traffic circulation by separating local from through traffic.
- Channelization – left and right turn lanes on adjacent roadway and on access. On average, left turn lanes have been shown to reduce crashes by 50 percent.

4.9.5 Turn Lane Criteria and Traffic Control

Certain crash types and the overall crash frequency at a location may have a potential to be addressed by mainline turn lanes or improved traffic control. Analysis of the existing or no-build conditions should identify these safety deficiencies which are addressed in the build alternative analysis. Left and right turn lanes at unsignalized locations are mainly installed for safety reasons to prevent high-speed rear-end collisions. Left turn lanes allow a safety refuge for vehicles waiting to turn left which will reduce the number of rear-end and turn collisions. Similarly, right turn lanes remove slowing vehicles out of the mainline lanes, reducing rear-end collisions. The criteria for turn lanes are shown in detail in Chapter 7.

Large amounts of turn or angle crashes may indicate a need to investigate traffic control improvements. Traffic control improvements may remove simultaneous conflict points such as an all-way stop, roundabout, or a traffic signal. Conflict points could also be removed or minimized by using medians, channelization, or grade separation. Traffic control may also include bike or pedestrian islands and devices. Traffic control is discussed in detail in subsequent chapters.
5 DEVELOPING EXISTING YEAR VOLUMES

5.1 Purpose

Traffic counts alone should not be used for design or operational analysis of projects. This chapter will outline procedures for developing 30th highest hour volumes (30HV) and average daily traffic volumes (ADT) for planning and project level analysis. Existing and count-level data is also needed to support other volume–related analysis inputs such as peak hour factors and truck percentages. This chapter also provides the basis for developing the future volumes shown in Chapter 6.

5.2 30th Highest Hour Volumes

For most traffic studies, the 30th highest hour volumes (30HV) should be used to represent existing and future volumes. Future volumes are often referred to as Design Hour Volumes (DHV). The 30HV is the target hour based on the concept that designs are not done to the absolute highest hour of the entire year, but to design to meet most of the needs. Plotting an entire year’s hourly volume data ranked from highest to lowest at a specific point will yield a flow curve. The break point between the steep and shallow regions of the curve is typically located at the 30th highest hourly volume as illustrated in the Exhibit 5-1 below. Alternatives are generally analyzed at the 30HV to be consistent with accepted analysis methods and comparisons.
The overall process for developing the 30HV is as follows:

1. Document raw count volumes, types and durations (see Section 5.5.3).
2. Identify a system peak hour (see Section 5.3).
3. Calculate seasonal adjustments; bring counts to a common month (see Section 5.4).
4. Calculate historical adjustments; bring counts to a common year (see Section 5.5).
5. Balance the 30HV across the network (see Section 5.5.1)
6. Round the 30HV (see Section 5.5.2)
7. Document on figures the 30HV process (see Section 5.5.3)

The peak hour from a manual count is converted to the 30HV by applying a seasonal factor. The 30HV is then used for design and analysis purposes. Experience has shown that the 30HV in large urban areas usually occurs on an afternoon on a weekday during the peak month of the year. The Metropolitan Planning Organization’s (MPO) of Metro, Salem and Eugene are large enough that the average weekday peak hour approximates the 30HV. Smaller MPO’s such as Corvallis and Medford do not have the steady flow throughout the year and the 30HV is concentrated into peak periods of the year. For the Bend MPO, the average weekday peak hour 30HV approximation is limited to commuter-flow dominated high volume arterials such as US97; other areas are subject to normal seasonal fluctuations. The 30HV for an urban area typically ranges from 9- to 12-percent of the Average Annual Daily Traffic (AADT). For a recreational route, the 30HV usually occurs on a summer weekend and ranges from 11- to 25-percent of the AADT.

It is recommended a top 200- to 500-hour count listing of the Automatic Traffic Recorders (ATR) is obtained from the Transportation Systems Monitoring Unit. The 30HV at the ATR(s) will be included in the list so that it will be possible to determine approximately when the 30HV
occurs during the day and in the week. Since the actual 30HV determination is based off of at least the previous year’s (ideally at least three years) data, the actual time and day when it occurs for the base year cannot be determined. Manual counts can then be timed for the period when the 30HV will likely occur, minimizing seasonal adjustments.

5.3 System Peak Hour Selection

Daily traffic volumes, while useful for planning purposes, cannot alone be used for design or operational analysis purposes. Once all of the traffic counts have been obtained, the intersection counts should be adjusted to a single system peak hour. The peak hour is the single hour of the day that has the highest hourly volume. Use of the 15-minute breakdowns in the traffic counts is necessary in order to determine the true peak hour, resulting in a time period such as 4:00 PM to 5:00 PM or, just as easily, 4:45 PM to 5:45 PM. The final selection of a peak hour may be based on a simple majority of counts that have the same peak hour, using a controlling intersection, or the count(s) that the analyst believes are the most accurate. Counts that have longer durations or that are taken close to the 30HV are generally more accurate. A procedure using TruckSum to determine the system peak hour volumes and other factors when the count peak hour is different from the system peak hour is provided in Chapter 11 of APM Version 1.

Generally PM peak hour volumes are higher than AM peak hour volumes. In areas where there are large industries with shift changes, the hour during the shift change may be as high as or higher than the PM peak hour for the remainder of the transportation network. If this is true, another set of volumes should be developed. Volumes for the non-standard peak hour should be developed along with the PM peak hour volumes so that all of the volumes may be analyzed at a later date. Multiple sets of volumes may be necessary in these circumstances, which may include areas of heavy industrial, retail or recreational uses; coastal routes; or on routes with highly directional commuter flows.

5.4 Seasonal Factors

Since manual counts are taken throughout the year, data derived from a count taken in a particular month may need to be converted to the peak month by applying a seasonal factor. The Highway Capacity Manual 2010 Chapter 3 has background information on variations in traffic flow. Seasonal factors can be created using data collected from the ODOT ATR stations.

As of November 2013, there are 177 active ATR stations and 6 proposed ATR sites throughout the State Highway System. Most of these locations have loops in the roadway that count traffic flows for 24 hours a day, 365 days a year, and many have been in operation for many years. In addition, some ATR sites have been replaced with Automatic Vehicle Classifiers (AVC) which classifies vehicles continually in addition to counting. As of the date mentioned, there are 18
AVC sites throughout the system. In the future, it may be possible to create seasonal factors for freight movements using data from the AVCs. ATR information is available from the ODOT Transportation (Traffic) Volume Tables (TVT) located on the TDD Transportation Data Traffic Counting Program web site, as well as the ATR Characteristic Table and the Seasonal Trend Table located on the Transportation Analysis webpage of the TDD Planning Section website.

Localized seasonal factors could be derived from other sources of data such as the PORTAL system on the Portland area-freeways and from the 170/2070 traffic signal controller downloads for local non-state streets.

ATRs provide the percentage of AADT that occurs in the count month and in the peak month. This information can then be used to develop a seasonal adjustment that may be applied to the manual count using one of the following three methods.

- On-Site ATR Method
- ATR Characteristic Table Method
- ATR Seasonal Trend Table Method

The On-Site ATR Method is the best and most accurate method to use, followed by the ATR Characteristic Table Method and then the ATR Trend Table Method. All of the seasonal adjustment tables and ATR information are updated annually.

Seasonal factors greater than 30% should be avoided. Factors such as these indicate that a count was NOT taken at or close to the time that the 30HV occurs. Using a winter count with a high seasonal factor to represent the peak summer period will likely not represent traffic turning movements accurately, as driving patterns change in the winter compared to the summer. If alternate periods are used other than the typical summer like what would be used for an alternate mobility standard, then counts need to be taken in those alternate periods so resulting seasonal factors do not exceed 30%. As an example, suppose a count was taken at a rural intersection in the winter months with one of the minor legs of the intersection serving a campground beyond the intersection. The turning volume in the direction of the campground may be small or non-existent; say 5 vph. Even with a seasonal factor of 50%, this would result in an adjusted volume of only 8 vph, compared to an actual summer 30HV that may be 20 vph. Simply factoring for the season would still leave the turning movements too low.

5.4.1 On-Site ATR Method

The On-Site ATR Method is used when an ATR is within or near the project area. If located outside of the project area, there should be no major intersections between the ATR and the project area, and it should be within a minimal distance so that the traffic characteristics such as road class, number of lanes, rural/urban area, etc., are comparable. It is also important to check that the project area’s AADT in the Transportation Volume Table is within +/- 10% of the ATRs AADT.
When using the ATR Summaries from the TVT’s, the analyst should note both the Average Weekday and Average Daily percentages. When there is little variation between the Average Weekday and Average Daily percentages, using Average Weekday supports the notion that the peak is likely on an average weekday. If the Average Daily is much larger than the Average Weekday, then the peak is likely on a weekend day, so use the Average Daily Percentage. Check the Weekly Traffic Trend column from the ATR Characteristic table to aid in this calculation.

Example 5-1 Seasonal Factor – On-Site ATR

On-Site ATR in Project Area

A traffic count was taken June 15th–18th along Kings Valley Highway No. 191 (OR 223) at MP 28.00.

- **Step 1: Transportation Volume Table** - ATR 02-005, located on Kings Valley Highway at MP 26.40, can be used.
- **Step 2: Check ATR Characteristic Table** weekly traffic trend column to identify whether to use the ADT or AWDT for seasonal factor. In this case, the Characteristic Table identifies this as a Weekend ATR; therefore the ADT column is used.
- **Step 3: ATR Trend Summary** - The ATR number corresponds to a table in the last half of the TVT that contains yearly summaries for each ATR. Since the Average Daily percentages are much higher than the average weekday, select a value from the column titled “Average Daily Traffic/Percent of ADT.” Both the count month and the peak month percentage of ADT should be recorded. This information should be obtained from the ATR Summaries in the TVT’s for the past five years. The peak month is the month with the highest percentage. The highest and lowest percentages should be eliminated to account for construction activity that may have occurred in the vicinity of the ATRs during the five year period. An average percent of ADT is then calculated for the remaining three years. The percentages shown in the TVT represent the 15th day of the month, so interpolation is needed if the count was taken near the beginning or end of a month.

### Seasonal Adjustment Using ATR #02-005

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Month (September)</td>
<td>115%</td>
<td>119%</td>
<td>124%</td>
<td>121%</td>
<td>126%</td>
</tr>
<tr>
<td>Count Month (June)</td>
<td>104%</td>
<td>104%</td>
<td>103%</td>
<td>106%</td>
<td>106%</td>
</tr>
</tbody>
</table>

† – Sometimes the Peak Month may vary between months, depending on the year. As in this case, 4 of the 5 Peak Months were in September. Therefore, you assume September is the Peak Month for every year of ATR data used.

As shown above, the percentage of ADT values listed during June and September for the past five years are reviewed to calculate the average. The highest and lowest values, shown as shaded, are dropped from this calculation. The average monthly factors are determined as follows:
• The average peak month (September) is: \((121\%+124\%+119\%)/3 = 121\%\).
• The average count month (June) is: \((106\%+104\%+104\%)/3 = 105\%\).
• The seasonal adjustment is September/June = 121\% / 105\% = 1.15.

Therefore, traffic volumes in the month of September are 1.15 times greater than in June. To convert the June traffic data to the 30HV:

\[
30HV = (\text{June PHV}) \times \left( \frac{\text{Peak Month Percent of ADT}}{\text{Count Month Percent of ADT}} \right).
\]

If one of the peak hour turning movement volumes was 75 vph in June, then the 30HV for September would be \(1.15 \times 75\) vph = 91 vph.

When there are two or more ATR’s within the project area use the following guidance to determine the appropriate seasonal adjustment:

Scenario # 1: The project area has two ATR’s one at each end. The project area ADT, roadway characteristics and roadway functional class are the same as at both ATR’s. In order to seasonally factor the peak hour volumes within the project area, an average of the two ATR seasonal factors recommended.

Scenario # 2: The project area has two ATR’s on the same highway within the project area but have a major roadway between them. The roadway has different characteristics on each side of the major intersecting roadway. With this scenario, each side should be seasonally factored using the ATR on that side.

Scenario # 3: The project area has two (or more) ATR’s located on different roadways. If the roadway has the same characteristics as the ATR then use that one, if not average the ATR’s. NOTE: If the ATR’s report dramatically different roadways (i.e. freeways and local streets), then they should not be averaged together.

5.4.2 ATR Characteristic Table Method

The ATR Characteristic Table provides general characteristics for each ATR in Oregon, and should be used when there is not an ATR on-site. The Characteristic Table is a filterable Excel table that will often provide more than one ATR with similar characteristics. To use the table, filter through the column characteristics from left to right to create a list of ATRs with similar characteristics. See example in Exhibit 5-2 which is an excerpt of the Summer<2500 trend.

Averaging multiple ATRs with similar characteristics will yield a more appropriate factor than if only one ATR is used. Follow the steps described in the on-site ATR Method for averaging count and peak months over 5 years for each ATR with similar characteristics. The factor used to convert the traffic data to 30HV will be an average of these similar characteristic ATR factors. Seasonal Traffic Trend groupings for the table were constructed by plotting the monthly percent...
of AADT for each ATR. The plots were then grouped into trends with the greatest influence in traffic patterns.
### Exhibit 5-2 ATR Characteristic Table Example

#### 2013 ATR Characteristic Table

<table>
<thead>
<tr>
<th>Seasonal Traffic Trend</th>
<th>Area Type</th>
<th># of Lanes</th>
<th>Weekly Traffic Trend</th>
<th>2012 AADT</th>
<th>OHP Classification</th>
<th>ATR</th>
<th>County</th>
<th>Highway Route, Name, Location</th>
<th>MP</th>
<th>State Highway Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer &lt; 2500</td>
<td>Rural</td>
<td>2</td>
<td>Weekday</td>
<td>790</td>
<td>District Highway</td>
<td>01-001 Baker</td>
<td>US 30, La Grande</td>
<td>37.70</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Summer &lt; 2500</td>
<td>Rural</td>
<td>2</td>
<td>Weekday</td>
<td>210</td>
<td>District Highway</td>
<td>01-007 Baker</td>
<td>OR 203, Medical</td>
<td>36.86</td>
<td>340</td>
<td></td>
</tr>
<tr>
<td>Summer &lt; 2500</td>
<td>Rural</td>
<td>2</td>
<td>Weekend</td>
<td>390</td>
<td>District Highway</td>
<td>13-005 Harney</td>
<td>OR 205, Frenchglen</td>
<td>0.01</td>
<td>440</td>
<td></td>
</tr>
</tbody>
</table>
It is important to note that the trends provided in the table are not the only trends attributed to each ATR, but are the dominant trends. Over time, some ATRs may shift trend categories which are mainly the Summer/Summer<2500 and Recreational Summer/Summer<2500 which are typically small changes. Typically, ATR characteristics stay constant from year to year. After the seasonal traffic trend characteristic is selected, other trend groupings, including area type (e.g., urban, rural), number of lanes and weekly traffic trends are broken down to provide more comparable sub-groupings.

ATRs are characterized by only one of eleven seasonal trends, described below and illustrated in Exhibit 5-3. Project areas should be characterized by these trends in the order listed below.

1. **Interstate Urbanized**: ATRs located on any section of urbanized (areas of population > 50,000).interstate. (Example: I-5, Iowa Street - ATR #26-016.)
2. **Interstate Non-Urbanized**: ATRs located on any non-urbanized interstate section. (Example: I-84, west of Troutdale - ATR #26-001.)
3. **Commuter**: ATRs characterized by small seasonal changes in traffic patterns and commuting between city pairs. (Example: OR 22, West Salem Bridges - ATR #24-014.)
4. **Coastal Destination**: ATRs characterized by summer peaks to/or within larger coastal city destinations as well as favorable routes from the valley. Favorable routes for Coastal Destinations include: Salmon River Highway (OR 18), Corvallis-Newport Highway (US 20/OR 34), Alsea Highway (OR 34), and Florence-Eugene Highway (OR 126). (Example: OR 18, east of Valley Junction - ATR #27-001.) Note: This grouping does not include the Sunset Highway.
5. **Coastal Destination Route**: ATRs characterized by high summer peaks on predominantly rural routes to/or between large coastal cities and coastal destinations. Rural routes include the Sunset Highway (US 26) from the Wilson River Hwy. junction, Umpqua Highway (OR 38), and Redwood Highway (OR 199). (Example: US 101, south of Rockaway - ATR #29-001.)
6. **Agriculture**: ATRs characterized by peaking in the late summer and fall harvest months. (Example: Kings Valley Highway - ATR #02-005.)
7. **Recreational Summer**: ATRs characterized by high summer peaks in recreational areas. (Example: Crater Lake Highway, south of Fort Klamath - ATR #18-021.)
8. **Recreational Summer/Winter**: ATRs characterized by both summer and winter peaks in recreational areas. (Example: timberline Highway - ATR #03-008.)
9. **Recreational Winter**: ATRs characterized by high winter peaks in recreational areas. (Example: OR35, Mt Hood Highway – ATR #03-007)

If the project area trend does not fall into Trends 1 through 9, either Trend 10 or 11 should be used.

10. **Summer**: ATRs characterized by a smaller summer increase in traffic patterns when compared to Recreational Summer. (Example: US 26, south of Warm Springs - ATR #16-006.)
11. **Summer < 2,500 ADT**: ATRs with less than 2,500 ADT characterized by a smaller summer increase in traffic patterns when compared to Recreational Summer. (Example: OR36, Mapleton-Junction City Highway - ATR #20-004)
5.4.3 Non-State and other Roadway Trends

Many of the state highways mimic characteristics on rural county roads and urban streets. Some of the ATR Characteristic trends can be used to approximate seasonal factors on non-state highway approaches.

- Commuter: Non-state streets in urbanized cities (Example: US20/OR99E, Albany Junction City Highway - ATR # 22-022)
- Summer: Non-state streets in small cities (Example: OR42, Coos Bay Roseburg Highway - ATR #10-006)
- Summer<2,500 ADT: Rural off-system county roads. (Example: OR36, Mapleton-Junction City Highway - ATR #20-004)

Interchange ramps mix characteristics of the mainline freeway and the intersecting cross-roads, so seasonal factors for ramps should be created by averaging mainline and cross-road factors. State frontage roadways should use the applicable seasonal trend other than Interstate, or the bulleted list above.
Exhibit 5-3 Seasonal Trends
ATRs are also characterized by weekly traffic trends and ADT/AWDT.

- **Weekday**: Day of the week when the 30HV occurs; typical occurs on weekdays (Monday through Thursday) for commuter trend and urban areas.
- **Weekend**: Day of the week when the 30HV occurs; typical occurs on weekends (Friday through Sunday) for recreational trend and coastal destination trend.

ATRs are also characterized by area type and number of lanes.

- **Urbanized**: ATRs within areas of population > 50,000. (Examples: Portland and Salem) Urban Fringe: ATRs influenced by an urban area, such as an MPO area. (Example: Wilsonville)
- **Small Urban**: ATRs within areas of population between 5,000 and 49,999. (Examples: Albany and Pendleton)
- **Small Urban Fringe**: ATRs influenced by a small urban area. (Examples: US 101 south of Coos Bay and I-5 north of Albany)
- **Rural**: ATRs on routes outside of areas with population <5,000.
- **Rural Populated**: ATRs in cities with a population of less than 5,000. This also includes unincorporated communities. (Examples: Sisters and Tillamook)

To use the table, filter through the column characteristics from left to right to create a list of ATRs with similar characteristics. The table must be filtered starting on the far left otherwise, the groupings at the end will not be correct. Starting with the “Seasonal Traffic Trend” column, filter out the traffic trend that best describes the project area. Next, filter the area type, number of lanes, and weekly traffic trend. Make sure that the section of highway where the ATR(s) is located and the project area for which the seasonal adjustments are being made have similar traffic characteristics. To be considered comparable, the AADT of the characteristic ATR should be within +/- 10% of the Transportation Volume Table AADT for the project area.

**Example 5-2 Seasonal Factor – ATR Characteristics Table**

ATR Characteristic Table Method for a Project Area

A count was taken June 15th–18th along Corvallis-Lebanon Highway No. 210 (OR 34), west of I-5 at MP 9.75. The 2012 Transportation Volume Table AADT is 24,900.

- **Step 1: Transportation Volume Table**: There are no ATRs on this section of the highway.
- **Step 2: ATR Characteristic Table**: This section of highway can be categorized as Commuter/Small Urban Fringe/Five-Lanes/Weekday. Filtering through the ATR Characteristic Table from left to right, two ATRs have similar characteristics to the project area. However, ATR 31-003 has an AADT of 11,300; as previously noted, characteristic AADT counts should be within +/- 10% of the Transportation Volume Table AADT in order to be considered comparable to the project area. Alternatively, ATR 09-020 has identical field
conditions to the project site and has an AADT of 26,300, which is within 10% of the TVT AADT. The characteristics of these two representative locations are summarized below.

**Example ATR Characteristic Table (Year 2013)**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>ATR Location 1</th>
<th>ATR Location 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal Traffic Trend</td>
<td>Commuter</td>
<td>Commuter</td>
</tr>
<tr>
<td>Area Type</td>
<td>Small Urban Fringe</td>
<td>Small Urban Fringe</td>
</tr>
<tr>
<td>Number of Lanes</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Weekly Traffic Trend</td>
<td>Weekday</td>
<td>Weekday</td>
</tr>
<tr>
<td>2010 ADT</td>
<td>11,300</td>
<td>26,300</td>
</tr>
<tr>
<td>OHP Classification</td>
<td>Statewide Hwy</td>
<td>Statewide Hwy</td>
</tr>
<tr>
<td>ATR</td>
<td>31-003</td>
<td>09-020</td>
</tr>
<tr>
<td>County</td>
<td>Union</td>
<td>Deschutes</td>
</tr>
<tr>
<td>Highway Route, Name and Location</td>
<td>OR82, Wallowa Lake Hwy</td>
<td>US97, The Dalles-CA Hwy</td>
</tr>
<tr>
<td>ATR Milepoint</td>
<td>1.74</td>
<td>124.40</td>
</tr>
<tr>
<td>State Hwy Number</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>

**Step 3: ATR Trend Summary:** Data from ATR #09-020 is located in the ATR summary in the back of the TVT and under the “ATR Trend Summaries” on ODOT’s Traffic Counter Program website TDD Transportation Data Traffic Counting Program. The count was taken on June 15th, which is in the middle of the month, so the ATR percentages from the TVT can be used directly without interpolation. The peak month was found to be August for two of the three years.

**Seasonal Adjustment Using ATR #09-020**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Month (August)</td>
<td>113%</td>
<td>111%</td>
<td>110%</td>
<td>108%</td>
<td>107%</td>
</tr>
<tr>
<td>Count Month (June)</td>
<td>109%</td>
<td>107%</td>
<td>108%</td>
<td>108%</td>
<td>107%</td>
</tr>
</tbody>
</table>

- The average peak month (August) is: \((111\%+110\%+108\%)/3 = 109\%\).
- The average count month (June) is: \((107\%+108\%+108\%)/3 = 108\%\).
- The seasonal adjustment is August/June = 109\% / 108\% = 1.01.

Therefore, traffic volumes in the month of August are 1.01 times greater than in June. To convert the June traffic data to the 30 HV: \(30 \text{ HV} = (\text{June PHV}) \times (\text{Peak Month Percent of ADT} / \text{Count Month Percent of ADT})\).

If one of the peak hour turning movement volumes were 100 vph in June, then the 30 HV
for August would be $1.02 \times 100 \text{ vph} = 101 \text{ vph}$.

### 5.4.4 Seasonal Trend Method

The seasonal trend table is used when there is not an ATR nearby or in a representative area. The Seasonal Trend Table was constructed by averaging seasonal trend groupings from the ATR Characteristic Table and is based on ADT. Essentially, by using a factor from the table, the average for the entire trend grouping is applied to the project area as shown in Exhibit 5-4.

#### Exhibit 5-4 Example ATR Seasonal Trend Table (Year 2013)

<table>
<thead>
<tr>
<th>Seasonal Factor</th>
<th>Jan 1</th>
<th>Jan 15</th>
<th>Feb 1</th>
<th>Feb 15</th>
<th>Dec 15</th>
<th>Peak Period Seasonal Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreation Summer/Winter</td>
<td>1.0783</td>
<td>0.9668</td>
<td>0.9719</td>
<td>0.9771</td>
<td>0.9091</td>
<td>0.7038</td>
</tr>
<tr>
<td>Recreation Winter</td>
<td>0.7454</td>
<td>0.6408</td>
<td>0.6536</td>
<td>0.6663</td>
<td>0.6398</td>
<td>0.6398</td>
</tr>
</tbody>
</table>

To determine the appropriate seasonal trend, select from the list the trend that best describes the project area. The seasonal trends have been placed graphically on an ATR Characteristic Trend Map for ease of reference. Trends should be characterized in the same order as previously described in the ATR Characteristic Table Method. The Seasonal Factor Table is updated yearly. It is not necessary to average five years’ worth of seasonal factors for this method, or compare AADTs because, as previously stated, this method uses an average of all ATRs in the characteristic trend. In certain areas, averaging seasonal trends may yield a more appropriate factor than just a single trend. These areas include:

- **Coastal Destination and Coastal Destination Route Trends:** It may be necessary to average trends in areas such as Warrenton, Depoe Bay and Yachats. While these cities are destinations along the Oregon Coast, they do not have the summer influx of traffic associated with larger coastal destinations such as Lincoln City and Seaside. A Coastal Destination Trend Factor for these areas may be too high, while a Coastal Destination Route Trend Factor may be too low. When analyzing coastal cities such as these, it is appropriate to average the trends to yield a more reasonable factor.

- **Summer and Commuter Trends:** It may be necessary to average trends when analyzing mid-sized cities such as Philomath, Dallas and Sutherlin. For urbanized areas the commuter trend is appropriate, while for smaller areas the summer trend is appropriate. However, for mid-sized areas such as these, the summer or
commuter trends may alone be too high or too low. A more reasonable factor would be obtained by averaging the summer and commuter trends.

- **Interstate and Interstate Urbanized Trends:** It may be necessary to average trends when analyzing interstates in small urban and fringe areas (urban and small urban) such as Albany, Wilsonville and north of Roseburg. For rural areas the interstate trend is appropriate, while for urbanized areas the interstate urbanized trend is appropriate. For small urban and fringe areas such as these, however, these trends may alone be too high or too low. A more reasonable factor would be obtained by averaging the interstate and interstate urbanized trends.

It is important to note that these are the only trend grouping pairs that would be appropriate to average, Interstate should only be averaged with interstate urbanized, and should never be averaged with Coastal or Recreational. The same is true for the other trends not listed in the above examples. The Seasonal Trend Table is located on the Transportation Analysis webpage of the TDD Planning website.

Factoring count data to the peak month requires dividing the seasonal factor for the count period by the seasonal factor for the peak period. The peak period seasonal factor for a traffic trend is the lowest value in the row, and is highlighted in the last column in the table.

Seasonal factors are given for the 1st and the 15th of each month so if the count date is not at the beginning/end or in the middle of a month interpolation is needed.

**Example 5-3 Seasonal Factor – Seasonal Trend Table**

This example demonstrates the Seasonal Trend Method for a Project Area.

A count of 11,000 was taken July 1st – 5th along Oregon Coast Highway No. 9 (US 101) at MP 63.19 which is just north of Tillamook city limits.

- **Step 1: Transportation Volume Table:** There are no ATRs on this section of the highway.
- **Step 2: ATR Characteristic Table:** This section of highway can be categorized as Coastal Destination/Rural/Two-Lanes. Filtering through the ATR Characteristic Table, from left to right, four ATRs have similar characteristics to the project area. However, none of the characteristic ADT values are within +/- 10% of the Transportation Volume Table ADT for the project area. Refer to the table below for details regarding these four candidate locations.
**Example ATR Characteristic Table (Year 2013)**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>ATR Location 1</th>
<th>ATR Location 2</th>
<th>ATR Location 3</th>
<th>ATR Location 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal Traffic Trend</td>
<td>Coastal Destination</td>
<td>Coastal Destination</td>
<td>Coastal Destination</td>
<td>Coastal Destination</td>
</tr>
<tr>
<td>Area Type</td>
<td>Rural</td>
<td>Rural</td>
<td>Rural</td>
<td>Rural</td>
</tr>
<tr>
<td>Number of Lanes</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Weekly Traffic</td>
<td>Weekday</td>
<td>Weekend</td>
<td>Weekend</td>
<td>Weekend</td>
</tr>
<tr>
<td>2012 ADT</td>
<td>2000</td>
<td>5700</td>
<td>4700</td>
<td>17200</td>
</tr>
<tr>
<td>OHP Classification</td>
<td>District Hwy</td>
<td>Statewide Hwy</td>
<td>Statewide Hwy</td>
<td>Statewide Hwy</td>
</tr>
<tr>
<td>ATR</td>
<td>02-003</td>
<td>20-005</td>
<td>21-006</td>
<td>27-001</td>
</tr>
<tr>
<td>County</td>
<td>Benton</td>
<td>Lane</td>
<td>Lincoln</td>
<td>Polk</td>
</tr>
<tr>
<td>Highway Route, Name and Location</td>
<td>OR34, Alsea Hwy No. 27, southwest of Corvallis-Newport Hwy No. 33 (US20/OR34)</td>
<td>OR126, Florence-Eugene Hwy No. 62, west of Territorial Hwy No. 200 (OR200)</td>
<td>US20, Corvallis-Newport Hwy No. 33, west of Lincoln-Benton County Line</td>
<td>OR18, Salmon River Hwy No. 39, east of Three Rivers Hwy No. 32 (OR22)</td>
</tr>
<tr>
<td>ATR MP</td>
<td>53.89</td>
<td>43.86</td>
<td>34.24</td>
<td>23.23</td>
</tr>
<tr>
<td>State Hwy Number</td>
<td>27</td>
<td>62</td>
<td>33</td>
<td>39</td>
</tr>
</tbody>
</table>

- **Step 3: Seasonal Trend Table**: Since there are no ATRs with similar characteristics, the Seasonal Trend Table must be used. The correct values are obtained by following the “Coastal Destination” row to the “Jul_1” count month column, and to the “Peak Period Seasonal Factor” column at the end of the table, as summarized below.

**Seasonal Trend Table (Year 2013)**

<table>
<thead>
<tr>
<th></th>
<th>Jun 15</th>
<th>Jul 1</th>
<th>Jul 15</th>
<th>Aug 1</th>
<th>Peak Period Seasonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Destination</td>
<td>0.9345</td>
<td>0.8749</td>
<td>0.8153</td>
<td>0.8005</td>
<td>0.7857</td>
</tr>
</tbody>
</table>

- The peak period seasonal factor is 0.7857.
- The count date seasonal factor (July 1st) is 0.8749.
- The seasonal adjustment is: Count Date Seasonal Factor/Peak Period Seasonal Factor = 0.8749/0.7857 = 1.11.

Therefore, the peak period volumes for a Coastal Destination are 1.11 times greater than volumes for the 1st – 5th of July.
To convert the July traffic data to the 30HV:

\[
30HV = (\text{July PHV}) \times (\text{Count Date Seasonal Factor} / \text{Peak Period Seasonal Factor}).
\]

If one of the peak hour turning movement volumes were 100 vph in July, then the 30HV would be \(1.11 \times 100 \text{ vph} = 111 \text{ vph}\).

Exhibit 5-5 below is a simplified flow chart of the process for seasonal adjustments.

**Exhibit 5-5 Process for Development of Seasonal Adjustments**
Seasonal Adjustment for Alternate Periods

If it is desired to factor count data to an annual average time of year (Oct or May typically) for determination of an alternate mobility standard, the values in the Seasonal Trend table can still be used. This is same process that the Transportation Data Section uses to create average annual daily traffic (AADT) to create the Transportation Volume Tables.

Example 5-4 Seasonal Characteristic Table Adjustment for Alternate Period

This is a continuation of Example 5-2 Seasonal Factor – ATR Characteristics Table (count taken June 15th–18th along OR 34 west of I-5). It is desired to obtain average annual peak hour volumes for this location. It was previously determined using the ATR Characteristic Table method that ATR #09-020 should be used for seasonal adjustments for this site.

Seasonal Adjustment Using ATR #09-020

<table>
<thead>
<tr>
<th>Count Month (June)</th>
<th>2012</th>
<th>2011</th>
<th>2010</th>
<th>2009</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>109%</td>
<td>107%</td>
<td>108%</td>
<td>108%</td>
<td>107%</td>
</tr>
</tbody>
</table>

For this site location, the ratio of (Count Month ADT)/(AADT) from ATR #09-020 is used. For the five years of this example, dropping the high and low, the average count month % of AADT was found to be 109%.

\[
\text{Count Month ADT} = 1.09 \\
\text{AADT}
\]

To convert to average annual volumes, count month volumes are divided by this ratio (1.09), i.e., the average annual peak hour volume = (Site June PHV) / (ATR June ADT/AADT)

If one of the site peak hour turning movement volumes were 100 vph in June, then the site average annual peak hour turning movement volume would be 100 vph / 1.09 = 92 vph.

Example 5-5 Seasonal Trend Table Adjustment for Alternate Period

This is a continuation of Example 5-3 Seasonal Factor – Seasonal Trend Table (count of 11,000 taken July 1st – 5th along US 101 north of Tillamook). It is desired to obtain the average annual peak hour volumes for this location. The seasonal trend table was used for this location. The applicable seasonal trend was determined to be Coastal Destination.
The factors in the seasonal trend table are ratios of AADT to the month ADT (AADT/Month ADT). The ratio of the AADT/Month ADT is assumed to be the same for the site peak hour volumes. To convert to average annual peak hour, the site month peak hour volume is multiplied by that ratio for that month.

Site Average Annual Peak Hour Volume = Site Month peak hour volume x Trend Table Factor for that month

In this example, the count was taken the week of July 1st. The seasonal factor for July 1st was found to be 0.8749. If one of the site peak hour turning movement volumes were 100 vph in July, then the site average annual peak hour turning movement volume would be 100 vph x 0.8749 = 87 vph.

5.5 **Historical Factors (Factoring to Current Year)**

In addition, to adjusting count volumes seasonally, they need to be adjusted to the current or base year of the project. This might mean increasing or decreasing the count peak hour volume. The historical factor process uses the Future Volume Table to adjust the volume regardless of what process is used to create the future volumes (see Chapter 6).

The Future Volumes Table is updated annually. The table is based on long-term 20-year trends of traffic counting sites (for the TVT) on Oregon highways. Each individual record trend has been analyzed to eliminate any unexplained spikes or dips in the data to improve its overall correlation with the 20-year regression curve. The trends are based on linear regression best-fit trends and are extrapolated out 20 years. Over the 20-year period, the linear trends show a steady growth and should not grossly under or overestimate the future 20-year value outside of travel demand model areas. Use of other curve extrapolation models (i.e. compound growth) shall not be used.

Within the table, the milepoint location for the project highway that most closely resembles the traffic flows for the section being analyzed is selected. Sometimes, another milepoint may be closer to the section being analyzed, but there may be a cross street that affects traffic volumes on the highway so that the growth rate is different.

There are three columns in the table for the most recent three years of traffic count data. Only one of the columns is filled; corresponding to the last year that the location was counted. The far right column contains the R-squared value for the regression equation that was used to estimate the historical trend. The R-squared value measures the degree of correlation between the dependent variable (historical traffic volumes) and the independent variable (time). A value of 1.0 indicates an exact linear relationship between the historical counts and time. Ideally, the R-squared value should exceed 0.75. However,
values higher than 0.50 are still acceptable, if there is nothing else available. Conversely, a low R-squared value indicates a weak relationship. In this case, the table should be investigated for a nearby location having similar traffic characteristics and a more acceptable R-squared value.

In areas that have travel demand models, the R-squared value is replaced by the “MODEL” code. This code indicates that the historical trend has been replaced by the model growth rate (future year divided by the base year). In larger areas, use of the historical growth rate can overestimate volumes, so the use of the model growth rate allows for consideration of capacity constraints. These model growth rates are updated as the models are updated (typically every five years or so).

For non-state roadways, or ramps/frontage roads, historical factors can be averaged from similar roadways with the same characteristics. The seasonal factor sections in this chapter can apply to help locating highway sections with similar characteristics. For example, an interchange ramp is affected by growth on the mainline freeway as well as the intersecting crossroad, so the ramp historical adjustment would be the average of the two.

Local land use changes should also be reviewed if they have occurred between the time that the count was taken and the desired base year of the project. In this case, the Future Volume Table should not be used because it is likely that double-counting would occur. The additional trips from the background and development sections in the traffic impact analysis document need to be added to the count volumes to approximate the existing traffic levels.

**Example 5-6 Adjusting Counts to Current Year**

The project base year is 2013 but the counts available were counted in 2010. The Future Volume Table is used to adjust the counts to the base year.

For the Madras ATR (#16-002) located on US 97 at MP 96.92, The following table shows the 2011 traffic volumes, projected Year 2032 traffic volumes and the R-squared value.

<table>
<thead>
<tr>
<th>Hwy#</th>
<th>DIR</th>
<th>MP</th>
<th>Description</th>
<th>2011</th>
<th>2032</th>
<th>RSQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1</td>
<td>96.46</td>
<td>0.02 mile N of Fairgrounds Road</td>
<td>17700</td>
<td>23200</td>
<td>0.9150</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>96.92</td>
<td>ATR 16-002 - Madras</td>
<td>12200</td>
<td>12500</td>
<td>0.7037</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>97.31</td>
<td>0.02 mile S of US 26</td>
<td>9300</td>
<td>13800</td>
<td>0.3994</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>103.61</td>
<td>0.02 mile N of SW Iris Lane</td>
<td>8200</td>
<td>10600</td>
<td>0.5093</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>105.63</td>
<td>0.10 mile N of Culver Hwy</td>
<td>8700</td>
<td>13000</td>
<td>0.7844</td>
</tr>
</tbody>
</table>

RSQ = Root Mean Square

Based on the data above, the 21-year growth factor would be 1.024 (12500/12200).
Assuming linear growth in the future, the annual growth factor would be \((1.024 - 1.0) / 21 = 0.00114\), or 0.114\%\%. The R-squared value of 0.7037 is acceptable. To convert the 2010 30HV, for example a minor approach left volume of 115 vph, to a 2013 DHV, the 2010 30HV is multiplied by the 3-year growth factor.

\[
\text{2013 DHV} = 2010 \text{ 30HV} \times [(3 \times \text{Annual Growth Rate}) + 1] = 115 \text{ vph} \times [(3 \times 0.0114) + 1] \\
= 115 \text{ vph} \times 1.034 \\
= 119 \text{ vph}
\]

5.5.1 Network Balancing

The 30HV network needs to be balanced. Balancing is somewhat of an “art” that techniques vary from project to project and within areas on a project, so it is hard to list out a specific process. The exhibits and examples below illustrate some different balancing techniques. Balancing is simply, “what goes into an intersection or segment needs to come out.” Without balancing, it is possible to have two intersections with nothing between them with the volume that leaves one intersection and enters the next one be 200 vph or more different.

Interstates and expressways with interchanges or roadway segments with no accesses need to balance perfectly from one intersection or interchange to another. Roadways with accesses probably will not balance perfectly, but should be consistent from intersection to intersection. Roadways with many non-counted accesses (especially major ones) should not be forced to balance as this will artificially increases or decreases the adjacent intersection volume beyond the realistic point. If a segment fails to balance because of accesses, it may be best to perform a peak hour count at the point or points to help reduce the balancing needed.

The timing of the traffic counts can help determine how easy a network is to balance. Counts that are spread throughout the allowable three-year span taken at different times of the year will be harder to balance than counts all taken on the same day or within a week of each other. Counts that have similar peak hours will be easier to balance than counts of varying peaks.

Network balancing should be done initially on paper as it is easier to track differences and proportional changes as the process proceeds. An intersection may have to be adjusted more than once in a single balancing process, so a record of the “chronological” adjustments/steps is needed for the analyst to retrace or a reviewer to follow. Trying to follow a spreadsheet-based balancing process is difficult and it becomes more of an effort to identify whether the right formula was used versus the right thought process was used. If a spreadsheet is used, then the thought-process needs to be shown via comments/notes. Once the network is balanced, then the results should be rounded and placed into spreadsheets or figures. The important point is that the balancing thought process be
reasonable, logical and be well documented. The balanced network must be reviewed before the values are used in any further analysis or construction of future year volumes.

When balancing, it is important to keep the general proportions of turn splits and leg directional factors relatively constant unless the analyst knows that the counts did not capture the true conditions.

**Identifying High/Low Imbalances**

A good way to start the balancing process is to first identify which intersections/segments are high or low and likely techniques that could be used. Sum up the inflows and outflows on each approach and exit leg and note the differences between them across each intersection. Doing this graphically via sketches on paper with different colors for high and low segments can expedite the process. Note whether the differences seem to be on through movements or turn movements. The count dates, durations, and the analyst’s overall confidence in the intersection counts should also be documented.

Small differences overall likely mean that a single point could be held and the differences proportionally distributed. Large differences likely mean that differences will need to be split between intersections first. Intersections with whole approaches that are low or high, especially on minor approaches, may mean that the whole approach will need to be adjusted. The average project study area will have many of these conditions so a combination of methods is necessary.

Intersections that are identified to have a high-low-high-low pattern generally have a better success rate in balancing cleanly versus a high-high-high or low-low-low pattern which might create too much of a difference at the network edge.

The following series of exhibits illustrates a small network consisting of three intersections on US 97 and will be used to demonstrate many of these network balancing techniques. Volumes shown in Exhibit 5-6 have been previously developed by factoring counts up to a common year and applying seasonal adjustment factors. The exhibit identifies the high and low imbalances between intersections. There are no driveways between intersections so volumes should balance.
Exhibit 5-6 Identify High/Low Imbalances in Network

After calculating the volume differences it is apparent that the Robal volumes are low compared to the adjacent intersections.

Low confidence in volumes at Robal due to age of counts and volume difference compared to adjacent intersections.

US 97 Project
Existing Unbalanced 30 HV

xxx = Volumes unchanged from previous step
[xxx] = Volumes revised in this step
+- xx = Volume change resulting from this step
**Holding an Intersection Constant**

If differences are relatively small between intersections, holding an intersection constant and pushing the differences away proportionally may be used. Another use of this method is if the analyst has good confidence in a major intersection count based on count year or duration. For example, long duration counts generally are better to hold than short duration counts. Larger intersections (number of legs and/or volumes) are generally better to hold than smaller intersections. Depending on the situation, it may be best to start with the intersection with the greatest differences.

The selected intersection is held constant and the differences are pushed to the next intersection. The difference is resolved by identifying the splits between the approach turn movements from the next intersection’s subject approach and applying those splits to the difference. The difference in the opposing direction is obtained from the proportional splits that make up the movements going onto the exit leg. This is repeated for each segment of the held intersection. Then, the difference is moved away from the held intersection and the difference is proportionally reduced the further away it gets as portions are removed by each turn movement.

It is possible that as the difference is worked downstream, the increases/decreases at an intersection become too great or seem to be going away from convergence (getting worse). In this case, either another intersection could be selected to be held, an entire approach may needed to be adjusted, or better, the differences need to be split instead of held.

This method can also be used to just hold particular approaches constant if desired. This is useful if the analyst believes that the minor street leg growth factors seem to be off and has more confidence in the major approaches.

**Factoring Approaches/Legs/Intersections**

Sometimes, after identifying the high and low imbalances, an approach, or a leg, or an entire intersection appears to be significantly low or high for some reason. These areas may be have been influenced by driveway closures, nearby road construction/diversion, incidents, or special events. Sometimes the count might have an error so this should be checked thoroughly even up to replacing the count with a new one if necessary. If no obvious errors/issues exist then these can be factored up or down to more closely agree with adjacent intersections which the analyst has more confidence in. If these are on state highways, these is most easily done by using the Future Volume Tables to adjust the appropriate leg or intersection further with a growth factor as similarly done in Section 5.5. If a travel demand model exists, then this can be used to create annual growth factors for local roadways.

Exhibit 5-7 illustrates a situation where the volumes on US 97 at Robal are low in comparison to adjacent intersections. In this case there is less confidence in the volumes.
at Robal because they are based on an older count even though they have been adjusted to a common base year. There is greater confidence in the volumes at Nels Anderson and the Target driveway. In this case volumes at the entire intersection of Robal volumes are increased by a factor of 1.057 based on the Future Volume Table growth along this segment. This factor represents three multiples of the annual growth factor to bring the intersection to as close as possible without making it too high. The volume imbalance is then recalculated. After this adjustment, Robal is now high compared to the Target driveway to the north, and low compared to Nels Anderson intersection to the south. But the imbalance is now smaller and more realistic.
**Exhibit 5-7 Factoring an Intersection to Improve Balance**

- **Target**
  - 107
  - 1350
  - US 97 Project

- **Robal**
  - 1243
  - 107
  - Low
  - 1492
  - High
  - 1464
  - 290
  - 322
  - 186
  - Increase growth at Robal by a multiple of the assigned growth factor until volumes better balance with adjacent intersections.

- **Low**
  - 1350
  - 1807
  - 1807

- **High**
  - 107
  - 26
  - 290
  - 322
  - 184
  - 12
  - 122
  - Result is better balance between Nels Anderson and Target driveway.

- **Nels Anderson**
  - 1647
  - 193
  - 1902
  - 1807

---

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- **xxx** = Volumes unchanged from previous step
- **[xxx]** = Volumes revised in this step
- **+- xx** = Volume change resulting from this step
Splitting the Difference

Large differences between intersection exit leg and the next intersection approach leg need to have the difference split. In this way the difference is moved proportionally in both directions rather than in just one. The proportional adjustments are the same as described above. This is repeated for every intersection until the edge of the network is reached. It may be necessary to re-adjust previously balanced sections of a particular leg does not balance cleanly (does not converge), or if the network circulates the difference back around to the starting spot. Some small differences may be possible to assign to minor streets or non-counted locations.

Exhibit 5-8 illustrates splitting the difference between Robal and Nels Anderson in both the northbound and southbound directions. In order to avoid increasing the imbalance to the north, only turn movement volumes at Robal to and from the south are adjusted. As balanced volumes are created they are rounded to the nearest five vehicles.

Next, the difference between Robal and the Target driveway to the north is addressed by splitting the difference as shown in Exhibit 5-9. Again, the through movement volumes at Robal are held to avoid re-introducing an imbalance to the south. The difference is proportionately assigned at Robal to the turn movements to from the north only.

In the next step as shown in Exhibit 5-10, the volume adjustments previously made are pushed off the network.

In reviewing the resulting volumes, the drop in turning movement volumes at Robal is determined to be excessive. An iteration is performed by holding the southbound turning movement volumes at Robal and instead applying the difference to the southbound through movement as shown in Exhibit 5-11. That volume adjustment is then pushed off the network. This results in more realistic volumes and illustrates how the balancing process is often iterative, i.e., initial assumptions may need to be changed during the process in order to improve the balance.

Once satisfied that no further improvements in network balance can be made, final balanced volumes are shown as in Exhibit 5-12. Any remaining volumes that were not adjusted and rounded in previous steps were rounded.
Exhibit 5-8 Splitting the Difference

Round volumes as part of the balancing process

Allocate 10 vph proportionally to turn movements; eg., 122+127=249; 122/249=.49; 10*.49=.5; 122+5=127~125

Split the difference

Allocate 29 vph proportionally to turn movements; eg., 238+17=255; 238/255=.93; 29*.93=27; 238+27=265

Split the difference

xxx = Volumes unchanged from previous step
[xxx] = Volumes revised in this step
+- xx = Volume change resulting from this step
Exhibit 5-9 Adjustment Between Robal and Target Driveway

Proportionally adjust volumes to the north; eg.,
1243+186=1429; 186/1429=.13; .13*35/2 = 2; 186+2=188~190

Drop turn movements proportionally

Split the difference

(1429+1464)/2=1446 1445

1807 1807 1807

1840 1840 1840

1429 [1445]

1464 [1445]

NORTH

NO SCALE

US 97 Project

Target

Robal

Nels Anderson

xxx = Volumes unchanged from previous step
[xxx] = Volumes revised in this step
+- xx = Volume change resulting from this step
Exhibit 5-10 Adjusting volumes on Side Streets and Off the Network

Target

NORTH

NO SCALE

US 97 Project

Further adjustments made to turn movements to match volumes to/from the south

xxx = Volumes unchanged from previous step
[xxx] = Volumes revised in this step
+- xx = Volume change resulting from this step

Turn movements at Nels Anderson are small and changes are made by inspection and rounding

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**Exhibit 5-11 Revising Initial Assumption to Improve Balance**

A reduction from 26 to 15 for the SB turn movements may be excessive for these small volumes. Alternatively, the turn movements at Robal could be held and the through movement reduced. This would actually improve the balance by reducing the gap to the south.
Exhibit 5-12 Final Balanced 30HV

Target

Robal

Nels Anderson

US 97 Project
Existing Balanced 30 HV

XXX = Volumes unchanged from previous step
[XXX] = Volumes revised in this step
+-XX = Volume change resulting from this step

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5.5.2 Rounding

The final 30HV need to be rounded. The traffic volumes are not that precise to go down to one vehicle with the normal errors that occur within the counting and adjusting processes. For reduction of systematic error, balancing should occur before rounding of values. However, balancing the network can be easier if the network is not down to the individual vehicle. The analyst can choose a methodology, but the important thing is to stick with one method consistently through the entire project. Volumes should be rounded to the nearest five for the existing or base year. Volumes less than five vehicles should use the “<5” symbol instead of using zero.

5.5.3 Documentation

It is critical that after every step in the 30HV volume development process that all of the assumptions and factors are carefully documented, preferably on the graphical figures themselves. Count specifics, raw and system peak hours used, ATR’s used, seasonal adjustments, ATR 30HV adjustments, and yearly growth factors are some of the items that need to be documented. If all is clearly documented then anyone can easily review the work or pick up on it quickly without questioning the assumptions made. The documentation figures will eventually end up in the final report or in the technical appendix. The volume documentation should include:

- Map-based figure showing (See Exhibit 5-13):
  - Roadway network and intersection lane configurations and control type
  - Raw traffic volumes showing raw peak hour
  - For each intersection, count date, duration, type, and raw peak hour time
- Map-based figure showing (See Exhibit 5-14):
  - Selected system peak hour time
  - Raw count data by movement for the selected system peak hour
- Map-based figure showing (See Exhibit 5-15):
  - Yearly growth and seasonal factors used for each intersection
  - Unbalanced factored 30HV
- Map-based figure showing (See Exhibit 5-16) balanced 30HV (this figure is used in an existing year analysis technical memorandum).
Exhibit 5-13 Raw Traffic Counts

Feb 2010
4:15 – 5:15 PM
16 hr Manual

Feb 2010
4:45 – 5:45 PM
16 hr Manual
Exhibit 5-15 Seasonal and Historical Growth

1.02 growth and 1.07 seasonal adjustment made to Feb 2010 count to get 2011 DHV
Exhibit 5-16 Balanced Network
5.6  **K-30 Factor Development**

For certain planning studies, such as a county TSP analysis, sketch planning level analysis of highway segments may be appropriate, for all or portions of the study. To develop planning-level design hour volumes, TVT AADT volumes can be used. The TVT AADT volumes are used to derive the 30HV by multiplying by the K-30 factor. A K factor is the ratio between a peak hour and the ADT. The K-30 factor is the ratio of the 30th highest hour to the AADT and should be used for this purpose. Short term count K factors should not be used for this purpose. A background report on this topic is available on the TPAU website.

K-30 factors are derived from ATRs and can be found in the TVT section on “Summary of Trends at ATR Stations”. They are listed under Historical Traffic Data, Percent of ADT for the 30th Hour. A representative ATR needs to be identified following the procedures described in Section 5.4.

**Example 5-7 Converting AADT to DHV using the (K30) factor**

This example illustrates how to calculate and apply the K-30 Factor.

Find the 30HV for sketch planning analysis for a segment of Kings Valley Highway No. 191 (OR 223) at MP 28.00.

- **Step 1: Transportation Volume Table** – The TVT is used to find the AADT for this segment.

  The 2012 AADT from the Transportation Volume Table is found to be 1000.

- **Step 2: ATR Trend Summary** – ATR 02-005, located on Kings Valley Highway at MP 26.40, can be used for this location. The ATR number corresponds to a table in the last half of the TVT that contains yearly summaries for each ATR. From the column titled “Percent of AADT” the 30th Hour percent of AADT should be recorded for the past five years. The highest and lowest percentages should be eliminated to account for construction activity that may have occurred in the vicinity of the ATR during the five-year period. An average percent of AADT is then calculated for the remaining three years.

**K-30 Factors Using ATR #02-005**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>K-30</td>
<td>12.6%</td>
<td>12.6%</td>
<td>12.6%</td>
<td>13.4%</td>
<td>12.6%</td>
</tr>
</tbody>
</table>

Note: Shaded values dropped from average calculation.

---

4 Use of Short-Term Interval Counts to Determine K Factors, Don R. Crownover, P.E., ODOT Transportation Systems Monitoring (TSM) Unit, August, 2006.
As shown in Example 5-1 Seasonal Factor – On-Site ATR, the percentage of AADT values listed during June and September for the past five years are reviewed to calculate the average. The highest and lowest values, shown as shaded, are dropped from this calculation. The average K-30 factor is determined as follows:

- The average K-30 factor is: \((12.6\% + 12.6\% + 12.6\%) / 3 = 12.6\%\).

Calculate the two-way 30HV:

\[30HV = (\text{AADT}) \times (\text{Average K-30 Factor}) = 1000 \times 0.126 = 126 \text{ vph}.\]

Obtain the directional split for the 30\(^{th}\) highest hour as defined by the D-30 factor from the TCM Ranked Hour report (see Traffic Count Management (TCM) Program Count Report Guide).

From the 2012 Ranked Hour report for ATR 02-005
D-30 NB = 0.30 and D-30 SB = 0.70

Calculate the directional 30HV:

\[30HV \text{ NB} = (30HV) \times (\text{D-30 factor}) = 126 \times 0.30 = 38 \text{ vph}.\]
\[30HV = (30HV) \times (1-\text{D-30 factor}) = 126 \times 0.70 = 88 \text{ vph}.\]

5.7 Average Daily Traffic (ADT) Development

A number of operational analysis processes need to use ADT instead of 30HV. Some of these are the preliminary signal warrants (link) and air/noise data (link). Many sketch planning and the HCM Planning analysis methods use ADT. ADT is also more perceivable by the public and is frequently used in meetings, environmental documents, and other traffic-related efforts. ADT should be thought of as a “peak month” ADT as it is developed using 30HV. This is not the same as annual average daily traffic (AADT) as AADT is developed using ATR sites which count all days of the year so seasonal trends can be accounted for.

ADT can be created directly on a link basis from 24-hr counts but these counts are unlikely to be done comprehensively over a study area or may be just limited to tube counts which do not catch turning movements. More typically, ADT is created from the 30HV or peak hour volumes.

The ADT conversion process requires the use of counts that can support ADT calculations (12 hours or more). In most cases, ADT cannot be created from peak hour or peak period counts. Use of shorter counts may be acceptable for use in preliminary signal warrants and safety-based analyses. K30 factors are not to be used in ADT development.
regardless of count duration as those are too general for a project analysis. K-factors and D (directional) factors need to come straight from an ADT-capable count or be derived from counts on other study area intersections/roadways with similar characteristics.

The TruckSum spreadsheet is a good source for obtaining initial K’s & D’s for all intersection legs of a count at once. Use the TCM TruckSum report to get the input data in the correct format for the spreadsheet (see TCM Program Count Report Guide and APM Version 1 Chapter 11). If non-cardinal directions (NW, SE, etc.) are included, the analyst will need to convert these to the cardinal directions (N, S, E, W) first before copying and pasting (Use Paste Special…Values Only) into the TruckSum Spreadsheet. As shown in Exhibit 5-17 below, the K-factors are shown explicitly and data is available to readily create the D-factor.

**Exhibit 5-17 TruckSum K and D-Factors**

<table>
<thead>
<tr>
<th>All Vehicle ADT Factor</th>
<th>NORTHLEG</th>
<th>EAST LEG</th>
<th>SOUTHLEG</th>
<th>WEST LEG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>volume</td>
<td>volume</td>
<td>volume</td>
<td>volume</td>
</tr>
<tr>
<td>NB</td>
<td>25</td>
<td>38,257</td>
<td>46,700</td>
<td>16,578</td>
</tr>
<tr>
<td>SB</td>
<td>25</td>
<td>18,934</td>
<td>24,816</td>
<td>17,950</td>
</tr>
<tr>
<td>TOTAL</td>
<td>50</td>
<td>55,191</td>
<td>71,516</td>
<td>34,538</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>All Vehicle PHY Factor</th>
<th>NORTHLEG</th>
<th>EAST LEG</th>
<th>SOUTHLEG</th>
<th>WEST LEG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>volume</td>
<td>volume</td>
<td>volume</td>
<td>volume</td>
</tr>
<tr>
<td></td>
<td>factor</td>
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K-Factor shown in decimal form for each direction on an intersection leg. For the north leg of the intersection, the K-factors would be 17.3% NB and 7.3% SB.

If a TruckSum spreadsheet is not available, develop Ks and Ds from the count. Exhibit 5-18 shows a typical intersection count output and where to pull the data needed for the calculations. Note that the system peak hour should be used to develop the K and D factors, rather than the individual intersection peak hour. For each directional link, calculate the K factor by dividing the system peak hour volume by the 24-hour volume ADT.
Exhibit 5-18 K & D – Factors from Counts

K and D- Factors from Counts

**K-Factor**

- **Westbound**
  
  \[
  \frac{941}{12938} = 0.073 \text{ or } 7.3\%
  \]

- **Eastbound**
  
  \[
  \frac{1199}{19666} = 0.061 \text{ or } 6.1\%
  \]

**D-Factor**

- **Westbound**
  
  \[
  \frac{12938}{16544} = 0.49 \text{ or } 49\%
  \]

- **Eastbound**
  
  \[
  \frac{12696}{16544} = 0.77 \text{ or } 77\%
  \]

**Summary of Traffic Count**

- **Site:** 22012110
- **Date:** 10/8/2010
- **Count:** Lane 1
- **City:** Altamont
- **Milepoint:** 0.64
- **Count Number:** 1.00
- **Hwy #:** 316
- **Location:** US 101 at First St & driveway site
- **Weather:** Clear/Cloudy

**Summary By Movements**

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</tbody>
</table>

**Entering Volumes**

- **Total Count:** 121
- **24-Hour Volume ADT:** 25544
- **24-Hour Volume Adjusted:** 25544
- **24-Hour Volume Actual:** 25544

**K & D Factor**

- **Westbound:** 0.73 or 7.3%
- **Eastbound:** 0.88 or 8.8%

Last Updated: 10/2014
When the full 24-hour volume is not available, use the count expansion factors in Exhibit 5-19 to estimate from shorter duration counts.

**Exhibit 5-19 Count Expansion Factors**

<table>
<thead>
<tr>
<th>Count Length (hours)</th>
<th>Expansion Factor</th>
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<tbody>
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<tr>
<td>14</td>
<td>1.18</td>
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<td>16</td>
<td>1.10</td>
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<tr>
<td>24</td>
<td>1.00</td>
</tr>
</tbody>
</table>

The D factor is calculated by dividing the highest 24-hour one-way volume by the two-way 24-hour volume.

Draw a link diagram of the study area. Label the K factors on one diagram and D factors on another diagram. Calculate average K factors between intersections. Links missing K or D factors (such as those using peak period counts) can be obtained (estimated) by averaging links with similar characteristics together in the study area. Divide the 30 HVs by the K factors to obtain the ADT on each directional link. Now sum the directional link ADTs to obtain two-way link ADTs. Now multiply the two-way ADTs by the D factor to obtain directional ADTs. The resulting splits may differ between the 30HV and ADT volumes.

ADT’s should be documented on a map-based figure on a link approach basis rather than showing individual turn movements.
Example 5-8  ADT Calculations

1. Label link diagram with K-Factors, average K-values between nodes:

   ![Diagram with K-Factors](image)

   (0.74+0.78) = 0.76
   (0.77+0.79) = 0.78

2. Divide 30 HV by average link K-value (Step 1) to calculate ADT, sum ADT:

   ![Diagram with 30th HV](image)

   30th HV: 1000 vph
   1000 / 0.076 = 13,158 ADT
   30th HV: 1200 vph
   1200 / 0.074 = 16,216 ADT

   ∑ 29,374

3. Label link diagram with count D-Factors, average D-values between nodes:

   ![Diagram with D-Factors](image)

   (0.46+0.48) = 0.47
   (0.50+0.44) = 0.47

4. Multiply ADT link sum (Step 2) by average D-value to calculate directional ADT:

   ![Diagram with Directional ADT](image)

   29,374 * 0.47 = 13,806 ADT
   29,374 * 0.53 = 15,568 ADT

5.7.1 Converting ADT to AADT

ADT can be converted to AADT by applying the seasonal factor (See Section 5.4) straight instead of using the inverse in the 30HV process. This will convert the ADT to an...
average value (May/October). Example 5-9 ADT to AADT Conversions shows the typical calculations.

**Example 5-9 ADT to AADT Conversions**

Counts used to create the ADT values from the previous Example 5-8 ADT Calculations, were taken October 8th in a location characterized by a summer trend. After review of the ATR Characteristic Table it is determined that there are no characteristic ATR’s that can be applied therefore, the Seasonal Trend Table must be used to convert the ADT to AADT.

1. Using the Seasonal Trend Table under Summer Trend, averaging the October 1st and 15th column, the factor is 0.9670.

2. Multiply the factor times by ADT to convert to AADT
5.8  Development of Volume-based Analysis Inputs

5.8.1  Existing Peak Hour Factors

Peak hour factors (PHF) are used to account for the non-uniformity of traffic flow within the peak hour by converting hourly volumes to peak flow rates associated with a selected interval of time within the peak hour. The most common interval of time selected for traffic analysis is the peak 15 minutes. In areas near capacity the peak 15-minute flow can cause up to several hours of congestion. This typically happens when the demand exceeds the available capacity of the transportation system resulting in “peak hour spreading”, which is the extension of the peak period caused by a system breakdown. Therefore, it is often essential that the transportation system be designed to accommodate the peak 15 minutes of the peak hour.

Peak hour factors should be applied in most capacity analyses in accordance with the HCM, which selected 15-minute flow rates as the basis for most of its procedures. It is especially critical to examine the peak 15-minute period when potential queue lengths may become an issue, and at locations with sharp peaking characteristics such as employment sites and locations with low peak hour factors (less than 0.90). Some alternate mobility standards do not use PHF’s where the volume-to-capacity standard is equal to or greater than 1. Alternate mobility standards procedures are discussed further in Chapter 10.

5.8.2  Calculation

The PHF is typically calculated using data from traffic counts. It is the traffic volume during the peak 60-minute period divided by four times the volume during the peak 15-minute period.

$$PHF = \frac{\text{Volume During Peak 60-Minute Period}}{4 \times (\text{Volume During Peak 15-Minute Period})}$$

Typical PHF values range between 0.80 and 0.98. Factors greater than 0.95 are indicative of high traffic volumes, while factors less than 0.80 occur in locations with high peak demand, (i.e. schools, factories with shift changes, venues w/ scheduled events). PHF’s calculated from actual traffic count data should always be used for analysis of existing conditions. For all applications other than sketch planning-level analysis, traffic count data should be obtained in 15-minute intervals, and one of the three methods for calculation and application of PHF’s described below should be followed. Each of the methods should be reviewed and the method that best represents the conditions should be used. In the following methods the system peak hour is first
selected, and PHF’s are calculated within that hour. For sketch planning-level analysis where traffic counts are not provided in 15-minute intervals, the HCM 2010 suggests the following defaults:

- 0.95 for urban freeways;
- 0.88 for rural freeways;
- 0.88 for 2-lane highways;
- 0.88 for multilane highways;
- 0.92 for interrupted flow facilities

**Method 1 - Intersection PHF:** This analysis method uses an intersection PHF to estimate peak 15-minute period equivalent hourly flow rates from the peak 60-minute period volumes. Intersection PHF is the preferred method for signalized intersections in the HCM 2010. The peak 15-minute period with the highest intersection total entering volume (TEV) should be used to determine the PHF for each intersection. The application of global PHF’s is generally not appropriate when count data is available. The intersection PHF is calculated as follows.

- **Step 1:** Determine the peak 15-minute period that has the highest intersection total entering volume (TEV).
- **Step 2:** Calculate the intersection PHF based on the time period determined in Step 1, by dividing the TEV peak 60-minute volume by four times the TEV occurring during the peak 15 minutes.
- **Step 3:** In the analysis, apply the intersection PHF from Step 2 to each movement peak 60-minute volume.

**Method 2 - Approach/Movement PHF:** As an option, in cases where unusual peaking occurs on individual approaches such as from a school or shift change, approach or movement PHF’s can be determined from the traffic count volumes. The peak 15-minute period with the highest intersection TEV should be used to determine the PHF’s. PHF’s are calculated for each approach or movement as follows. If an approach or movement PHF is calculated to exceed 1, entering a value of 1.00 will ensure a slightly conservative analysis.

- **Step 1:** Determine the peak 15-minute period that has the highest intersection total entering volume (TEV).
- **Step 2:** Calculate the PHF for each approach or movement based on the time period determined in Step 1 by dividing the approach peak 60-minute volume by four times the approach or movement peak 15-minute volume.
- **Step 3:** In the analysis, apply the approach or movement PHF’s from Step 2 to the approach or movement peak 60-minute volumes (usually calculated by the analysis software).

**Method 3 – Direct Entry of 15-min Volumes:** As an additional option in cases where unusual peaking occurs on individual approaches, the traffic count volumes for all movements that occur during the single peak 15-minute period can be used
directly in software that multiplies the peak 15-minute period volumes by a factor of four. If this method is used both the actual 60-minute period hourly volumes and the equivalent peak 15-minute hourly flow rates should be shown on the Existing Traffic flow diagrams, and clearly labeled to avoid confusion.

- **Step 1**: Determine the peak 15-minute period that has the highest intersection total entering volume (TEV).
- **Step 2**: For the time period determined in Step 1, enter the peak 15-minute volumes directly in the software.
- **Step 3**: Select software analysis procedure based on the peak 15-minute period.
- **Step 4**: On the flow diagrams show and clearly label both the actual 60-minute period hourly volumes and the equivalent peak 15-minute hourly flow rates to avoid confusion

### 5.8.3 Future Conditions PHF

Because traffic flow patterns may change over time and future conditions cannot be directly measured, analysis of future years should incorporate the following default values by approach for the PHF unless better information is available:

- 0.85 for minor street inflows and outflows
- 0.90 for minor arterials
- 0.95 for major streets

Engineering judgment must be used in the selection of PHFs for future years. In cases where the existing PHF is higher than the default value for the future PHF, it may be appropriate to retain the existing value for the future year, as PHFs do not typically decrease as traffic volumes and congestion increase. Likewise for areas that have low existing peak hour factors, using the future PHF default values could produce results that would underestimate the future traffic conditions. For areas with aggressive traffic demand management strategies contained in an adopted plan, a different PHF (to reflect spreading of the demand) may be used for future year analysis if agreed to by ODOT during the scoping process. For areas with pronounced peaking characteristics, such as industrial sites and schools, PHFs lower than the default values listed above should be considered.

**Revising PHF for Future Year**

In areas where alternative mobility standards are in place and the volume to capacity ratios are at or exceed 1.0 (capacity), PHF’s may be assumed to be equivalent to 1.0.

### 5.8.4 Truck Factor Development and Documentation

Most deterministic analyses will require truck percentages. These can be developed directly from the counts or from the TruckSum spreadsheets. Truck percentages are made up of the bus, single unit, single trailer, and multiple trailer vehicle classifications. Exhibit 5-20 shows a typical intersection count with the necessary fields highlighted.
### Exhibit 5-20 Truck Classifications to use in an intersection count

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<th>Trp. Trailer Trucks</th>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15:00</td>
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<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>51</td>
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<tr>
<td>15:15</td>
<td>32</td>
<td>11</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>43</td>
</tr>
<tr>
<td>15:30</td>
<td>34</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>46</td>
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<tr>
<td>15:45</td>
<td>33</td>
<td>10</td>
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<td>0</td>
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<td>0</td>
<td>43</td>
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<tr>
<td>16:00</td>
<td>34</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>43</td>
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<tr>
<td>16:15</td>
<td>36</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>16:30</td>
<td>36</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>47</td>
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<tr>
<td>16:45</td>
<td>36</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>47</td>
</tr>
</tbody>
</table>

This is the peak hour. This line will need to be “pulled” from each sheet for each direction and movement.

In the count shown above, truck volumes need to be added up for this movement (S-W) for the system peak hour. To calculate the truck percentage for the northbound approach from the south leg, sum the trucks from the S-W, S-N and S-E movements and divide by the total entering volume from the south leg. To calculate the percent trucks for each movement, divide the truck volume by the total volume for that movement.

**Example calculation for Northbound Truck % on west leg (Note: Don’t forget to include buses)**

\[
NB \text{ Truck}\% = \frac{\sum S\rightarrow N_{\text{truck}} + \sum S\rightarrow E_{\text{trucks}} + \sum S\rightarrow W_{\text{trucks}}}{\text{All NB}_{\text{veh}}} = \frac{22}{1184} = 0.01858 = 1.86\%
\]

**Example calculation for S-W Truck %**

\[
S\rightarrow W \text{ Truck}\% = \frac{\sum S\rightarrow W_{\text{truck}}}{\text{All } S\rightarrow W_{\text{veh}}} = \frac{(1 + 1 + 5)}{626}
\]

Some analysis tools have different splits than just a “percent trucks.” Highway Capacity Software (HCS) has bus and recreational vehicle splits. Buses can be obtained from the count directly but the recreational vehicle split has to be ignored as ODOT does not specifically call out this vehicle type. Once the appropriate classifications to use are identified, the values are summed up by intersection approach (or movement if desired).

Truck percentages can also be determined from the TruckSum Spreadsheets (if individual bus splits were not needed). The TruckSum spreadsheets split out trucks into medium and heavy categories. Medium trucks are two-axle single unit and buses while heavy trucks are the three-axle and greater single unit and all combination vehicles. See Exhibit 5-21 for identification of the peak hour medium and heavy percentages. The medium and heavy percentages in TruckSum can be summed to determine the final truck percentage to be used in the analysis.

**Exhibit 5-21 TruckSum vehicle classifications**

<table>
<thead>
<tr>
<th>PHV Trucks Only</th>
<th>NORTH LEG</th>
<th>EAST LEG</th>
<th>SOUTH LEG</th>
<th>WEST LEG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>volume</td>
<td>factor</td>
<td>volume</td>
<td>factor</td>
</tr>
<tr>
<td>All factors apply</td>
<td>Medium</td>
<td>0</td>
<td>0.000</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Heavy</td>
<td>0</td>
<td>0.000</td>
<td>Heavy</td>
</tr>
</tbody>
</table>

Sum the medium and heavy trucks (expressed as decimals) together to obtain the truck percentage on an intersection leg. For the east leg, the total truck percentage is 3.7% medium trucks and 0.8% heavy trucks for a total of 4.5%.

Generally, the truck percentages are entered into analysis software and used as is. However, in some projects and plans where truck movement is a large concern (or part of the project need) the truck percentages will need to be split out by movement and multiplied by the movement volume to determine the actual volume of trucks. This truck volume will need to be balanced as any other volume set and the actual truck percentages re-figured so the analysis is accurate. See Example 5-10 Actual Link Truck Factors.

Just using approach volumes would create areas where truck volumes would be inconsistent either by having trucks “disappear” or “appear” in the middle of a link or between links that would not make sense.
Example 5-10  Actual Link Truck Factors

When truck movements are of concern on a project, it may be necessary to balance the truck volumes. This requires the truck percentages from the counts as calculated above, as well as balanced 30 HV volumes (see Exhibit 5-12). Truck volumes are not rounded as the final outputs desired are percentages. The Figure below shows the truck percentages that were calculated from the intersection counts and the balanced base year volumes.
Step 1: Calculate the 30HV Truck volumes by multiplying the calculated truck percentage and the 30HV balanced total volume. Sample calculations for the Target.
intersection are shown below.

Sample Truck Volume Calculations for the Target intersection

\[ \text{Truck Vol} = \text{Truck \%} \times \text{Movement}_{\text{Total Vol}} \]
\[ N \rightarrow S_{\text{truck vol}} = 0.068 \times 1255 = 85.3 = 85 \text{ Trucks} \]
\[ N \rightarrow W_{\text{truck vol}} = 0.021 \times 105 = 2.2 = 2 \text{ Trucks} \]
\[ S \rightarrow N_{\text{truck vol}} = 0.066 \times 1840 = 121.4 = 121 \text{ Trucks} \]
\[ W \rightarrow S_{\text{truck vol}} = 0.019 \times 190 = 3.61 = 4 \text{ Trucks} \]

Step 2: After calculating all raw truck volumes, they must now be balanced. Balance the truck volumes using the same procedure used to balance a network. In this example, the difference was split between Nels Anderson and Robal Rd. Then holding Robal Rd constant the volumes at Target were proportionally adjusted to balance the remainder of the network.

Step 3: Once the truck volumes have been balanced, a new balanced truck percentage must be calculated by dividing the balanced truck volume by the total balanced volume for each movement. Sample calculations for the balanced truck percentages for the Target intersection are shown below.

Sample Calculated Truck Percentages

\[ \text{Truck \%} = \frac{\text{Balanced Truck Vol}}{\text{Movement}_{\text{Balanced Total Vol}}} \]
\[ N \rightarrow S_{\text{truck \%}} = \frac{95}{1255} = 0.0756 = 7.6\% \]
\[ N \rightarrow W_{\text{truck \%}} = \frac{2}{105} = 0.190 = 2.0\% \]
\[ W \rightarrow S_{\text{truck \%}} = \frac{5}{190} = 0.0263 = 2.6\% \]
\[ S \rightarrow N_{\text{truck \%}} = \frac{121}{1840} = 0.0657 = 6.6\% \]

The figure below shows the balanced truck volumes and the new calculated truck percentages. NOTE: The overall volumes do not change. The overall network is still balanced, no balanced volumes were changed. Only the truck volumes were changed and percentages adjusted to reflect the balancing of the truck volumes.
Balanced Truck Volumes and Percentages

xxx = Balanced Truck Volume
[xx] = Balanced Truck %
5.8.5 Analysis Input Documentation

It is recommended that the truck percentages for each approach be put on a figure for future reference and for ease of entering into software packages. On the same figure, approach PHF’s, and K-factors should also be added. This will streamline the entering of data plus make it an easy reference for the preliminary signal warrant process (which uses K-factors). See Exhibit 5-22 for a sample figure.
6  FUTURE YEAR FORECASTING

6.1  Purpose

Design Hour Volumes (DHV) are used for ODOT planning and project level analyses. These are based on the existing year volumes developed in Chapter 5. The DHV is generally defined as the future year 30\textsuperscript{th} highest hour (30 HV). Depending on scope and complexity of the analysis, different future methodologies are needed from simple historical trends to complex travel demand models. This chapter will outline the procedures for developing DHV and future Average Daily Traffic (ADT) used for ODOT planning and project level analysis. In addition, the processes for developing pavement design traffic volumes are also discussed. Future design hour volumes are a key input in following analysis steps and methodologies explored in later chapters. For more details on many of the methods in this chapter also refer to NCHRP Report 765.

6.2  General Considerations

The DHV typically controls the design of the project or represents a planning horizon year such as in a Transportation System Plan (TSP). These volumes can either be for no-build or build conditions.

6.2.1  Rounding

The DHV’s need to be rounded before the network is balanced. The traffic volumes are not that precise to go down to one vehicle, especially considering projections that may be out 20 plus years. Balancing the network is easier if the network is not down to the individual vehicle. Future years five or ten years out should be rounded to the nearest five vehicles. Twenty-year future volumes can either be rounded to the nearest five or ten vehicles. Volumes less than five vehicles should use the “<5” symbol instead of using zero.

6.2.2  Need for Balancing

The DHV networks need to be balanced, even more so than with the existing conditions. Small differences in the existing year can become large differences in future years. Future planned changes in the network or land use remove the ability to use relationships between the obtained traffic counts as multiple growth rates are likely in effect. For areas that have travel demand models, balancing is critical to the success of post-processing. Refer to Section 5.3.2 for additional details on the balancing techniques.
6.2.3 Documentation

It is critical that after every step in the DHV process that all of the assumptions and factors are carefully documented, preferably on the graphical figures themselves. While the existing year volume development is relatively similar across types of studies, the future year volume development can go in a number of different directions with varying amounts of documentation needed. Growth factors, trip generation, land use changes are some of the items that need to be documented. If all is documented then anyone can easily review the work or pick up on it quickly without questioning what the assumptions were. The documentation figures will eventually end up in the final report or in the technical appendix. The volume documentation should include:

- Figures/spreadsheets showing starting volumes (30 HV)
- Figures/spreadsheets showing growth factors, cumulative analysis factors, or travel demand model post-processing.
- Figures/spreadsheets showing unbalanced DHV
- Figure(s) showing balanced future year DHV. See Exhibit 6-1
- Notes on how future volumes were developed:
  - If historic trends were used, cite the source.
  - If the cumulative method was used, include a land use map, information that documents trip generation, distribution, assignment, in-process trips, and through movement (or background) growth.
  - If a travel demand model was used, post-processing methods should be specified, model scenario assumptions described, and the base and future year model runs should be attached.
6.3 Determining the Future Year(s)

The analyst should work with the region project leader/planner ideally during the scoping phase to determine the future year before beginning any future year forecasting. The future year determination is typically documented in a methodology and assumptions memorandum in addition to the overall scope of work/work plan.

The design hour that is used for many projects is 20 years after the year of project opening. It can be a considerable period of time between when the traffic analysis is
completed and when the project is completed. Environmental documents (EA/EIS), Final design and approvals, permits, environmental clearances, right-of-way purchases, and funding availability/STIP programming, may add anywhere from two to five years before a project starts the construction phase. Depending on the project complexity, construction may take from one to many years with phases.

In planning, a 20-year horizon is typically used when evaluating transportation needs and solutions. Future horizon years should be, at a minimum, 20 years after the estimated plan completion/adoptions year. This is typically two years after the plan starts. For refinement and other similar plans, the horizon year should be 25 to 30 years out, which would increase the life of the plan, especially if the project development process does not directly follow. Existing policies may determine the planning horizon such as the Transportation Planning Rule. Transportation Impact Analysis (or Study) (TIA/TIS) horizon year procedures are provided in the Development Review Guidelines.

Many times, additional future years are necessary beyond just the typical 20-year future. In projects, the year of opening (build year) plus interim future years may be needed to support project phases or environmental air/noise/energy analyses. For example, if a project base year is 2011, its build year could be 2014, a 10-year future year would be 2024, and the project future (design) year would be 2034. This would mean three separate future years to be developed by the analyst.

For TSP’s, build years are not typically done, but there may be interim years to support Urban Growth Boundary (UGB) expansions or to maintain consistency with adopted plans. For example, a TSP refinement plan with an existing conditions year of 2011 may have a 2025 year to stay consistent with the earlier TSP, but would still have a 2033 planning horizon year for a 20-year life beyond adoption.

Refinement plans that will be directly supporting later project development efforts will typically have year of opening (build year) future years. Planning efforts with three or more years between the plan and a start of a following project generally do not need build year analyses as the traffic analysis will likely need to be redone anyway.

Care should be taken to not extend the horizon year beyond the normal accuracy level. The limits of detailed analysis go out to about 30 years; anything beyond this is an estimation/approximation. If a travel demand model is used, five years is the limit of extrapolation beyond the model future year. If a project/plan requires more than five years, then the model needs to be updated, which typically involves creating a new future year (reference year) for the model. Contact TPAU or modeling staff in Metro for the Portland metropolitan area, Mid-Willamette Valley Council of Governments (MWVCOG) for the Salem-Keizer metropolitan area, and the Lane Council of Governments (LCOG) for the Eugene-Springfield metropolitan area immediately if a model update seems necessary. In some cases, if the travel demand model area is slow-growing, the extrapolation limit can be longer.
6.4 Growth Patterns

Different growth pattern types can all be present in a study area. There can be areas of fast growth (i.e. next to an urban fringe interchange), steady growth, or slowing growth (infill). Growth can be negative over the short or long term (i.e. recessions, declining industries, migration, or competition with nearby areas). The analyst must have knowledge of the study area in order to make the proper future year assumptions. The typical long-term growth curve can be a combination of three conditions on the overall timeline (see Exhibit 6-2). For instance, for the first 5 years the growth is exponential (compound), the next 10 years is linear, but the last 5 years the growth is declining (logistic). Growth curves can also be estimated by using a combination of differently sloped lines (piecewise, such as linear with different growth rates).

Exhibit 6-2 Traffic Volume Growth Types

- **Exponential Growth (Compound)** – An exponential increase in traffic volumes, typically associated with brand new growth in an area that has plenty of land and road capacity. Exponential growth predicts the future volume for a given year based on a percentage of growth from the previous year. This is typically limited to five years or less. Use of an exponential curve over a prolonged period can seriously overestimate future growth.

\[
\text{Future Volume} = \text{Base Year Volume} \cdot (1 + \text{Growth Rate})^{\text{Number of Years}}
\]
\[ \text{Volume}_{FY} = \text{Volume}_{BY} \times (1 + Gr)^{(FY-BY)} \]

Where:
- \( Gr \) = Geometric growth rate
- \( FY \) = Future year
- \( BY \) = Base Year

This method is not generally recommended unless it can be supported by data.

- **Linear Growth** - Linear increase in traffic volumes over time. This method assumes a constant amount of growth in each year and does not consider a capacity restraint. Areas that have or will likely have capacity constraints should use the declining growth curve shown below as long as there is sufficient evidence of a potential change. In many cases a linear growth rate is used since often there is insufficient data to support use of a more specific type of curve.

  Future Volume = (Linear Growth Rate x Number of Years) + Base Year Volume
  \[ \text{Volume}_{FY} = G_{\text{Linear}} \times N + \text{Volume}_{BY} \]

  Where:
  - \( G \) = Linear growth rate (volume)
  - \( N \) = Years beyond the base year
  - \( FY \) = Future year
  - \( BY \) = Base Year

- **Declining Growth (Logistic)** - Growth tapers off as land approaches built-out status and capacity of roadways. Future growth is mainly contributed by growth in background (through) traffic.

  \[ V = \frac{V_0C}{V_0+(C-V_0)e^{-rt}} \]

  Where:
  - \( t \) = time (years)
  - \( V \) = the volume at time \( t \)
  - \( V_0 \) = the initial volume at time 0
  - \( C \) = capacity (maximum sustainable volume)
  - \( r \) = rate of volume growth when volume is very small compared to the capacity.

  \( C \) (capacity) is defined as service flow or saturation flow per lane. For interstates, multilane highways, and two-lane highways, it would be the maximum service flow at level of service (LOS) E. Signalized arterials would start with the ideal saturation flow which is reduced to the actual saturation flow with a few basic parameters as shown in Equation 18-5 in the 2010 Highway Capacity Manual (HCM). Alternatively, the capacity estimator in the Highway Design Manual (HDM) Section 10.12 can be used and then use a characteristic K-factor to convert to an hourly value.
or can leave everything as ADTs (so C is an ADT-based value instead of hourly).

Once a “C” is found, then use the FVT/model to project linearly as a test to see if C is exceeded within the design/planning horizon or close (no more than 30-40 yrs.). If volumes exceed or get close to C then this curve would be used instead of linear. This would be the curve to use for future no-build. For the build, a determination would have to be made of the potential change in C. A significant increase in capacity may result in a linear relationship while a small change may affect it only a little in which the same curve could be used but with a higher C value. Use of this curve may indicate that there is peak spreading effects in play (see Chapter 8).

Estimates for rate (r) are done for the linear portion of the curve, so they can be based from the Future Volume Tables (see Section 6.5) or from a travel demand model. Growth rates have to be large enough over time (t) to be affected by the capacity value so the curve will flatten out. Small growth rates may never reach the capacity level so the curve will remain linear.

Exhibit 6-2 shows the three types of curves, starting off as exponential (compound), transitioning to linear, and then to declining growth.

### 6.5 Historical Trends

The historical trends method uses traffic volumes from previous years to project future volumes. This method assumes that the future growth trend will be similar to the historical trend. It is used mainly in rural or small urban areas where significant growth is not anticipated. Current and future year traffic volumes are available in the Future Volumes Table webpage. More detail on the Future Volume table structure is in Section 5.5. If desired, different growth curves can be used on historical trend data if the overall trend does not seem to be linear. Most of the time, the differences between alternate growth curves and the linear growth curve are small and not worth the effort to create the trend.

Certain areas may be in long-term decline with negative growth rates. It is not generally appropriate to forecast a negative linear growth rate as many areas could result in a zero or an unrealistically low volume before the horizon year is reached. A conservative method is to assume no growth (base year = future year). It may be warranted to do a detailed investigation of the past trends to see if a different growth curve should be used. TPAU has data on past trends (20+ years) on the state highway system and can help with these types of issues.

Recessions/economic downturns can cause short-term dips in growth trends. It is possible to have a short-term low, none, or negative growth while still maintaining a long-term positive growth. Short-term recessions have little effect on a long-term analysis. Longer term recessions or slow growth periods need to be reviewed to make sure that the analysis is not starting from the low point (could underestimate volumes) or is projecting off the high point (could overestimate future volumes). These kinds of situations typically
require a sensitivity or “bookend” type of analysis where both conditions are analyzed. While the terms, “growth rates” and “growth factors” appear to be interchangeable, they are not. Growth rates are decimal percentages versions of the yearly percentage growth. For example, if the growth rate is 2.5% per year, this would be 0.025. Growth factors are used in calculations and may represent one or more years (i.e. 1.025). Adding a “1” will convert a growth rate into a factor. It is important to remember when to convert or not. When converting multiple year growth factors into a single growth rate, make sure to remove the “1” before dividing (See Example 6-1). The basic growth rate and factor equations are shown below:

Growth Rate = \((\text{Growth Factor} - 1) / \text{Number of Years}\)

Growth Factor = \(1 + (\text{Growth Rate} \times \text{Number of Years})\)

**Example 6-1 Future Volumes Using Historic Trend**

In this example, the forecast 20-year traffic volumes are developed based on historical counts.

For the Lava Butte ATR (#09-003) located on US 97 at MP 142.41, The following table shows the 1999 traffic volume, Year 2019 traffic volume and the R-squared value.

<table>
<thead>
<tr>
<th>Hwy#</th>
<th>DIR</th>
<th>MP</th>
<th>Description</th>
<th>1999</th>
<th>2019</th>
<th>RSQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1</td>
<td>141.01</td>
<td>.01 miles S of Badger Rd</td>
<td>28400</td>
<td>47200</td>
<td>0.9212</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>141.52</td>
<td>.22 miles S of Murphy Rd</td>
<td>24000</td>
<td>41400</td>
<td>0.656</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>142.21</td>
<td>ATR 09-003 - Lava Butte</td>
<td>19600</td>
<td>32000</td>
<td>0.9338</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>143.47</td>
<td>.01 miles S of Galen Baker Rd</td>
<td>14200</td>
<td>23600</td>
<td>0.7328</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>153.09</td>
<td>.01 miles S South Century Dr</td>
<td>9600</td>
<td>11100</td>
<td>0.5788</td>
</tr>
</tbody>
</table>

RSQ = R-squared is an indication of data fitting to a line.

Based on the data above, the 20-year growth factor would be 1.63 (32,000/19,600). Assuming linear growth in the future, the annual growth rate would be \((1.63 - 1.0) / 20 = 0.032\), or 3.2%. The R-squared value of 0.9338 is acceptable, indicating a strong relationship. To convert the 1997 30 HV from this example to a 2019 DHV, the 1997 30 HV is multiplied by the 20-year growth factor, with an additional two years of growth added to this.

\[
2019 \text{ DHV} = 1997 \text{ DHV} \times (20-\text{Year Growth Factor} + 2 \times \text{Annual Growth Rate}) = 112 \text{ vph} \times (1.63 + (2 \times 0.032)) = 112 \text{ vph} \times 1.694 = 190 \text{ vph}
\]

When dividing the estimated future year volume by the most recent count volume it is important to note the numeric difference between the two years. In the example above, a
20-year growth rate was used between 1999 and 2019. Other highways may have been last counted in 1997 or 1998. This would mean that a 21- or 22-year growth rate should be applied. Dividing the total growth by 20 years would, in these cases, overestimate the growth rate.

For areas with calculated multiple growth factors, discard any with an R-squared value less than 0.75. Remaining growth factors that are within 1 or 2 percent can be averaged.

6.6 Trip Generation

Vehicle trips generated by future development are estimated using the Institute of Transportation Engineers (ITE) Trip Generation Manual (if manual trip calculations are used) or a travel demand model for larger studies (see Section 6.10 as well as the Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012). ITE trip generation rates are based on a database of trip generation studies conducted in the U.S. These studies collected data at existing land use generators including driveway vehicle counts and land use characteristics such as floor area size, number of parking spaces, etc. For each land use type, models were developed from the counts and the characteristics of the land uses, resulting in trip rates or equations for various time periods. ITE trip generation should not be confused with travel demand model trip generation, which is based on household surveys of person trips rather than vehicle counts. The following is a summary of ITE trip generation manual procedures. The manual itself should be consulted as part of any trip generation estimation process.

Trip generation rates are typically average values. There can be a large difference between the local trip generation potential and the national average values in the ITE manual. For common uses, such as single-family homes, gas stations, and shopping centers there have been plenty of studies done over the years that make up the research that is the basis for the trip generation rate or equation. Many land uses such as some commercial types have only a few studies, so the data should be used with caution. It is not uncommon for the standard deviation to exceed the averages if only a few studies exist. The ITE Trip Generation manual has guidance and cautions on the data limitations, what the assumptions/definitions for each land use are, procedures for use and conducting local trip generation studies if necessary.

Note that trip generation software such as Trip Generation by Trafficware is not standalone as it does not have the necessary background information on each land use like the manual does. The software is just a calculator tool that needs to be used in conjunction with the ITE Trip Generation Manual.

Trip generation may be composed of three basic types of trips: new/primary trips, pass-by trips, and diverted linked trips. New or primary trips are those trips that are new to the study area specifically attracted to or produced by a land use. Pass-by trips already exist along the roadway fronting the site, but now access the site before continuing on. Diverted linked trips exist in the study area but must divert onto local roads in order to access the site. Each of these types of trips is illustrated in the following Examples.
External versus Internal Trips

ITE Trip Generation rates are based primarily on single-use, free-standing sites. There are some exceptions such as shopping centers. Multi-use or mixed use developments may have interactions such as where some trips may occur internal to the site, whether by motor vehicle or by walking. The total external trip generation of these sites may be less than the sum of the individual stand-alone trip rates calculated using the ITE trip generation rates. ITE Trip generation Manual provides a methodology to estimate this effect, called internal capture (Volume 1, Trip Generation Handbook, Chapter 7 Multi-Use Development). This is a percentage reduction applied to the sum of the individual land use trip generation.

Other Considerations

The ITE trip rates are based on data collected primarily at suburban locations with little or no transit service, nearby pedestrian amenities, or travel demand programs. The ITE Trip Generation Manual suggests the user may modify trip generation rates to reflect the presence of public transportation, Transportation Demand Management (TDM) measures, enhanced pedestrian and bicycle trip making opportunities, or other special characteristics of the site or study area. The Transportation Planning Rule (TPR) contains such a provision. OAR 660-012-0060 (6)(a) states that a ten percent reduction in ITE trip generation rates (that do not specifically account for mixed use effects) shall apply for proposed land use plan amendments which consist of mixed-use, pedestrian-friendly development and prohibit uses which rely solely on auto trips, such as gas stations, car washes, storage facilities, and motels.

ITE encourages users to supplement trip generation analysis with local data where practical. If local studies are conducted they should follow the ITE Trip Generation Manual guidelines for conducting a trip generation study.

Example 6-2 Trip Generation

A supermarket with floor area of 30,000 square feet is proposed as a new development within a suburban area as shown below. The proposed use is adjacent to an east-west arterial and located to the west of a north-south arterial. It is desired to estimate the trip generation for the site.
From the ITE Trip Generation Manual, 9th Edition, Volume 3, a supermarket is assigned Land Use Category 850. This is only a single land use so neither the internal trip capture reductions apply nor does the TPR mixed use reduction. The trip rates or equations, as appropriate, for this land use type are obtained from the manual and shown below. The manual provides trip generation data for certain days of the week such as the average weekday, Saturday and Sunday, as well as for specific hours of the day, such as the peak hour of the adjacent street traffic, or the peak hour of the generator. In this example the peak hour of adjacent street traffic is used. Average percentages of trip entering and exiting the site are also provided. Calculations are performed either in a spreadsheet or using commercial software. The resulting trips are typically summarized in a table as shown below. These represent all motor vehicle trips with origin or destination external to the site.

### Site Trip Generation Summary

<table>
<thead>
<tr>
<th>ITE Land Use</th>
<th>Trip Rate or Equation</th>
<th>Enter</th>
<th>Exit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM&lt;sup&gt;3&lt;/sup&gt; 850</td>
<td>3.40X</td>
<td>63 (62%)</td>
<td>39 (38%)</td>
<td>102</td>
</tr>
<tr>
<td>PM&lt;sup&gt;3&lt;/sup&gt; 850</td>
<td>Ln(T)=0.74Ln(X)+3.25</td>
<td>163 (51%)</td>
<td>157 (49%)</td>
<td>320</td>
</tr>
<tr>
<td>Average Weekday 850</td>
<td>102.24X</td>
<td>1,534 (50%)</td>
<td>1,534 (50%)</td>
<td>3,067</td>
</tr>
</tbody>
</table>

<sup>1</sup> ITE Trip Generation 9<sup>th</sup> edition  
<sup>2</sup> X = independent variable (thousand square feet of floor area) = 30.0 ksf  
<sup>3</sup> Peak hour of adjacent street traffic

---

For commercial/retail types of land uses, peak hour site trips need to be further subdivided into new (primary), pass-by, and diverted linked trips. The ITE Trip Generation Handbook may have estimates of those percentages. These ITE estimates vary by land use size and other characteristics, so the chosen estimates should be close to the size of the proposed land use. Ideally, there will be more than one applicable estimate which can be averaged together. If not, other studies may be used or conducted, along with engineering judgment.

In this example, the ITE Trip Generation Handbook lists studies of average PM peak hour pass-by and diverted linked trip generation rates for supermarkets. Average rates are taken from data points where both pass-by and diverted linked rates are provided. Select those locations with size near that of the subject site. There are five study locations near 30,000 square feet in size. Of those, four locations provide both pass-by and diverted linked trip percentages. The average of these four sites is used. The average pass-by percentage is \( \frac{32 + 44 + 19 + 28}{4} = 31\% \). The average diverted linked trip percentage is \( \frac{20 + 27 + 45 + 32}{4} = 31\% \). The average primary trip percentage is \( \frac{48 + 29 + 36 + 40}{4} = 38\% \). The number of PM peak hour trips by type are then calculated and displayed in a table as follows.

### Site PM Peak Hour New, Pass-By, and Diverted Linked Trips

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
<th>Enter</th>
<th>Exit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>38%</td>
<td>62</td>
<td>60</td>
<td>122</td>
</tr>
<tr>
<td>Pass-by</td>
<td>31%</td>
<td>51</td>
<td>49</td>
<td>100</td>
</tr>
<tr>
<td>Diverted Linked</td>
<td>31%</td>
<td>51</td>
<td>49</td>
<td>100</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100%</td>
<td>164</td>
<td>158</td>
<td>322</td>
</tr>
</tbody>
</table>


6.7 Trip Distribution

Traffic generated by a future development is distributed from the site based on existing origin-destination (O-D) study data if available, traffic count patterns for nearby similar land uses, local knowledge, or use of a travel demand model for larger studies (see Section 6.10 as well as the [Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012](#), together with engineering judgment. Use of a travel demand model typically involves creation of the land use in a model scenario then having a select-zone analysis performed to determine in/out percentages from the site.

Example 6-3 Trip Distribution

The existing PM peak hour volumes in the study area are shown below. All of the site trip adjustments will be added or subtracted from these values.

Background PM Peak Hour Traffic Volumes

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Continuing from the previous example, the distribution of new trips to/from the proposed supermarket has been determined based on existing count patterns and engineering judgment and is shown in the diagram below.

**PM Peak Site Distribution of New (Primary) Trips**

The distribution of pass-by and diverted linked trips should also be determined if present. Typically pass-by and diverted linked trips are based on traffic counts or travel demand models. In this example, the pass-by trip percentages are assumed to be proportional to...
the existing east-west PM peak hour directional volume of traffic on the adjacent roadway, as shown below.

Adjacent roadway volume both directions = 340 + 620 = 960 vph.
Westbound proportion = 340 / 960 = 0.35
Eastbound proportion = 620 / 960 = 0.65

Existing PM Peak Distribution of Site Pass-by Trips

The diverted linked percentages in this example are assumed to be proportional to the north-south PM peak hour directional volume on the non-adjacent roadway, as shown in the next diagram.
6.8 Trip Assignment

Traffic distribution to and from a future development is assigned to specific roadways either manually or using a travel demand model for larger studies (see Section 6.10 as well as the Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012). To create the trip assignment, apply the percentage distribution to the trip generation for the assignment of new, pass-by and diverted linked site trips. Summing up the background, new, pass-by and diverted linked trips results in the final total trip assignment.

The assignment of each of the components of site trips (primary, pass-by, and diverted linked) should be calculated and displayed on separate flow diagrams. Calculations are typically performed in a spreadsheet or with a specific software application such as Vistro.

Example 6-4 Trip Assignment

The assignment of new (primary) trips for each turning movement is calculated by multiplying the previously determined number of directional new (primary) trips (trip generation) by the new (primary) distribution percentage applicable to that movement.

Sample calculation for eastbound to northbound left turn movement at the nearby intersection:
This movement is outbound from the site.
Trip generation of outbound new (primary) trips = 60
Trip distribution of outbound new (primary) trips = 10 percent
Trip assignment = 60 x 0.10 = 6 PM peak hour new (primary) site trips

**Assignment of PM Peak New (Primary) Site Trips**

<table>
<thead>
<tr>
<th>Land Use</th>
<th>New Site Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>48</td>
</tr>
<tr>
<td>50</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
</tr>
</tbody>
</table>

The assignment of pass-by trips for each turning movement is calculated by multiplying the previously determined number of directional pass-by trips (trip generation) by the pass-by distribution percentage applicable to that movement.

Sample calculation for westbound right turn movement from the adjacent roadway onto the site driveway:
- This movement is inbound to the site.
- Trip generation of inbound pass-by trips = 51
- Trip distribution of inbound pass-by trips = 35 percent
- Trip assignment = 51 x 0.35 = 18 PM peak hour pass-by site trips

Note that at the intersection of the adjacent roadway with the site driveway, through movement pass-by trips will have negative values, since they turn into the site instead of traveling through.

Also note that beyond the site driveway intersection, pass-by trips are zero. Pass-by trips do not add new trips to the system; they only change turning movement volumes at the site driveway(s).
The assignment of diverted linked trips for each turning movement is calculated by multiplying the previously determined number of directional diverted linked trips (trip generation) by the diverted linked distribution percentage applicable to that movement.

Sample calculation for northbound to westbound left turn movement from the non-adjacent roadway to the adjacent roadway:

- This movement is inbound to the site.
- Trip generation of inbound diverted linked trips = 51
- Trip distribution of northbound diverted linked trips = 57 percent
- Trip assignment = 51 x 0.57 = 29 PM peak hour diverted linked site trips

Note that at the intersection of the non-adjacent roadway with the adjacent roadway, northbound and southbound through movement diverted linked trips will have negative values, since they turn onto the adjacent roadway instead of traveling through.
Assignment of PM Peak Diverted Linked Trips

Each of the components of site trips are then summed for each vehicle movement and displayed in a flow diagram of total site trips as shown below.

PM Peak Total Site Trip Assignment

The total site trips are then combined with Background Traffic to create Background plus Site trips as shown below.
6.9 **Travel time-based Trip Assignment**

Traffic distribution to and from a future development is assigned to specific roadways either manually or using a travel demand model for larger studies (see Section 6.10 as well as the [Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012](#)).

Future development trip assignment is often made based on shortest path distance or travel time. Shortest path travel time in some cases may be approximated using segment lengths and posted speeds. However, this method does not account for intersection delay, which can be a significant component of total travel time in some situations. The following methodology identifies path travel times inclusive of intersection delay.

In this method, for a specified origin and destination, competing O-D paths are evaluated iteratively by assigning trips, calculating resulting nodal delay values, computing overall travel times, and repeating the process until the competing paths have roughly the same travel time. It should generally be assumed that if travel times are within 20%, there will be some split of the site trip assignment. If the travel time difference exceeds 20%, all of the site trips can generally be assigned to the shortest travel time path. If the travel time difference is less than 10%, an equal split of site trips can be assumed. The end result is the number of site trips assigned to each route.

Travel time on the paths is the sum of the travel time on links, based on link distance and posted speed, and control delay at intersections, based on deterministic analysis results.
such as using HCS or Synchro. Note that this method assumes relatively uncongested conditions.

**Analysis Steps**

1. Develop background traffic volumes.
2. For the initial site assignment, assign 100% of site trips to the shortest distance path.
3. Add the site trip assignment in Step 2 to the background volumes to obtain initial Total Traffic volumes.
4. For each alternative O-D path and direction (inbound or outbound from the site) being studied,
   a. Calculate segment travel times using posted speed and link lengths.
   b. Using initial Total Traffic volumes, apply HCM 2010 methodology to calculate delays for the movements along the path that pass through stop-controlled or signalized intersections.
   c. Sum the segment travel times and delays from Steps 2a and 2b to determine the total travel time for each path. Identify the path with the shortest travel time.
   d. If the shortest distance path travel time is significantly shorter than the next competing path, the site trip assignment is complete (100% of site trips are assigned to the shortest distance/travel time path).
   e. If the shortest distance path travel time is close to or greater than the travel time of the next competing path, further iterations are required.
5. Re-assign some proportion of the site trips to the shortest travel time path identified in step 2c. Using this site trip assignment, sum with Background Traffic to develop second iteration Total Traffic volumes.
6. Repeat Steps 2b and 2c using the revised iteration of Total Traffic volumes developed in Step 5b. Incrementally re-assign a proportion of site trips until each path is equal in travel time. The site trip assignment is then complete.

The following example illustrates this method.

**Example 6-5 Estimating Trip Assignment Based on Travel Time**

A land development is proposed near a state highway. The site is located near the unsignalized intersection of Main Street at Oak Street, as shown below. There are two potential paths for outbound site trips from the development onto the highway in the westbound direction. By inspection, the shortest distance path is ABC. This requires site trips to turn left at the intersection of Main Street at Oak Street, an unsignalized two-way stop controlled intersection. The stop-controlled left turn movement at this intersection experiences high delay. The alternate path, ADEC, is less direct. However, this path has less intersection delay where it accesses the highway at the signalized intersection of Maple Street and Main Street.

It is desired to assign the outbound site PM peak hour trips such that either path will
provide an equal travel time from the development.

Site Vicinity Diagram

Step 1. For the purpose of this exercise it is assumed that background traffic volumes have been previously developed.

Step 2. Site trips are initial assigned 100% to the shortest distance path, ABC.

Step 3. The initial site trip assignment from Step 2 is added to Background Traffic from Step 1 to create Initial Total Traffic volumes.

Step 4a. Link lengths and posted speeds are obtained and shown in the next figure below. Link lengths are typically measured from aerial photos and posted speeds collected from a field visit.
Segment travel times are calculated as follows, using sample segment BC.

\[
\text{Travel Time Segment BC} = \frac{0.26 \text{ mi}}{35 \text{ mi/hr}} \times 3600 \text{ sec/hr} = 26.7 \sim 27 \text{ sec}
\]

Travel times for each segment are summarized in a table:

<table>
<thead>
<tr>
<th>Roadway</th>
<th>Segment</th>
<th>Segment Travel Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak St</td>
<td>AB</td>
<td>9</td>
</tr>
<tr>
<td>Main St</td>
<td>BC</td>
<td>27</td>
</tr>
<tr>
<td>Oak St</td>
<td>AD</td>
<td>19</td>
</tr>
<tr>
<td>2nd St</td>
<td>DE</td>
<td>37</td>
</tr>
<tr>
<td>Maple St</td>
<td>EC</td>
<td>23</td>
</tr>
</tbody>
</table>

Origin-destination (O-D) path segment travel times are calculated by summing the segment travel times.

\[
\text{O-D Path ABC} = AB + BC = 9 + 27 = 36 \text{ sec}
\]
\[
\text{O-D Path ADEC} = AD + DE + EC = 19 + 37 + 23 = 79 \text{ sec}
\]

Step 4b. For the purpose of this exercise, assume that HCM intersection analysis has been previously conducted for background volumes, resulting in the following intersection delays. Please note that the delay values in this example are for illustrative purposes only and are not actual HCM-calculated values. For this example, it is assumed that delay at other intersections along each path is negligible.
### Background Traffic Movement Delay

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Movement</th>
<th>Movement Delay (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main St at Oak St</td>
<td>South to West left turn</td>
<td>44</td>
</tr>
<tr>
<td>Main St at Maple St</td>
<td>Westbound through movement</td>
<td>14</td>
</tr>
<tr>
<td>Main St at Maple St</td>
<td>South to West left turn</td>
<td>21</td>
</tr>
</tbody>
</table>

Intersection movement delays are summed for each O-D path

- O-D Path ABC = 44 + 14 = 58 sec
- O-D Path ADEC = 21 sec

Step 4c. Segment travel times and delays are summed to determine the total travel time for each path.

<table>
<thead>
<tr>
<th>O-D Path</th>
<th>Segment Travel Time (s)</th>
<th>Intersection Delay (s)</th>
<th>Total Travel Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>36</td>
<td>58</td>
<td>94</td>
</tr>
<tr>
<td>ADEC</td>
<td>79</td>
<td>21</td>
<td>100</td>
</tr>
</tbody>
</table>

The O-D path with the shortest travel time is path ABC.

Step 3. Site trips are assigned 100% to the shortest path ABC.

Step 4. The site trip assignment in Step 3 is added to the background volumes to obtain initial Total Traffic volumes.

Step 5. HCM methodology is applied to re-calculate intersection delays based on Total Traffic volumes.

### Total Traffic Movement Delay (First Iteration)

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Movement</th>
<th>Movement Delay (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main St at Oak St</td>
<td>South to West left turn</td>
<td>58</td>
</tr>
<tr>
<td>Main St at Maple St</td>
<td>Westbound through movement</td>
<td>16</td>
</tr>
<tr>
<td>Main St at Maple St</td>
<td>South to West left turn</td>
<td>24</td>
</tr>
</tbody>
</table>

Intersection movement delays are summed for each O-D path

- O-D Path ABC = 58 + 16 = 74 sec
- O-D Path ADEC = 24 sec

Segment travel times and delays are summed to determine the total travel time for each path.

<table>
<thead>
<tr>
<th>O-D Path</th>
<th>Segment Travel Time (s)</th>
<th>Intersection Delay (s)</th>
<th>Total Travel Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>36</td>
<td>74</td>
<td>110</td>
</tr>
<tr>
<td>ADEC</td>
<td>79</td>
<td>24</td>
<td>103</td>
</tr>
</tbody>
</table>
At this point, the shortest path based on travel time is now path ADEC. Since path travel times are close, the next iteration would be to assign some of the site trips to path onto path ADEC. Step 5 is then repeated. When path travel times are approximately equal, the site trip assignment is complete.

6.10 Zonal Cumulative Analysis

In quick growing areas or for entire cities, where a more accurate analysis is needed of the impacts (differing growth and trip patterns across the study area), the zonal cumulative analysis process should be used rather than the first-level TIA-level cumulative analysis. The zonal cumulative analysis process is essentially a manually-constructed travel demand model. The process includes the major three modeling steps (trip generation, trip distribution, and trip assignment). The major difference between the zonal cumulative and a travel demand model is that the zonal cumulative uses ITE trip generation instead of population and employment, and projects the incremental growth in trips rather than creating separate base year and future year assignments. Generally, this level of effort is too complex for a TIA.

Like with other cumulative analyses, the zonal cumulative method should be limited to cities of 10,000 or less population or a chunk of no more than 10,000 of a larger urban area. Areas larger than these can theoretically be done, but the number of zones and network size becomes overwhelming to do manually. In addition, anywhere multiple analyses (TSP, corridor or refinement plans, projects) are likely in the near (5-10 year) future then construction of a travel demand model should be considered. Re-purposing a zonal analysis for another project can be more time consuming than just building a travel demand model initially. These larger areas would require the enhanced zonal cumulative analysis process shown in Section 6.11 or use of a travel demand model as shown in Section 6.12.

The basic steps for a zonal cumulative analysis are:

1. Identify the study area and divide into transportation analysis zones (TAZ)
2. Identify vacant lands, in-process developments, comprehensive plan allowed land uses/densities, and development rates.
3. Estimate future trip generation potential
4. Determining the through trip percentages (external – external, E-E) and E-E trips for the external stations
5. Determining the internal – external (I-E) and external –internal (E-I) trips at each external station (external zone)
6. Determining the trip distribution for the internal – external (I-E) and external – internal (E-I) trips for each internal TAZ.
7. Determining the trip distribution for internal-internal (I-I) trips
8. Calculating network link travel times
9. Assigning total trips to the network

The above process is setup for multiple traffic assignments based on a single land use scenario. Doing an additional land use scenario would require repeating of Steps 3-9 or
using the more-automated enhanced zonal cumulative analysis. Use of software such as Vistro and its predecessor, Traffix, may help streamline the accounting of generated trips and the distribution/assignment of them if the network and land uses assumed are not too complex.

6.10.1 Step 1 – Identification of Study Area and TAZ’s

The study area should completely cover the project limits and all adjacent land areas that would affect the project area. The study area should be defined such that all relevant facilities are included, since there may be other roadways that could directly influence the traffic patterns on the facilities being analyzed. The location where each relevant roadway facility crosses the outside edge of the study area needs to be noted as an “external station.” The external station is where traffic enters/exits the study area and can also be considered an external zone. The study area needs to be broken into homogenous land-use zones (i.e. residential, commercial, or industrial) called transportation analysis zones (TAZ). There generally is no need to break the land use into further sub-categories (i.e. low vs. medium density residential). If zones are not completely homogenous, there will need to be additional accounting of internal trips between residential and commercial for example as there will be trips generated that will never extend beyond the zone boundaries. It is likely that a Geographic Information Systems (GIS) land-use or tax-assessment file is available from the local city or county that will be of great assistance and streamlining of this and the following tasks.

Each TAZ boundary generally needs to follow physical or man-made boundaries. This would include rivers, railroads, and major roadways. Property lines generally break on these major features, and the GIS file can be used to help ensure that the TAZ boundaries do not cross or break up properties.

Example 6-6 Study Area and Zone Identification

This example is based on an actual zonal cumulative analysis done for the US97/South Century Drive project in the Sunriver resort area south of Bend. The overall project area is shown in the figure below. The study area reflects the area that would feed into South Century Drive and eventually to US97. Areas to the south of the project area would most likely feed into the next major road to the south (LaPine State Recreation Road) or into the City of LaPine.

TAZ’s were split on land use or on natural or man-made boundaries. Examples for land use:

- Zone 1 is the current Sunriver resort development and is generally residential.
- Zone 2 is the existing Spring River residential subdivisions
- Zone 9 is vacant Forest Service forest lands (although zoned for resorts).
- Zone 10 is the Sunriver business district and is generally commercial uses.
- Zone 12 is the Crosswater resort/golf course

TAZ zone boundary splits examples:
The Deschutes River forms the boundaries between Zones 1 and 2 and Zones 3 and 4.

The Little Deschutes River forms the boundary between Zones 5 and 6.

The BNSF railroad tracks forms the boundary between Zones 7 and 11.

South Century Drive forms the boundaries between Zones 1 and 10, Zones 12 and 9, and between Zones 6 and 7.
6.10.2 Step 2 – Identification of Land Use Characteristics and Zoning

After the homogenous TAZ’s have been developed, all of the land use characteristics and related zoning needs to be identified. This will create the parameters necessary for
estimating the future trip generation in Step 3. The zonal cumulative process assumes that the traffic counts (and the resulting 30 HV) obtained for the study area account for all built properties. The main focus of the process is to determine the total change from the base to the future condition. Areas that are vacant or partially built will need additional data to help determine the future growth potential. Exhibit 6-3 shows the process for determining the TAZ land use data for vacant lands.

Vacant Lands

For each TAZ, any vacant buildable lands need to be identified. This can be facilitated by obtaining the following items:

- **Buildable Lands Inventory (BLI)** – Not every study area will have an applicable BLI available, but when available, they will limit the amount of data needed. The BLI will specifically identify buildable areas that can be coordinated directly with the study area TAZ’s. Detail levels vary but at a minimum, the truly developable vacant lands can be determined. The BLI will help identify areas that are not suited for future development such as wetlands, riparian zones, flood plains, steep slopes, resource areas, etc. The BLI needs to be relatively recent (no more than 3-5 years old for normal growth areas but longer periods might be okay for slow growth areas).

- **Comprehensive Plan, Zoning Map and Code** – Obtaining the comprehensive plan, zoning map and zoning code is the minimum information needed in order to do a zonal cumulative analysis. The comprehensive plan and related zoning code (see Exhibits 6-4 and 6-5.) will tell what the allowed (permitted outright and through the conditional use permit process) uses are, and lot requirement details such as minimum/maximum sizes, development densities, building heights, floor-area- (coverage) ratios, green/open space requirements, etc. The zoning map allows for easy identification of where the different zoning is applied (see Exhibit 6-6). Generally, land uses should be limited to outright permitted uses only as there is no guarantee that a conditional use would be granted. Exceptions need to have concurrence with the local planning staff.

- **GIS-based land-use/property/tax assessor’s database** – If available, a GIS-based property database will greatly streamline the identification of zoning and whether a property is vacant. These databases generally include, location, tax-lot numbers, zoning, acreage, ownership, improvements (structures), and year of improvement (building permit issued). Use of GIS allows the properties to be grouped by TAZ.
Obtain local planning documents

Review and make initial assessment of vacant lands and zoning types

Identify and subtract out unbuildable areas: riparian zones, too-steep slopes, built-out parcels, park lands, etc.

Obtain detailed in-process development plans, reports, etc.

Subtract out in-process development lands

Apply zoning code to vacant lands: street right-of-way allowance, open space requirements, divide into developable lots, etc.

Assumptions OK

Check all assumptions with local planner

Revisions Needed

Apply residential zoning code density requirements to calculate potential dwelling units and floor-area ratios for commercial/industrial zones to calculate gross leasable floor area.
• Transportation System Plan (TSP) – Newer TSP’s may show environmental baseline information such as wetlands, park lands, greenways, historic properties, etc. that can be used to further identify non-buildable areas (especially if a BLI is not available). The TSP will also show future road improvements that can be used to modify the road network.

• Other land-use plans – These cover a wide range of planning maps such as subdivision plats and development master plans that can identify in-process or future developments. Certain areas may not have BLI’s so park plans, school district plans, wetland plans, park plans, and other plans of this type fall into this category. All of these can be used for identification of future growth potential. Contacting the local planning office is the best source for this information.

• Current aerial photos – If current aerial photos are available, identification of vacant lands can be easily done with a GIS database or comprehensive plan. However, use of aerals can be a potential pitfall if the aerial has not been verified to be recent. Please note that commercial aerial mapping such as Google Maps could be 3-5 years out of date and is not recommended to be used (unless extensively field-verified) for this process.

Exhibit 6-4 Urban Standard Residential Zone Excerpts

(1) Purpose. The RS Zone is intended to provide for the most common urban residential densities in places where community sewer services are or will be available and to encourage, accommodate, maintain and protect a suitable environment for family living.

(2) Permitted Uses. The following uses are permitted:

(a) Single-family dwelling.

(b) Agriculture, excluding the keeping of livestock.

(c) Rooming and boarding of not more than two persons.

(d) Home occupations subject to the provisions of Subsection (15) of Section 25.

(e) Park rehabilitation, minor betterment and repairs.

(f) Accessory dwelling in a subdivision or Planned Unit Development (PUD) approved after December 2, 1998, provided that overall density in subdivision or PUD does not exceed 7.3 dwelling units per gross acre.

(5) Lot Requirements. The following lot requirements shall be observed, provided that the approval authority may allow smaller lots of different housing types in a new subdivision or Planned Unit Development (PUD) approved pursuant to this ordinance and consistent with the Comprehensive Plan designations for preservation of areas of significant interest when these lots or housing types are internal to the subdivision or PUD.

(a) Lot Area: A lot in a subdivision or planned unit development approved after the date of adoption shall have a minimum area of 4,000 square feet provided that the overall density does not exceed 7.3 dwellings gross per acre, and provided that where new subdivisions abut lots of 20,000 square feet or less the exterior lots shall be at least 75% of the abutting lot sizes and lot lines or be approved through a hearing process. All other lots shall have a minimum area of 6,000 square feet.
The first step to obtaining any of the above is to get in contact and establish a good relationship with the local planning office or local planner. They will know all of the details, recent and past development history, insight on building rates and typical/likely growth patterns. You will need to have them review your development assumptions that you make, vacant lands, and growth potential to make sure that the analysis is reasonable before moving on to more detailed steps.
Once the unbuildable areas have been identified, then any in-process developments need to be identified. Contact the local planning office and ask about any approved but not yet built residential or commercial developments. Obtain documentation such as plats, site plans, or transportation impact analyses (TIA) describing the development. The total number of lots, units, or square footage needs to be noted for the later trip generation calculations. These developments need to be subtracted from the total vacant land to determine the truly vacant buildable land available for future growth.
Exhibit 6-6 Sample Comprehensive Plan (Zoning) Map
Estimating Potential Future Land Use

At this point, the remaining vacant land would be available for future development but is not planned as such. For each TAZ and/or parcel clumps within a TAZ, the zoning code requirements need to be applied.

For residential lands, there will be likely minimum lot sizes or minimum/maximum dwelling unit per acre requirements. A good way to judge what these might be is to take a GIS-based survey of adjacent similarly-zoned single-family home subdivisions and figure out a typical lot size (this is one of those assumptions that the local planner should review for reasonability). About 24% of vacant residential lands should be reserved for local street right-of-ways. The zoning code may indicate additional specific values for green or open space requirements that will need to be accounted for. Buildable residential lands then would be calculated by subtracting the local street and green space requirements from the total land area and then dividing by the typical lot size to determine the number of single-family dwelling units for each TAZ.

Multi-family residential lands such as apartments, condominiums or townhouses need to be figured on a dwelling units per acre basis. The zoning code should tell the range of acceptable densities regardless of building heights. GIS can be used to help determine a typical value by surveying similarly-zoned areas in the local area. The local planning office should be able to give some guidance in this area. Once a typical dwelling unit per acre value is determined then this can be directly multiplied by the vacant buildable multi-family lands to determine the total amount of multi-family dwelling units. The final value may need to be summed from multiple parcels depending on how these lands are spread around in a single TAZ.

Non-residential (commercial/industrial) lands are generally figured on a parcel basis as parcels are generally large. Zoning codes typically use floor-area-ratios (FAR) for determining maximum lot coverage. The typical FAR range is between 25 and 35% of the lot size which covers green/open space, access roads and parking. For denser areas or industrial areas, height requirements may allow more than a single story which would allow more square footage for the maximum lot coverage. However, if maximum square footage requirements are shown, then these apply to the total of all floors. Multiplying the lot size by the FAR or using the maximum square footage per parcel will determine the maximum potential gross leasable floor area. Commercial and industrial lands need to be kept separate as trip generation multipliers will be different.
Example 6-7 Estimating Future Buildable Land Use

For a particular TAZ, there are 100 acres of vacant buildable zoned RM (medium-density single family residential) land. The zoning code indicates that lot sizes are to be 5,000 square feet at a minimum. A survey of recently completed subdivisions in the area shows that the average lot size is about 6,000 square feet. This particular TAZ is covered by additional provisions that require 10% of the total development to be common open space. This TAZ also has 5 acres of neighborhood commercial at a maximum FAR of 35%.

Deduct the common open space from the total land area = 100 ac – 100 ac x 0.10 = 90 ac.

Subtract out the typical 24% allotment for local streets = 90 ac – 90 ac x 0.24 = 68.4 ac

Calculate the total number of potential dwelling units = (68.4 ac x 43,560 sq ft/ac) / 6,000 sq ft = 496.6 = 496 lots (need to round down).

Calculate the commercial maximum gross leasable floor area = 5 ac x 0.35 x 43,560 sq ft/ac = 76,230 sq ft = 76,200 sq ft.

Building Rates

Typically at this point a spreadsheet is setup by TAZ showing the potential dwelling units for residential and square footage for commercial or industrial areas. These TAZ totals represent build-out which may or may not occur within the study horizon (future or design year). Some TAZ’s will be currently mostly built out, so it may only take a few years to reach build-out while other TAZ’s are vacant and build-out may be over 40 or more years. Faster growing areas (i.e. Central Oregon) will take less time than historically slower growing areas (South Coast).

For each land use type within each TAZ, a building rate needs to be calculated. This aspect of the zonal cumulative method can be one of the most difficult to obtain accurately. The best way to help determine this is to use a GIS-based tax assessor’s database to group properties by TAZ and to indicate in which year an improvement occurred. Non-GIS spreadsheets/databases can also be used, but these will require visual matching of tax- lots with the TAZ’s. An alternate source is to use issued building permits assuming that these are available for at least the last 10 years. These values can be plotted over the long-term to determine a curve or best-fit regression line to determine a rate of growth. The rate curve will be the best with a good amount of data points covering at least 10 or more years. Another method is to take the total amount of improved lots divided by the number of years those improvements represent to get an average historical building rate.

There may be areas with little or no historical growth, so these should be estimated by using nearby areas with similar characteristics. If an area is relatively homogenous (i.e.
all residential) then the building rates could be simplified to a few or a single area-wide value. Commercial or industrial areas building rates could be simplified to a few or a single value depending if the characteristics are similar. Keep in mind that if there are a lot of in-process developments, these may skew the historic building rate. Any of these results need to be tempered by the advice of the local planner on the historic or future building rates. At a minimum, there needs to be a single building rate for each land use type used. If a database or permits are not available or available for enough years, then the application of this method becomes difficult at best and the enhanced zonal cumulative method should be used. The enhanced zonal cumulative method uses explicit base and future models and is less concerned with a historical building rate.

### Example 6-8 Historical Building Rate

Within a residential TAZ, there are a number of subdivisions that were ready for development in the year 2000. These subdivisions made up a total of 400 lots. The future year for this analysis is 2030. From the county tax assessor’s database the following data was obtained from 2000 to 2010:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Permits Issued</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>20</td>
</tr>
<tr>
<td>2001</td>
<td>27</td>
</tr>
<tr>
<td>2002</td>
<td>6</td>
</tr>
<tr>
<td>2003</td>
<td>4</td>
</tr>
<tr>
<td>2004</td>
<td>22</td>
</tr>
<tr>
<td>2005</td>
<td>42</td>
</tr>
<tr>
<td>2006</td>
<td>37</td>
</tr>
<tr>
<td>2007</td>
<td>9</td>
</tr>
<tr>
<td>2008</td>
<td>0</td>
</tr>
<tr>
<td>2009</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>3</td>
</tr>
</tbody>
</table>

From a review of the data, it is apparent that growth was relatively unsteady and that a regressed trend would not give a good predicted rate. The residential area has the same general characteristics so an average TAZ historical rate is probably the best method.

From 2000 to 2010 a total of 170 lots had building permits issued. This equates to 170 lots / 11 years = approximately 15 lots per year

This TAZ was not built out in 2010 with 170 of the 400 total built. There are 400 – 170 = 230 vacant lots remaining. With a 15 lots / yr rate, this TAZ would be built out in 230 lots/15 lots per yr = approximately 15 years or 2025. Since the future year is 2030 we would use the maximum potential 230 new lots in the analysis.
6.10.3 Estimating Future Trip Generation

At this point, the land uses for each TAZ have been calculated. Use the ITE Trip Generation manuals or Trip Generation software to compute the increase in peak hour trip generation potential for each TAZ as per Section 6.6. Use major ITE land uses (i.e. shopping center, office park, apartments, etc.) that have ideally equations or reasonable data points. For each land use, make sure to specify the split between the entering and exiting trips. Depending on zone structure and land uses, commercial trips should be primary (new trips on the system) trips, unless there is not enough background traffic to accommodate the potential pass-by trips. Trip generation documentation should be in a spreadsheet form.

Example 6-9 Projected Trip Generation

A zonal cumulative analysis was performed for a growing rural residential community along a state highway. This example study area will be used throughout the rest of this section. The study area was split into four zones (1-4). The number of vacant lots and the building rate were estimated following Section 6.10.2. The current year is 2002 with a project horizon year of 2027. All of the zones except for Zone 2 reach build-out. The trip generation is based on the ITE Trip Generation PM peak single family home rates (Category 210) of 1.01 trips per dwelling unit in the peak hour.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Vacant Lots (2002)</th>
<th>Building Rate (Homes/yr)</th>
<th>New Homes built by 2027</th>
<th>2027 Trip Generation Total (Enter/Exit) (vph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>537</td>
<td>80</td>
<td>537</td>
<td>542 (349/193)</td>
</tr>
<tr>
<td>2</td>
<td>984</td>
<td>30</td>
<td>750</td>
<td>758 (488/270)</td>
</tr>
<tr>
<td>3</td>
<td>167</td>
<td>17</td>
<td>167</td>
<td>169 (109/60)</td>
</tr>
<tr>
<td>4</td>
<td>640</td>
<td>35</td>
<td>640</td>
<td>646 (416/230)</td>
</tr>
</tbody>
</table>

6.10.4 Trip Types

The total trips in the study area are made up of internal and external trips. External trips are those trips that have at least one end located outside of the study area, as defined by the study area boundary. Internal trips begin and end within the study area. There are four trip types that make up the total trips that are the focus of the next three sections. The trip types are external-external (E-E), external-internal (E-I), internal-external (I-E), and internal-internal (I-I). See Exhibit 6-7.
6.10.5 Estimating Through (External-External) Trips

External-external or E-E (through) trips are trips that have both ends (origin and destination) outside of the study area. The E-E trips are the first of the four basic trip types that need to be created from the overall study area volumes. The objective of this section is to calculate the proportion of E-E trips compared to the total trips and eventually the total E-E trips.

The point where each study area roadway crosses the study area boundary is known as an external station. This point represents the connection to the outside world. The external stations are shown as the black circled "A" and "B" in Exhibit 6-7. External stations are treated essentially as additional zones in this methodology, so number them to not conflict with the TAZ number to avoid confusion. Examples could be using letters (A, B, C…) or a completely different and distinctive number series (500, 501, 502…).

The E-E trips for the base and future years are calculated at each external station. Only roadways with significant volume in the study area should be counted as having external stations. While it is possible to have every local road study area boundary crossing an external station, the complexity of the analysis rapidly increases, the extra work may not be justified, and the necessary detail level needed may not be achievable. Use of origin-destination, license plate matching, or a Bluetooth MAC-address matching study are desired with areas having multiple external stations to simplify finding the E-E trip proportions.

At each external station, the proportion of E-E trips needs to be calculated. This can be obtained directly from an origin-destination or other matching study between each external station pair and for each direction of travel. In most cases, an approximation procedure is necessary to estimate the E-E proportion. Using the directional peak hour (30HV) volumes at an external station, hold that volume and proceed to the other external station by subtracting all turn volumes at each intersection downstream. The remaining volume is the E-E trip volume. This remaining volume is divided by the total directional volume at the external station to determine the percentage of E-E trips. The process is repeated in the other direction and for each external station and for each external station pair (i.e. three external stations: 1-2, 2-1, 1-3, 3-1, 2-3, 3-2).
It is possible to end up with a negative value upon reaching the other external station especially if there are a large proportion of turning volumes compared to the non-turning volume. The turn movements inside the study area are made up of all the trip types so it is possible that large internal-internal trip patterns skew the turning movements to an extent so a negative value is obtained. A negative value indicates a need to investigate the higher local turn movements to see where they are destined to and to make sure that other external trips are not mixing in. For areas with complex trip patterns or a good amount of external stations, some sort of origin-destination study is recommended for all or part of the study area.

**Example 6-10 E-E Approximation Process**

In the figure below, there are two external stations, labeled A and B representing the roadway as it enters and leaves the study area. The volumes at intermediate study area intersections are shown below. The initial external station volume is determined from the given volumes. For example, at External Station A, the eastbound volume starts with 305 vph (280 EBT + 10 EBL + 15 EBR) entering the study area.

Starting with the first intermediate intersection and proceeding eastbound, the turning volumes are subtracted from the initial 305 vph value. The resulting value is the total E-E trips for the eastbound External Station A movement. This is repeated for the westbound direction.

\[
\text{Total EB E-E trips} = 305 - 10 - 15 - 8 - 35 = 237 \text{ vph} \\
\text{Total WB E-E trips} = 407 - 60 - 22 - 7 - 8 = 310 \text{ vph} \\
\text{At External Station A, the total EB trips are} 10 + 280 + 15 = 305
\]
At External Station A, the total WB trips are \(12 + 350 + 15 = 377\)
At External Station B, the total EB trips are \(31 + 267 + 10 = 308\)
At External Station B, the total WB trips are \(22 + 325 + 60 = 407\)

The External Station A E-E EB trip percentage = \(237 / 305 = 0.77\)
The External Station A E-E WB trip percentage = \(310 / 377 = 0.83\)
The External Station B E-E EB trip percentage = \(237 / 308 = 0.77\)
The External Station B E-E WB trip percentage = \(310 / 407 = 0.77\)

Therefore, there is a 77% chance that trips entering or leaving External Station A are E-E trips. There are 305 total trips on the EB approach at External Station A and it was calculated that 237 of them travel all the way to External station B above. So, \(237 / 305 = 0.77\) or 77%. In the WB direction at External Station A, there are 377 trips on the approach and it was determined that 310 trips travel from External Station B to A. So \(310 / 377 = 0.83\) or 83%.

Example 6-10 determined the base year E-E trips. In order to calculate the future year E-E trips, a growth factor needs to be calculated for each external station. This growth factor is computed from the Future Volume Tables for the road segment(s) in question. Non-state roadways can be estimated from historical local counts if available or using a state highway with similar volumes and characteristics as a surrogate. The growth factor is a multi-year factor depending on the number of years between the base and future year. For example, if the base year was 2002 and the future year was 2027, then a 25-year growth factor would need to be computed. See Section 6.5 for more information.

**Example 6-11 Future Year E-E Calculations**

Given in this example:

- Traffic volumes at the External Station A are 625 entering and 700 exiting.
- Traffic volumes at the External Station B are 735 entering and 630 exiting.
From the figure, the 25-year historical growth factor is 1.83 for External Station A and 1.53 for External Station B and shown in Column (2). The base year 2002 volumes shown in Column (1) are multiplied by the appropriate historical growth factor to obtain 2027 design hour volumes and are shown in Column (3).

The E-E trip proportions were calculated using the method in Example 6-10 for each direction at each external station and are shown in the below table in Column (4):

- External Station A – Entering = 0.83
- External Station A – Exiting = 0.86
- External Station B – Entering = 0.82
- External Station B – Exiting = 0.82

The total new E-E trip growth from 2002 and 2027 is calculated by multiplying the E-E proportions times the difference between the 2002 and 2027 DHV and is shown in Column (5).

<table>
<thead>
<tr>
<th>Ext. Trip Table</th>
<th>Direction</th>
<th>(1) 2002 DHV (vph)</th>
<th>(2) Growth Factor</th>
<th>(3) 2027 DHV = (1)* (2) (vph)</th>
<th>(4) E-E Trip Prob.</th>
<th>(5) 2027 E-E Trip Growth = (4)*((3)-(1)) (vph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Station A</td>
<td>Enter</td>
<td>625</td>
<td>1.83</td>
<td>1144</td>
<td>0.83</td>
<td>431</td>
</tr>
<tr>
<td></td>
<td>Exit</td>
<td>700</td>
<td>1.83</td>
<td>1281</td>
<td>0.86</td>
<td>500</td>
</tr>
<tr>
<td>External Station B</td>
<td>Enter</td>
<td>735</td>
<td>1.53</td>
<td>1125</td>
<td>0.82</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td>Exit</td>
<td>630</td>
<td>1.53</td>
<td>964</td>
<td>0.82</td>
<td>274</td>
</tr>
</tbody>
</table>

Assumptions:
Growth factors at External stations A and B are 1.83 and 1.53, respectively, over 25 years.
6.10.6 Estimating External-Internal (E-I) and Internal – External (I-E) Trips

Once the total E-E trips have been determined, the External-Internal (E-I) and Internal-External (I-E) trips can be determined. The E-I and I-E trips have one end of the trip in the study area and one end outside of the study area.

The E-I trip growth is the total external station growth entering the study area minus the directional E-E growth. Conversely, the I-E trip growth is the total external station growth exiting the study area minus the directional E-E growth.

Example 6-12 Future Year E-I and I-E Trip Calculation

From the information in Examples 6-10 and 6-11, the 25-year growth of E-I and I-E trips are calculated as shown in Column (6).

<table>
<thead>
<tr>
<th>Ext. Trip Table</th>
<th>Direction</th>
<th>(1) 2002 DHV (vph)</th>
<th>(2) Growth Factor</th>
<th>(3) 2027 DHV = (1)*(2) (vph)</th>
<th>(4) E-E Trip Prob.</th>
<th>(5) 2027 E-E Trip Growth = (4)*((3)-(1)) (vph)</th>
<th>(6) 2027 E-I, I-E Trip Growth = (3)-(1)-(5) (vph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Station A</td>
<td>Enter</td>
<td>625</td>
<td>1.83</td>
<td>1144</td>
<td>0.83</td>
<td>431</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>Exit</td>
<td>700</td>
<td>1.83</td>
<td>1281</td>
<td>0.86</td>
<td>500</td>
<td>81</td>
</tr>
<tr>
<td>External Station B</td>
<td>Enter</td>
<td>735</td>
<td>1.53</td>
<td>1125</td>
<td>0.82</td>
<td>320</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Exit</td>
<td>630</td>
<td>1.53</td>
<td>964</td>
<td>0.82</td>
<td>274</td>
<td>60</td>
</tr>
</tbody>
</table>

6.10.7 Trip Distribution of E-I and I-E trips

Trips entering a zone are also known as an “attracted” trip while trips leaving a zone are a “produced” trip. The zonal cumulative analysis uses a gravity-based method for determining a TAZ’s distribution of attractions and productions. Larger zones (on a trip generation basis, not geographical area) attract and produce more trips than smaller zones on a relative basis. This process is known as trip distribution.

After the external-external trip growth has been removed from the total external trip growth, the remaining trips are distributed to the internal zones according to the following procedure.

- Distribution of growth in external-internal trips:
  - Calculate the attraction probability of each zone’s new trip attractions by dividing its new trip attractions by the study area’s total new trip attractions.
  - Distribute the growth in external-internal trips for each external station by
multiplying these trips by each zone’s attraction probability.

- Distribution of growth in internal-external trips:
  - Calculate the production probability of each zone’s new trip productions by dividing its new trip productions by the study area’s total new trip productions.
  - Distribute the growth in internal-external trips for each external station by multiplying these trips by each zone’s production probability.

When distributing trips, care needs to be taken considering the land use within each zone. For the typical afternoon peak hour analysis, trips will be traveling from employment zones (commercial/industrial) to residential zones; from residential zones to commercial zones (i.e. shopping/eating after work); and from commercial to other commercial zones (trip chaining). Residential to residential trip distribution should be avoided as it will likely cause unrealistic results.

**Example 6-13 E-I and I-E Trip Distribution**

Distribute the new external-internal and internal-external trips in Example 6-12 to the four zones shown in Example 6-11.

Solution:

The total new trips are obtained from the trip generation done in Example 6-9 (Column 5). All zones are summed up to determine the grand new trip total for the entire study area. The trip attractions and productions are the entering and exiting trips, respectively, also from Example 6-9. The attractions and productions are also summed up across all zones to determine the total attracted and produced trips.

The calculation of the attraction and production probabilities is shown in the external trip attraction and production probability table below. All trips are in vehicles per hour. For example, Zone 1’s attraction probability is 349/1362 = 0.256 and its production probability is 193/753 = 0.256.

**External Trip Attractions and Productions Probabilities**

<table>
<thead>
<tr>
<th>Zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total New Trips (from Example 6-9)</td>
<td>542</td>
<td>758</td>
<td>169</td>
<td>646</td>
<td>2115</td>
</tr>
<tr>
<td>Trip Attractions (from Example 6-9)</td>
<td>349</td>
<td>488</td>
<td>109</td>
<td>416</td>
<td>1362</td>
</tr>
<tr>
<td>Attraction Probability</td>
<td>0.256</td>
<td>0.358</td>
<td>0.080</td>
<td>0.306</td>
<td>1.000</td>
</tr>
<tr>
<td>Trip Productions (from Example 6-9)</td>
<td>193</td>
<td>270</td>
<td>60</td>
<td>230</td>
<td>753</td>
</tr>
<tr>
<td>Production Probability</td>
<td>0.256</td>
<td>0.359</td>
<td>0.080</td>
<td>0.305</td>
<td>1.000</td>
</tr>
</tbody>
</table>

The distribution of new external-internal trips is shown in the E-I table below. For example, Zone 1’s new external-internal trips at External Station A are 88*0.256 = 23 vph.
External-Internal Trip Attraction Distribution

<table>
<thead>
<tr>
<th>External Station</th>
<th>New E-I Trips</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>88 (from Example 6-12)</td>
<td>23</td>
<td>31</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>B</td>
<td>70 (from Example 6-12)</td>
<td>18</td>
<td>25</td>
<td>6</td>
<td>21</td>
</tr>
</tbody>
</table>

The distribution of new internal-external trips is shown in the I-E table below. For example, Zone 1’s new internal-external trips at External Station A are 81*0.256 = 21 vph.

Internal-External Trip Production Distribution

<table>
<thead>
<tr>
<th>External Station</th>
<th>New I-E Trips</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>81 (from Example 6-12)</td>
<td>21</td>
<td>29</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>B</td>
<td>60 (from Example 6-12)</td>
<td>15</td>
<td>22</td>
<td>5</td>
<td>18</td>
</tr>
</tbody>
</table>

6.10.8 Trip Distribution of Internal – Internal Trips

After the new external-internal and internal-external trips have been distributed for each zone, the remaining new attractions and productions are internal-internal trips. While these attractions and productions balance in the examples for simplification, typically they do not. The I-I table would need to be balanced using a Frater methodology (i.e. see NCHRP Report 765). External-External proportions or zone production/attraction probabilities may need to be slightly adjusted for balance to occur. Internal –internal (I-I) trips are trips that both start and end in the study area. The total I-I trips are determined by subtracting the total new E-I/I-E trips from the total new trips for each TAZ.

Example 6-14 I-I Total Trip Calculation

From the previous example, the total new attraction/production trips for each zone in vehicles per hour are shown on the first line of the trip attractions and productions probability table. The total E-I and I-E trips for each zone are summed up and subtracted from the total new trips.

For Zone 1, the total new trips are 542. The total E-I trips (from Example 6-13’s trip attraction distribution) are 23 + 18 = 41 while the I-E trips are 21 + 15 = 36 (from Example 6-13’s trip production distribution table).
The total I-I trips are calculated by subtracting the total E-I and I-E from the total new trips: Total Zone 1 I-I trips = 542 – 41 – 36 = 465 trips. This is repeated for all remaining zones. Note that the table is balanced as the sum of the total new trips minus the total E-I and I-E trips equals the sum of the column totals. For the above table: 465 + 651 + 145 + 555 = 1816 and 2115 – 158 – 141 = 1816.

To distribute the internal-internal trips for each zone, use the same distribution process as described in Section 6.10.7. Once the total I-I trips are determined for each zone following the process shown in Example 6-13, the total internal attractions and productions need to be calculated. The total internal attractions are determined by subtracting the total external-internal attractions from the total attractions. Likewise, the total internal productions are determined from subtracting the total internal-external productions from the total productions. Attraction probabilities are calculated by dividing the total attractions for each zone by the total attractions. Production probabilities are done similarly.

**Example 6-15 I-I Trip Distribution**

For each zone, the total internal attractions and productions need to be calculated. For Zone 1, there were 464 total internal-internal trips determined in Example 6-14 and shown below in the internal-internal trip attraction/production probability table. In Example 6-13 the total external-internal trip attractions were 349 while the total external-internal trip productions were 193. The total external-internal trip attraction distribution table has a total of 41 (23+18) trips for Zone 1. Likewise, the corresponding internal-external trip production table has a total of 36 (21 + 15) trips for Zone 1.

Total I-I trip attractions = 349 – 41 = 308 trips
Total I-I trip productions = 193 – 36 = 157 trips

The calculations are repeated for all zones and are shown in the below table. The total I-I trip attractions and productions are summed up across all zones for a grand attraction and production totals. Attraction and production probabilities are also calculated for all zones. For Zone 1 the 308 internal attracted trips are divided by the total 1204 attracted trips = 308 / 1204 = 0.256 Production probabilities for Zone 1 are 157 / 612 = 0.256.

### Internal Trip Attractions and Productions Probabilities

<table>
<thead>
<tr>
<th></th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Internal-Internal Trips</td>
<td>464</td>
<td>650</td>
<td>145</td>
<td>553</td>
<td>1812</td>
</tr>
<tr>
<td>Internal Attractions</td>
<td>308</td>
<td>432</td>
<td>96</td>
<td>368</td>
<td>1204</td>
</tr>
<tr>
<td>Attraction Probability</td>
<td>0.256</td>
<td>0.358</td>
<td>0.080</td>
<td>0.306</td>
<td>1.000</td>
</tr>
<tr>
<td>Internal Productions</td>
<td>156</td>
<td>218</td>
<td>49</td>
<td>185</td>
<td>608</td>
</tr>
<tr>
<td>Production Probability</td>
<td>0.257</td>
<td>0.358</td>
<td>0.081</td>
<td>0.304</td>
<td>1.000</td>
</tr>
</tbody>
</table>

The distribution of new internal-internal attractions is shown in the table below. For
example, the attraction trips to Zone 1 from Zone 2 are $308 \times 0.358 = 110$.

**Internal Trip Attraction Distribution**

<table>
<thead>
<tr>
<th>Zone</th>
<th>I-I Attraction</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>308</td>
<td>79</td>
<td>110</td>
<td>25</td>
<td>94</td>
</tr>
<tr>
<td>2</td>
<td>432</td>
<td>111</td>
<td>155</td>
<td>34</td>
<td>132</td>
</tr>
<tr>
<td>3</td>
<td>96</td>
<td>25</td>
<td>34</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>368</td>
<td>94</td>
<td>132</td>
<td>30</td>
<td>112</td>
</tr>
</tbody>
</table>

The distribution of new internal-internal productions is shown in the table below. For example, the production trips from Zone 1 to Zone 2 are $156 \times 0.358 = 56$.

**Internal Trip Production Distribution**

<table>
<thead>
<tr>
<th>Zone</th>
<th>I-I Production</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>156</td>
<td>40</td>
<td>56</td>
<td>13</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>218</td>
<td>56</td>
<td>78</td>
<td>18</td>
<td>66</td>
</tr>
<tr>
<td>3</td>
<td>49</td>
<td>13</td>
<td>18</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>185</td>
<td>48</td>
<td>66</td>
<td>15</td>
<td>56</td>
</tr>
</tbody>
</table>

### 6.10.9 Initial Trip Assignment

Following trip distribution, the next step in the procedure is trip assignment, which involves placing the growth in trips on the road network. Trip assignment is the process used to estimate paths the trip will take, which ultimately results in traffic flow on the network. It assigns the trips to specific routes and establishes volumes on links, taking into consideration network characteristics to find the shortest path between origins and destinations.

The trip assignment is based on the shortest path in the network by time. A travel time needs to be identified for each link on the network. At the minimum, each route should be traveled at least once in each direction during the analysis hour to help estimate a travel time for that direction on the link. The ideal method to determine travel times would be following the procedures in Chapter 3 for travel time studies. For roadways that do not exist, speeds should be estimated using distance and likely travel or posted speed.

The analyst has to establish the travel times for the four trip-types. For each production-attraction pair in the trip table, the likely paths need to be identified. There is likely to be more than one path for each pair, depending on the network. The link travel times are summed to create the total path travel time.

Where there are multiple paths for an individual production-attraction pair, the appropriate path needs to be selected. The selection should be based on the smallest travel time. If the path travel times are within 10% of each other, the trips can be assigned equally across those paths. When the times are more than 50% different then assign the trips all to the shortest path. When the difference is between 10 and 50%, the
trips should be assigned on a weighted average based on the inverse proportion. For example, assume that the paths were 4 minutes versus 3 minutes. Since the 4 minute path is 33% longer than the 3 minute path, the trips are assigned 33% to the longer 4-minute path and 67% to the shorter 3-minute path. Engineering judgment must be used when reviewing travel times of closely spaced parallel paths to assure that actual driver behavior is modeled and not just a mathematical difference.

The analyst must now assign the trips by trip types starting with E-E and progressing to E-I, then I-E and finally I-I as illustrated in the example.

6.10.10 Total Trip Assignment

Once all the trips have been assigned by trip type, the analyst must check for links that have been over-assigned based on capacity. The analyst should first review the base year analysis to determine whether certain links are below, near/at or over capacity. For links in the base year that are approaching or over capacity, a flag for possible trip reassignment is identified. Also, links with a large amount of growth in traffic should be identified as needing a check for over capacity conditions.

Any flagged links may require that the assignment of the growth trips be reassigned to links with available capacity. The analyst needs to use an HCM segment methodology to determine the link capacity. The analyst will need to convert the base year intersection volumes into link volumes. The growth trips need to be added to the base year trips to determine total trips assigned to a link. The analyst then identifies any links that have trips assigned in excess of the capacity. For the over-capacity links, the excess trips above capacity from growth need to be reassigned to other logical paths. This iterative process should be continued until the excess trips have been assigned logically onto the network. Depending on the network, there may be limited additional paths so the excess trips cannot always be completely reassigned.

Example 6-16 Trip Assignment for Eastbound Through

This example illustrates the aggregation of the individual trip types for the future for one movement on one approach at an intersection within the study area. This would need to be repeated for the other movements and other intersections. This example focuses on the eastbound through (EBT) movement.

Base Year Trips

The process starts with the existing year (base year) 30HV volume previously calculated using procedures from Chapter 5. From the figure below, there are 525 base-year trips to be assigned to the EBT movement.
External-External Trips

Next, the external-external trips are added. From Example 6-11, the future year eastbound E-E trips are 431 and are shown in the next figure below.

External-Internal Trips

From the figure below, note that Zone 1 and 2 E-I trips will leave the roadway before the intersection at access points or turning left or right at the side street. Both of these do not add to the assignment for the eastbound through (EBT) movement. However, they would be part of the assignments for the eastbound left and right.
EBT Assignment, External-Internal

There are seven total external-internal trips from External Station A to Zone 3. These seven trips can access to Zone 3 by turning left at the intersection or through downstream accesses via the mainline based on assignment assumptions. Two of the seven trips will travel to Zone 3 by turning left at the intersection and the remaining five trips will travel to Zone 3 through downstream accesses via the mainline.

The same process is followed for trips from External Station A to Zone 4. The total external-internal trips from External Station A to Zone 4 are 27. The same accessibility assumptions from Zone 3 apply to Zone 4. Here, assuming 20 out of the 27 will access to Zone 4 by downstream accesses on the mainline and seven via the side street.

The resulting total E-I trips for the EBT movement is 25 (20 +5).

Internal-External Trips

From the figure below, note that Zone 3 and 4 I-E trips will turn onto the mainline roadway at the intersection or access it downstream of the intersection. These movements would not be counted into the EBT movement assignment. They would be part of the assignment for the northbound right and southbound left movements.

EBT Assignment, Internal-External
The total internal-external trips from Zone 1 to External Station B are 15. The assignment of these trips depends on the accessibility from Zone 1 to the external station B. Nine (9) of the 16 trips (depending on the accessibility from Zone 1 to the road network) will travel to External Station B by using upstream access points. The remaining six trips will travel to External Station B by turning left at the intersection.

The total I-E trips are 23 (9+14) for the EBT movement.

**Internal-Internal Trips**

There are internal-internal production trips from Zone 1 to Zones 2, 3 and 4, and from Zone 2 to Zones 1, 3 and 4. The internal-internal production trips from Zone 1 to Zones 2 and 3 and from Zone 2 to Zones 1 and 4 do not go through the subject intersection as they use other smaller connectors or accesses. The only applicable internal-internal production trips are between Zone 1 and 4 and Zones 2 and 3.

The total internal-internal production trips from Zone 1 to Zone 4 (See Example 6-15) are 47 trips and from Zone 2 to Zone 3 are 18 trips. The internal-internal trip assignment from Zone 1 to Zone 4 and from Zone 2 to Zone 3 is based on the network accessibility assumptions.

On the side street, I-I trips from Zone 1 to 4 will take a couple different paths by either traveling through the intersection southbound (10 trips) or turning left (6 trips) as seen in the figure below. On the mainline, the I-I trips from Zone 1 to 4 will access the mainline mid-block and travel through the intersection eastbound (20 trips) or turn right at the intersection (12 trips). Of the 48 total I-I trips from Zone 1 to 4, only 20 trips are assigned to the EBT movement.

**EBT Assignment, Internal-Internal: Zone 1 to 4**

Likewise, between Zone 2 and 3, the I-I trips will either travel between the two zones by the side street or the mainline. On the side street, I-I trips from Zone 2 to 3 will either travel northward through the intersection (3 trips) or turn right (2 trips) as seen in the figure below. On the mainline, I-I trips from Zone 2 to 3 will turn left at the intersection.
(3 trips) or travel through the intersection to downstream accesses (10 trips). Of the 18 total I-I trips between Zone 2 and 3, only 10 trips are assigned to the EBT movement.

EBT Assignment, Internal-Internal: Zone 2 to 3

The total I-I trips on the EBT movement is 30 (20 + 10) from both zones.

Total Trip Assignment

The resulting total trip assignment is created by summing up the base year trips, the external trips and the internal trips as seen in the table below.

<table>
<thead>
<tr>
<th>Trip Type</th>
<th>Trips (vph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Year 30HV</td>
<td>525</td>
</tr>
<tr>
<td>E-E</td>
<td>431</td>
</tr>
<tr>
<td>E-I</td>
<td>25</td>
</tr>
<tr>
<td>I-E</td>
<td>23</td>
</tr>
<tr>
<td>I-I</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1034</strong></td>
</tr>
</tbody>
</table>

For Build Alternatives, the trip generation and distribution are fixed, so only the trip assignments need to be modified. The travel times would have to be determined for the new roadway network and then the trips assigned by the methods above.

6.11 Enhanced Zonal Cumulative Analysis

EZCA is not and shall not be considered the equivalent of a travel demand model, even though it uses similar techniques and tools. It should not be used for analysis other than the original use without coordination with TPAU to determine if significant re-evaluation and possible updating of information is required.
The enhanced zonal cumulative analysis (EZCA) methods provide a series of enhancements to the typical application of zonal cumulative analysis methods. The purpose of the EZCA application is to enhance traffic circulation and operations analysis that can account for details that are otherwise not captured in the cumulative analysis approach. The full application of these enhancements has also been referred to as the small community forecast tool (SCFT) methodology. The EZCA methods can be used wherever the regular zonal cumulative analysis process is used, as well as larger areas (greater than 10,000) that do not have a travel demand model in place. The development and application of the EZCA methods can be cumbersome and labor-intensive; however, the methods provide significant refinements and application beyond the typical zonal cumulative analysis. Larger areas will still require the manual spreadsheet-based setup, however, the enhanced zonal cumulative allows greater automation in trip assignment using VISUM (or other modeling assignment software). By using assignment software tools, the process can be streamlined to more closely resemble a travel demand model. The creation of an enhanced zonal cumulative analysis should be weighed against the creation of a full travel demand model. As with a travel demand model, analysts should coordinate with TPAU to determine if subsequent project application (i.e., use for project analysis beyond the original study) is appropriate for the scope and development of the EZCA. Appendix 6A provides a sample application of the EZCA process that was performed for Canby.

6.11.1 Process

The general process for developing an EZCA tool follows a similar process to the zonal cumulative analysis, while adding enhancements that address some of the key limitations. Primary enhancements include:

- **Scope of land use and trip assignment** - The major difference (enhancement) is to include an estimation of base year and future year total land use (and trips), instead of only using a growth increment. This allows redistribution and reassignment of existing trips that may occur due to adjacent changes in land use or the transportation network. For example, an existing trip from a residence to a grocery store may use a different route (assignment change) if a new street connection is build. Similarly, if a new grocery store is built and is located closer, the driver may decide to travel to this store instead of the other store (distribution change). This fundamental difference provides additional flexibility and options for project application.

- **Trip Matrix** – All trips in the network are typically assigned using a trip matrix, including existing trips. Fixed trips (such as driveway pass-by trips) can be added, but doing so removes trip assignment flexibility and routing effects due to network condition and changes. Existing count data is used for calibration purposes, but is not considered “background” trips.

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5 While larger areas may trigger development of travel demand model, in some cases full model development may not be feasible given project application needs and schedule. In these areas, EZCA may still provide an alternative tool for forecasting traffic volumes or other project application. An example of a larger area with EZCA application is Canby, Oregon, which had a population over 15,000 in 2010.

• **Trip assignment approach** - The EZCA utilizes an equilibrium assignment procedure that automates the routing choices with improved accuracy over manual assignment. Depending on the assignment software tool used, more detail such as link and/or nodal delay can be added to better represent the effects of congestion. This will allow a more responsive, accurate and comprehensive analysis of the base and future conditions. This approach provides two key benefits:
  o Fundamentally, assignment and routing is automated based on a comprehensive, analytical check of available routes and travel times.
  o Network detail (connector loading, street system, traffic control, etc.) can be scaled by project need, as described in Chapter 8 (Mesoscopic Analysis)\(^7\).

• **An iterative process of checks, back-checks, and balances** – The use of spreadsheets (land use summaries and matrix development) and assignment software (trip assignment) allows for a semi-automated process that can be used to perform iterative checks and testing.

• **Calibration of a base year “tool”** – Since all internal trips (rather than just the growth increment) are being estimated through land use, trip generation, trip distribution, and trip assignment, the network coding and analysis assumptions (including land use and trip generation) can be validated in a way that is not feasible with the standard TIA level and zonal cumulative analysis methods.

• **Various other enhancements that may be performed to refine a standard zonal cumulative analysis application**, such as data to refine land use development (Section 6.8.2) collection of Bluetooth data (Section 6.8.5) to inform external trip patterns.

The overall EZCA Process (Exhibit 6-8) is generally similar to the typical zonal cumulative analysis method. However, subtle differences exist as listed in Exhibit 6-8.

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The analysis results are impacted by the combined effects of the integrated EZCA components (land use, trip rates, loading locations, network coding, etc.). For this reason, it is important to balance the level of detail and effort that is put into each component to minimize compounded errors. For instance, trip generation relies on both land use and trip rates. A perfect inventory of land uses will not provide true enhancements to this procedure unless trip rates are also appropriate.

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\(^7\) Typical applications of EZCA will include an all-street system reflecting comprehensive traffic control, as described in Windowed Area Models.
Exhibit 6-8 EZCA Process

Create Base Year Forecast

- Land Use Inventory (S)
- Roadway Network Coding (A)
- Trip Table Estimation (Generation and Distribution) (S)
- Trip Assignment (A)
- Error Checking (S, A)
- Network Edits / Calibration (A)
- Analysis

Future Year Scenario

- Network Edits for Future Year (A)
- Create and Import Trip Table to Future Year Network (S, A)
- Assignment (A)
- Validation of Reasonable Assignment (S, A)
- Post Process (S)

Note: Typical tools for the above process include spreadsheets and the traffic assignment software. Steps noted with (S) are typically conducted in a spreadsheet, while those marked with (A) are typically performed in the assignment software.
### Exhibit 6-9 Comparison of Standard Zonal Cumulative Analysis and EZCA

<table>
<thead>
<tr>
<th>Zonal Cumulative Analysis Step (Standard Approach)</th>
<th>Enhanced Zonal Cumulative Analysis (EZCA)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Set Up</strong></td>
<td></td>
</tr>
<tr>
<td>1- Identify the study area and divide into</td>
<td>Study area typically whole community or large subarea</td>
</tr>
<tr>
<td>transportation analysis zones (TAZ)</td>
<td></td>
</tr>
<tr>
<td>(Step not used)</td>
<td>Set up the transportation network coding</td>
</tr>
<tr>
<td><strong>Land Use &amp; Trip Generation</strong></td>
<td></td>
</tr>
<tr>
<td>2- Identify vacant lands, in-process developments, comprehensive plan allowed land uses/densities, and development rates.</td>
<td>Determine all existing and future land use totals (not just growth)</td>
</tr>
<tr>
<td>3- Estimate future trip generation potential</td>
<td>Estimate existing trips using ITE average trip rates as the initial assumption.</td>
</tr>
<tr>
<td><strong>Trip Distribution</strong></td>
<td></td>
</tr>
<tr>
<td>4- Determining the through trip</td>
<td>Approximation by subtraction procedure is difficult due to larger network size, and typically need OD data such as Bluetooth.</td>
</tr>
<tr>
<td>percentages (external – external, E-E) and E-E trips for the external stations</td>
<td></td>
</tr>
<tr>
<td>5- Determining the internal – external (I-E) and external – internal (E-I) trips at each external station (internal zone)</td>
<td>Completed for all trips, not just growth increment.</td>
</tr>
<tr>
<td>6- Determining the trip distribution for the</td>
<td>Complete for all trips, not just growth increment.</td>
</tr>
<tr>
<td>internal – external (I-E) and external – internal (E-I) trips for each internal TAZ.</td>
<td></td>
</tr>
<tr>
<td>7- Determining the trip distribution for the</td>
<td>Complete for all trips, not just growth.</td>
</tr>
<tr>
<td>internal-internal (I-I) trips</td>
<td></td>
</tr>
<tr>
<td><strong>Trip Assignment</strong></td>
<td></td>
</tr>
<tr>
<td>8- Calculating network link travel times</td>
<td>Not done manually. Assignment software uses the “free flow” travel time as the initial assumption (updated through an iterative assignment process) based on link and/or nodal travel times. Link delay may be needed to account for congestion on free-flow facilities.</td>
</tr>
<tr>
<td>9- Assigning total trips to the network</td>
<td>Not done manually. Assignment software is used.</td>
</tr>
<tr>
<td><strong>Additional Steps for EZCA</strong></td>
<td></td>
</tr>
<tr>
<td>(Step not used)</td>
<td>Calibration of tool estimation of traffic volumes compared to counts</td>
</tr>
</tbody>
</table>

Although this process is not a travel demand model, many of the elements are similar so general background information can be obtained from the Modeling Procedures Manual for Land Use Changes (MPMLUC) on the Transportation Planning website under Analysis Procedure Manual Version 2 6-55 Last Updated 10/2014
The following sections provide details for each component of the ECZA process, with a focus on methods that differ from the standard zonal cumulative analysis approach. Unless otherwise noted, the approach generally follows Section 6.8.

6.11.2 Land Use

Land use inventories for EZCA are required similar to the standard zonal cumulative analysis approach (typically collected at the parcel level and aggregated to the zonal level), with the following differences:

- Inventories include all land use, not just the growth increment. For this reason, both base year and future year inventories are developed for the study area.
  - Base year inventories should be consistent with traffic data that was collected for calibration.
  - Future year inventories include not only development, but potential redevelopment as well.
- The study area is typically comprised of a large area, and may even represent an entire community. Larger study areas that encompass the entire community provide the ability to compare to coordinated population projections that may not provide as much value to a smaller area.
- The land use data is typically grouped into five main categories – households (which may be split between single family and multifamily uses), retail employment, service employment, education employment, and other employment. However, these categories may vary by application depending on the community, allowed zoning uses, and context. These land uses should generally correlate with ITE categories or combinations of ITE categories based on related uses that exist in the community. For instance, a community may have the following uses, grouped as shown:
  - Single Family Residential Household
  - Apartment/Condo
  - Retail Employment (Gas station, Fast Food, Bank, Shopping Center)
  - Service Employment (Strip mall offices, auto shops, and specialty shops that do not generate as many trips as active retail uses)
  - Education Employment
  - Other Employment (Office Park, Industrial Uses)
- Land use inventories are aggregated to transportation analysis zones, as shown in Exhibit 6-10.
- For future conditions, the future population projection from the analysis must be consistent with the county-coordinated population forecast for the city. The future employment needs to be at a level that can be supported by the population in the study area. The future employment and population must be consistent with

8 The Modeling Procedures Manual for Land Use Changes, ODOT Transportation Planning Analysis Unit, February 2012 identifies employment ratios that are reasonable.
the local jurisdiction’s comprehensive plan. The analyst will need to consult with the local jurisdiction to determine where future growth is to be allocated. The local jurisdiction will also need to review the final allocations for consistency. The modular integration of the EZCA elements allows the ability to easily test different land use scenarios (update trip generation and copy resulting trip matrix to assignment software).
### Exhibit 6-10 Sample Land Use Totals (Households and Employees) by TAZ

<table>
<thead>
<tr>
<th>TAZ</th>
<th>HH_BASE</th>
<th>RETL_BASE</th>
<th>SERV_BASE</th>
<th>EDUC_BASE</th>
<th>OTHER_BASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>26</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>102</td>
<td>9</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>103</td>
<td>295</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>104</td>
<td>68</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>105</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>106</td>
<td>149</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>107</td>
<td>175</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>108</td>
<td>162</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>109</td>
<td>163</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>110</td>
<td>131</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>111</td>
<td>70</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>112</td>
<td>109</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>113</td>
<td>66</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>114</td>
<td>164</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>115</td>
<td>140</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>116</td>
<td>85</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>117</td>
<td>63</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>118</td>
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<td>13</td>
</tr>
</tbody>
</table>

#### 6.11.3 Roadway Network

The standard application of zonal cumulative analysis can require rigorous manual calculations and checks to determine appropriate assumptions about travel time and vehicle routing. As an enhancement, assignment software can be used to provide a
platform for assigning the trip matrix in place of manual assignment methods. This enhancement provides a technical basis (such as travel time or other factors) for assumptions related to trip routing. For this reason, the roadway network needs additional detail that is not typically included in a standard travel demand model (See network details in Chapter 8 regarding mesoscopic modeling and subarea models).

The network should include, at a minimum, arterial and collectors within the study area. Local streets may also be desired. Additional details can be added which include posted speeds, traffic control, lane geometries and the number of travel lanes. The analyst in consultation with the local jurisdiction must determine whether committed (funded), financially constrained and/or all planned projects are to be added to the future network. Elements of the transportation network should include:

- **Link (Street) Detail**
  - Location – the more roadways included the more flexibility of assignments is included, specifically roads that are subject to cut-through traffic and any roads that are parallel to major routes. Some software allows for importing GIS shapefiles from sources such as local agency inventories, or the Open Street Network which has much of this information. However, the amount and accuracy of this data needs to be (field) verified or edited. More links in the network does not necessarily increase the accuracy of the assignment results, and care should be taken with calibration.
  - Speed – free flow speeds initially based on posted speeds. In some cases the addition of a volume-delay-function (vdf) may be needed to account for delay accrued on uncontrolled facilities.
  - Lanes – number of lanes based on field conditions. This input affects the number of fully developed approach lanes at intersections and is utilized for intersection geometry and delay.

- **Node (Intersection) Detail**
  - Control – type is specified based on field inventory and is used to calculate the turn-based travel delay using HCM methodology for the given control type. Calibration may require modifying the control (i.e. yield to stop) to better match field operations.
  - Lane Configuration – (turn lanes) based on field inventory to determine the intersection turn delay

- **Zone Detail**
  - Centroid connectors represent the non-modeled minor streets and accesses within a zone to load trips from a TAZ centroid onto the network. Extra connectors should be added, as needed to represent a particular network scenario, to distribute trips from the TAZ to match the loading of the trips onto the network such as from new roads, minor streets and off-street parking.
6.11.4 Trip Table Estimation

Trip table estimation is a component that appears generally similar, yet is fundamentally different between the zonal cumulative analysis and EZCA. One notable deviation from the zonal cumulative analysis is including all trips in the forecast rather than just the growth component. This develops volumes for the base year that can be used to calibrate the analysis tool, as well as providing more reasonable trip distributions. The approach of distributing only new growth does not allow for the redistribution of existing trips. For this reason, all trips, including those that are currently part of the roadway system, are estimated in the trip table as E-E, E-I, I-E, or I-I trips (see Section 6.8 for additional information about trip types and distribution).

Trip Generation

External Trip Ends

- There are three steps to prepare for the distribution of external trips. First, the number of external trip ends is estimated based on design hour volumes at external nodes. Second, these external trip ends are separated into external-external (E-E), external-internal (E-I), and internal-external (I-E) trips. Third, projected future growth rates are applied (to determine future trips levels). The base year external trip ends are based on 30th HV design volumes at key gateway locations (Design Hour Volumes at External Nodes).
- Traffic counts should be collected at major external gateways.
- The impact of low volume external gateways (typically minor rural roads serving less than 50 vehicles during a peak hour\(^9\)) that do not serve as major regional connections may be important to the overall estimation of the trip table, but it may not appropriate to consume data resources collecting detailed traffic data at each location. The total number of external gateways needs to be coordinated and agreed upon with TPAU. For example, many communities have rural roads that extend outside the UGB that connect to outlying homes but do not provide regional connections to other communities. The traffic volumes at these gateways may be initially estimated based on agreement and coordination with TPAU and a combination of the following resources, as available:
  - An inventory of the land uses (typically number of homes) that are likely to be served.
  - Adjacent traffic counts with an assumption made about the difference in demand that would result. While traffic counts may not be collected at these specific gateways, there should be other internal network counts that are collected at key junctions that can be used to estimate if the inventory is reasonable. Counts that are too far away with many intersecting roads may result in overestimation at the gateway and a tube count should be obtained at these locations.
- Future external trip ends are estimated based on forecasted growth at each of the external gateways. The FVT growth projections are utilized to estimate the growth rate at the external gateways.

\(^9\) This general threshold may vary based on the context of the area and system connectivity.
Internal Trip Ends

- The number of internal trip ends is determined using land use trip generation methodology by applying ITE trip rates to the land uses described in Section 6.9.2. In some cases, combinations or “blended” rates that represent multiple ITE uses and trip rates may be used depending on the grouping of land use categories. For instance, if a single category is used for households and both single family and multifamily homes are present, a blended rate that combines both the single family rate and multifamily rate may be used. For these cases, combinations of trip rates should be used that are representative of the land uses occurring in the community and reflected in each general land use category.

- National average ITE trip rate data may not reflect the unique characteristics of the study area. When sufficient data is available, trip rates may need to be adjusted during the calibration process. Any adjustments to the ITE trip rates need to be documented and reviewed by TPAU. (See calibration section for additional detail). Exhibit 6-11 shows a summary of land use and trips (inbound) for each zone.
## Exhibit 6-11 Sample Internal Trip Generation (Trips Inbound) by Zone and Land Use

<table>
<thead>
<tr>
<th>TAZ</th>
<th>Land Use (HH, EMP)</th>
<th>Trips (Inbound)</th>
<th>Total Trips</th>
</tr>
</thead>
<tbody>
<tr>
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<td>RELT_BASE</td>
<td>SERV_BASE</td>
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</tr>
<tr>
<td>130</td>
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<td>105</td>
</tr>
</tbody>
</table>
**Trip Distribution**

Trip distribution estimates the percentage of trips from any one zone to another. In this analysis, trip distribution and generation are used to define the vehicle trip tables that are incorporated into the existing and future tools.

Distribution is based on the trip ends generated as either productions or attractions for each zone. The productions and attractions are used to determine an attraction probability and production probability for each zone relative to other zones in the network.

Trips are distributed between TAZs using two trip tables:
1. **Production Trip Table** – Each zone’s productions are multiplied by the other zone’s attraction probabilities resulting in a set of trips from one TAZ to every other TAZ.
2. **Attraction Trip Table** – Each zone’s attractions are multiplied by the other zone’s production probabilities resulting in a different set of trips from each TAZ to every other TAZ.

The distribution procedure includes the following steps:
1. Distribute E-E trips based on data collected from origin-destination study (such as Bluetooth data collection)
2. Allocate remaining external trips to E-I and I-E, based on directionality, as applied to zonal cumulative analysis.
3. Allocate remaining internal trips to I-I based on the attraction and production probabilities as done in the zonal cumulative analysis, resulting in a productions trip table and an attractions trip table. These steps need to be performed for trips generated by household land uses and then for trips generated by employment land uses. Household-based trips should use only employment land uses to calculate attraction and production probabilities.
4. Unlike a zonal cumulative analysis, this method requires the creation of a single I-I trip distribution table. To balance the trip productions and attractions and avoid double counting (since the trip generation process identifies trip ends, and every trip has two trip ends), the production and attraction trip tables must be averaged to result in a final I-I trip table.
5. The I-I trip table is combined with the I-E and E-I trip tables to address all identified internal growth. The E-E trips are then added to complete the trip table for all growth. The resulting trip table will be used as the input into the trip assignment tool. This procedure was followed for both the base and future years.
6.11.5 Trip Assignment

The use of Visum (or other assignment software) facilitates this trip assignment process by incorporating intersection delay which allows for the higher level of detail for approach delay. Route selection is set by the shortest path based on travel times between locations. The Visum travel times include both link (street) and node (intersection) components. The intersection delay in Visum is based on Highway Capacity Manual (HCM) methods. Including the concept of intersection turn delay allows for a greater level of detail than zonal cumulative analysis, and allows for comparing future network alternatives. Because this process has more HCM intersection level-detail, less calibration of and post-processing adjustments of turn movements are needed. In some cases link delay (in addition to free flow travel time) may also be considered using a volume delay function (vdf) to account for delay on uncontrolled facilities.

Other link-based tools like EMME can be used in place of a turn-based delay component, but requires more detail in the vdfs than is typically included. The route selection is also set by the shortest path based on travel times between locations. Because this is link-based delay, this method will take more calibration to match field conditions. Traffic assignment is applied in an iterative process until equilibrium is reached, similar to a travel demand model.

6.11.6 Calibration

The calibration process requires an iterative approach that assesses how well the EZCA tool is performing relative to real-world data (such as traffic counts). The integrated enhancement components allow for feedback in the form of “model error” if the tool is not performing well. Such error could be a result of many individual or combined factors, so it is important to have a systematic approach for calibrating and validating the tool prior to project application.

The calibration process includes three tiers, which should be approached in the following order:

1. Error Checking – Check for indication that an entry error has been made. Potential errors may include an allowable turn being closed in the travel network, incorrect stop sign orientation, or missing zone connectors, etc.
2. System Issues – Check for issues related to overall system assumptions. These issues may include system-wide trip generation rate used for all households in the system.
3. Spot Location Issues – Issues that are localized and do not have a greater system effect (such as local circulation patterns in the assignment that that do not match turn movement data and local circulation patterns).

Calibration Measures
Qualitative calibration checks outlined in Chapter 8 (Mesoscopic Analysis) should be used depending on the scale of the traffic assignment network. Typically, a windowed subarea-model will provide a similar approach. However, since the EZCA is not based on...
a travel demand model, there are additional checks and considerations.

The following series of checks should be used through the calibration process.

- Do assigned traffic patterns match general routes that are observed?
- Do traffic counts match data for roadway segments and the specified intersection turn movements? Calibration compares assigned volumes to the base year 30th Highest Hourly Volumes (30th HV) on links and nodes. Typically the volumes should be within 10% of each other. Major outliers should be investigated and remedied, as feasible.
- Do systematic comparisons of model error indicate that the tool is generally reflecting count data? A plot comparing the existing traffic counts and the base year tool volumes for all study intersection turn movements should be analyzed to evaluate the accuracy of the tool. In addition to a visual verification of the goodness of fit, the following quantitative measures should also be considered:
  - The slope of the fitted curve should be close to 1.0. This value is generally indicative of how the overall magnitude of traffic estimated by trip generation compares to the traffic counts. A value of 1.2 would indicate that the estimated volumes are generally skewed 20 percent higher than the existing counts.
  - The $R^2$ value should also be close to 1.0. This value generally indicates how well the estimated volumes fit the observed, target volumes.

Exhibit 6-12 demonstrates a plot of the estimated turn movement volumes with the observed (counted) volumes. The slope of the fitted curve is 1.025, indicating that the model volumes are generally only two percent higher than the existing counts and that the trip generation is appropriate and does not require further refinement. Furthermore, the $R^2$ value of 0.976 indicates that the model volumes are consistent with the target volumes.
Both system metrics are equally important and should be considered. An R2 value of 1.0 with a slope of 1.5 does not indicate a calibrated tool (since volumes are consistently being overestimated by 50%).

Calibration processes may include the adjustments to account for the following items. The resulting impacts of adjustments to these parameters can easily be measures using the calibration measures to determine if the adjustment is beneficial to the overall calibration of the tool. Model calibrations are performed in an iterative process to determine the relative effect of each calibration measure.

- Pedestrian Conflicts - The pedestrians crossing a roadway influences the capacity and travel time of the corridor. The additional delay attributed to vehicles stopping for pedestrians can be emulated using “dummy traffic signals” at midblock locations.
- Street Speeds – Speeds on some links may need to be adjusted to account for driver behavior, such as increasing the speed on a downtown link to have it remain as a primary attractive route. Conversely, lowering the speed on a link will make it less attractive, so trips use other routes.
- Centroid Connectors – These connections may be needed to added, deleted or
changed to match the field operations within the study area. It may be determined that an initial approximation for centroid loading did not provide adequate detail and additional refinements (such as additional spreading of demand within the zone) may be needed.

- **Trip Generation Rates** – It may be that an individual land uses (such as residential or industrial uses) are isolated in the network with limited access, in a way that allows for determining how many actual trips (from count data) are being generated by the use. If the land use is sufficiently intense, it may provide adequate data to determine that a modification or reconsideration of the trip generation rates are needed. Any modifications of rates or uses need to be reviewed by TPAU. The following adjustments may need to be explored, in the following order:
  
  o Consideration for a “special trip generator” in unique cases that a location exists that isn’t reflected in the overall land use and trip generation estimates. These uses could include major landmarks, recreational areas, or tourist destinations that have more traffic than would be otherwise estimated using typical land use categories and rates. An example could be a waterfront area or park that is regionally popular. Sufficient traffic count data should be available to estimate the trips generated by such uses. The application of such uses and rates would generally be limited to a single zone or small set of zones, relative to the overall number of zones in the network.
  
  o For more comprehensive or system-wide trip rate adjustments, the assumptions about representative ITE uses and rates (Section 6.9.4) may need to be reexamined. Such assumptions could include both the selected types of representative land uses as well as the overall share or weight within the category.
  
  o Finally, it may be determined that a local trip generation rate is a better fit than the national average rate\(^\text{10}\). Adjustments to account for local trip rates that differ from the ITE national average should be taken with care and only performed in cases where there is sufficient traffic data to support the adjustment. Such traffic data would typically include a combination of a network-wide calibration measure (slope) that indicates an overall trend of traffic estimation being too high/low and specific traffic count locations that serve to somewhat isolate a homogenous set of land use (for example a gated community or other large development, residential or commercial, with limited, consolidated access points). Adjusted rates should typically stay within 25% above/below the average ITE rate and include data that was used for the basis of the adjustment.

- **Zone Trips (Land Use or Trip Rates)** – **Origin-Demand Matrix Estimation (ODME)** can be used as a general tool to indicate zones or O-D pairs that are skewing the calibration of the model. While the raw results of the ODME should not be applied directly to the model, running ODME can be used to discover

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\(^{10}\) Adjustments made to trip rates should be made on the basis of traffic count data and taken with care. Areas that are forecasted to have larger amounts of land use growth have a higher sensitivity to adjustments that are made to trip generation rates.
zones that may require additional investigation into assumed land uses and/or trip rates for those land uses.

Because the EZCA process uses travel demand assignment software, the resulting volumes must be appropriately post-processed like other travel demand model outputs for formal traffic alternatives analysis\textsuperscript{11}. However, depending on the amount of data and calibration success, turn-based post-processing may be feasible. See Section 6.12.1 for additional detail on post-processing traffic volumes.

6.12 Urban Travel Demand Models

6.12.1 Post Processing Methods

Growth Method

The Growth Method uses growth equations to calculate future design hour volumes. Caution should be used with the method as it may severely overestimate growth on links that have little volume in the base year and significant volume in the future year. The basic form of the growth method (per NCHRP Report 765\textsuperscript{,} the replacement for the old Report 255) is:

\[
\text{Future model year} / \text{Base model year} = \text{Future DHV} / \text{Base 30 HV}
\]

Example 6-17 Post-Processing – Growth Method, No Build

- Example: 2035 DHV = (2035 Model / 2014 Model)\textbullet{} 2014 30 HV
- If the 2035 Model had 800 vph, the 2014 Model had 50 vph and the 2014 30 HV had 550 vph, the growth method using a simple linear method would be:

\[
2035 \text{ DHV} = (800/50)\textbullet{} 550 = 8,800 \text{ vph}
\]

Note that the future model year link volume is 16 times that of the base model year. Large differences like this will result in a volume overestimation and indicate that another method should be used.

Difference (Incremental) Method

The Difference (Incremental) Method should be used in areas where large differences in base and future model link volumes exist. This method is preferred in NCHRP Report 765. The basic form of the difference method is:

\[
\text{Future DHV} - \text{Base DHV} = \Delta \text{DHV}
\]

\textsuperscript{11} Some preliminary alternative testing may be conducted within the forecast tool to inform a set of alternatives for further evaluation.
Future DHV = Base 30 HV + (Future model year – Base model year)

**Example 6-18 Post-Processing – Difference Method, No Build**

2035 DHV = 2014 30 HV + (2035 Model -2014 model)

Using the same numbers from the growth method above, using the difference method would be: 2035 DHV = 550 + (800 − 50) = 1,300 vph.

Comparing the results between this and the above example show that this example represents the more appropriate, truer value to use.

**Selection of Method to Use**

Both methods should be compared in a spreadsheet on a directional link basis using percent and absolute difference. Areas with large percent and absolute differences (greater than 10-15%) should use the difference method. Areas that compare favorably can use one or the other or an average of the two (a.k.a. Average or Combined Method). The analyst will need to analyze the data to find the natural breakpoints of when and where to use each method.

The two previous examples show the large difference between the growth and difference methods where the growth method overestimates the future 2035 volume because the base year model volume is much smaller than the future model year volume. In this case the difference method would be used.

If the 2014 Model had 600 instead of 50, the growth method would result in 733 vph and the difference method would result in 750 vph. When the base and future models are closer, the results from the two methods are much closer. In this case, the growth method or an average of the growth and difference method would be used.

Adjacent link growth rates can be averaged together to reduce the number of calculations/adjustments necessary if they are close together (less than 10%).

**Spreadsheet Application**

A spreadsheet is necessary to track the post-processing calculations, especially on larger networks. A sample spreadsheet area is shown in Exhibit 6-13. Directional links are represented as rows. Columns represent the post-processing calculations through Step 4. In this case, since the model base and future years do not match the project existing and future years, they are adjusted according to the following formula:

Existing Year Model Volume = Base Year Model Volume x (1+ Annual Growth Rate x (Project Existing Year - Model Base Year))
The growth and difference methods are then applied. In the spreadsheet, conditional formatting was used to help identify links where the difference in future year volumes between the difference and growth methods exceeded 10 percent, in which case the difference method was selected, or where it is less than or equal to 10 percent, in which case the average of the two methods was used.
## Exhibit 6-13 Post-processing Spreadsheet, No Build

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<th>Route</th>
<th>Direction</th>
<th>From</th>
<th>To</th>
<th>Existing Year</th>
<th>Raw Model Base</th>
<th>Raw Model Future</th>
<th>Annual Growth Rate</th>
<th>Base Adj. to Existing Year</th>
<th>Future Adj. to Project Year</th>
<th>Difference Method</th>
<th>Growth Method</th>
<th>Percent Difference</th>
<th>Selected Method</th>
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<tbody>
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<td>SB</td>
<td>Tolo Rd</td>
<td>Kirtland Rd</td>
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<td>255</td>
<td>110</td>
<td>154</td>
<td>0.02</td>
<td>108</td>
<td>154</td>
<td>301</td>
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</tr>
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<td>Tolo Rd</td>
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<td>0.01</td>
<td>155</td>
<td>194</td>
<td>349</td>
<td>388</td>
<td>10%</td>
</tr>
<tr>
<td>OR 99</td>
<td>NB</td>
<td>I-5 SB Ramps</td>
<td>I-5 NB Ramps</td>
<td>2008</td>
<td>575</td>
<td>435</td>
<td>665</td>
<td>0.02</td>
<td>426</td>
<td>665</td>
<td>814</td>
<td>898</td>
<td>9%</td>
</tr>
<tr>
<td>OR 99</td>
<td>SB</td>
<td>I-5 SB Ramps</td>
<td>Eric Ave</td>
<td>2008</td>
<td>400</td>
<td>218</td>
<td>354</td>
<td>0.02</td>
<td>214</td>
<td>354</td>
<td>540</td>
<td>662</td>
<td>18%</td>
</tr>
<tr>
<td>OR 99</td>
<td>NB</td>
<td>Eric Ave</td>
<td>I-5 SB Ramps</td>
<td>2008</td>
<td>495</td>
<td>380</td>
<td>562</td>
<td>0.02</td>
<td>372</td>
<td>562</td>
<td>685</td>
<td>748</td>
<td>8%</td>
</tr>
<tr>
<td>OR 99</td>
<td>SB</td>
<td>Eric Ave</td>
<td>Seven Oaks Rd</td>
<td>2008</td>
<td>395</td>
<td>218</td>
<td>383</td>
<td>0.03</td>
<td>211</td>
<td>383</td>
<td>567</td>
<td>717</td>
<td>21%</td>
</tr>
<tr>
<td>OR 99</td>
<td>NB</td>
<td>Seven Oaks Rd</td>
<td>Eric Ave</td>
<td>2008</td>
<td>485</td>
<td>380</td>
<td>574</td>
<td>0.02</td>
<td>372</td>
<td>574</td>
<td>687</td>
<td>748</td>
<td>8%</td>
</tr>
<tr>
<td>OR 99</td>
<td>SB</td>
<td>Seven Oaks Rd</td>
<td>Jaybee Ln</td>
<td>2008</td>
<td>385</td>
<td>218</td>
<td>383</td>
<td>0.03</td>
<td>211</td>
<td>383</td>
<td>557</td>
<td>699</td>
<td>20%</td>
</tr>
<tr>
<td>OR 99</td>
<td>NB</td>
<td>Jaybee Ln</td>
<td>Seven Oaks Rd</td>
<td>2008</td>
<td>480</td>
<td>380</td>
<td>574</td>
<td>0.02</td>
<td>372</td>
<td>574</td>
<td>682</td>
<td>741</td>
<td>8%</td>
</tr>
<tr>
<td>Kirtland Rd</td>
<td>WB</td>
<td>High Banks</td>
<td>Blackwell Rd</td>
<td>2008</td>
<td>395</td>
<td>216</td>
<td>362</td>
<td>0.03</td>
<td>210</td>
<td>362</td>
<td>547</td>
<td>681</td>
<td>20%</td>
</tr>
<tr>
<td>Kirtland Rd</td>
<td>EB</td>
<td>Blackwell Rd</td>
<td>High Banks Rd</td>
<td>2008</td>
<td>340</td>
<td>133</td>
<td>202</td>
<td>0.02</td>
<td>130</td>
<td>202</td>
<td>412</td>
<td>528</td>
<td>22%</td>
</tr>
<tr>
<td>I-5 NB</td>
<td>WB</td>
<td>I-5 OFF RAMP</td>
<td>Blackwell Rd</td>
<td>2008</td>
<td>180</td>
<td>201</td>
<td>235</td>
<td>0.01</td>
<td>199</td>
<td>235</td>
<td>216</td>
<td>213</td>
<td>1%</td>
</tr>
<tr>
<td>I-5 WB</td>
<td>WB</td>
<td>Blackwell Rd</td>
<td>I-5 NB ON Ramp</td>
<td>2008</td>
<td>395</td>
<td>443</td>
<td>737</td>
<td>0.03</td>
<td>430</td>
<td>737</td>
<td>702</td>
<td>677</td>
<td>4%</td>
</tr>
<tr>
<td>Willow Springs</td>
<td>EB</td>
<td>RR</td>
<td>OR-99</td>
<td>2008</td>
<td>145</td>
<td>99</td>
<td>95</td>
<td>0.00</td>
<td>99</td>
<td>95</td>
<td>141</td>
<td>139</td>
<td>1%</td>
</tr>
<tr>
<td>Willow Springs</td>
<td>WB</td>
<td>OR-99</td>
<td>RR</td>
<td>2008</td>
<td>115</td>
<td>82</td>
<td>78</td>
<td>0.00</td>
<td>82</td>
<td>78</td>
<td>111</td>
<td>109</td>
<td>2%</td>
</tr>
<tr>
<td>Willow Springs</td>
<td>EB</td>
<td>OR-99</td>
<td>I-5 SB Ramps</td>
<td>2008</td>
<td>125</td>
<td>137</td>
<td>162</td>
<td>0.01</td>
<td>136</td>
<td>162</td>
<td>151</td>
<td>149</td>
<td>1%</td>
</tr>
<tr>
<td>Willow Springs</td>
<td>WB</td>
<td>I-5 SB Ramps</td>
<td>OR-99</td>
<td>2008</td>
<td>280</td>
<td>236</td>
<td>424</td>
<td>0.03</td>
<td>229</td>
<td>424</td>
<td>475</td>
<td>518</td>
<td>8%</td>
</tr>
</tbody>
</table>

1 Shaded cells indicate use of the Difference method. Non-shaded cells indicate use of the Growth method.
Basic Steps - Build Alternatives

The basic steps to developing future Build link volumes links are outlined below.

1. Start with Future No-Build DHV directional link volume set.
2. Review the Build Alternative assignment plots to see whether any manual reassignments are needed.
3. Compare the model future No-Build and Build scenarios. *Note that No-Build as used here may not be the exact same scenario as the typical Model No-Build that does not have any projects included. The requested output needs to have the appropriate projects identified and included in the scenario run.* To facilitate comparisons, difference plots (between Build and No-Build scenarios) may be obtained. If differences are within 10-20 percent, no further adjustments are needed and No-Build DHVs may be used for Build DHVs. Otherwise proceed to next step.
4. Adjust model year volumes to match project future year. The model future year must be adjusted up or down to match the project future year.
5. Apply growth and difference equations between No Build and Build scenarios (see examples below). For each directional link, select growth, difference or averaged methods following the guidance provided previously. This will result in preliminary directional link volumes.
6. Use screenlines to determine volumes on any links that are not in both No-build and Build model scenarios.
7. Calculate the inflows and outflows at each intersection based on link volumes. Determine the difference between the flows. The inflows and outflows must be equal for each intersection. Split the difference (typically 50-50) to each of the flows by increasing or decreasing link volumes in proportion to the total flow volume.
8. Determine intersection turn movements using a tool such as TurnsW32.
9. Re-balance network and round volumes to obtain Future Build DHVs.

Determining the Latent Demand Effect

Future Build link volumes are developed by comparing model assignments between the future Build alternative and the future No-Build. It is important to check for any latent demand effects where the Future Build volume is significantly greater than the Future No-Build volume, for the same year. Latent demand can occur where the Future No-Build demand has exceeded capacity, and a portion has shifted to other routes, destinations, modes, or time periods to avoid congestion. Once the facility is at capacity, peak hour volumes no longer increase over time, while latent demand may continue to grow. When a Build alternative alleviates the congestion, a portion of the shifted demand may return, which is reflected by an increase in the Future Build volumes.

Determining latent demand may be facilitated by requesting a model plot that compares the two model scenarios, such as plotting the difference or ratio between the Build and No-Build scenarios for each directional link. If the volume difference on each link is not
significant, i.e., less than 10-20 percent, then the future No-Build DHVs may be assumed to be the future Build DHVs. If the difference is significant (meaning that there is a latent demand effect), the appropriate growth or difference method should be determined and applied to the Future No-Build DHVs as shown in either of the two processes shown.

Growth Method:

1. Divide the Future Year Build model scenario volume by the Future Year No-Build model scenario volumes to derive the factor.
2. This factor is then multiplied by the Future Year No-Build Design Hour Volume to arrive at the Future Year Build Design Hour Volume (DHV).

**Example 6-19 Post-Processing – Growth Method, Build**

- Example: 2025 Build DHV = (2025 Model Build/ 2025 Model No-Build)* 2025 No-Build DHV
- If the 2025 Model No-Build had 800 vph, the 2025 Model Build had 1,000 vph and the 2025 No-Build DHV had 1600 vph, the growth method using a simple linear method would be:

\[
2025 \text{ Build DHV} = \left(\frac{1000}{800}\right) \times 1600 = 2,000 \text{ vph}
\]

Difference Method:

1. Subtract the Future Year No-Build model scenario volume from the Future Year Build model scenarios volumes *(Note: this change in volume can be either positive or negative).*
2. Add the difference to the Future Year No-Build Design Hour Volumes (DHV).

**Example 6-20 Post-Processing – Difference Method, Build**

\[
2025 \text{ Build DHV} = 2025 \text{ No-Build DHV} + (2025 \text{ Model Build} - 2025 \text{ Model No-Build})
\]

Using the same numbers from the growth method above, using the difference method would be: 2025 Build DHV = 1600 + (1000 – 800) = 1,800 vph.

**6.12.2 Screenlines**

Screenlines can be used for calculating overall growth rates or used for calculating volumes on new links (links that only exist in one of the scenarios that you are comparing).

Screenlines are useful where there are significant differences in growth within the study area. Screenlines should be strategically placed to cross the major links of the different analysis.
growth areas. Screenlines are drawn the same in both the base model year and the future model year on the model volume plots. The link volumes crossing each screenline are summed. The summation of each future screenline is divided by the corresponding base screenline summation. This provides the growth rate for the different areas cut by the screenlines.

**New Links**

The main use of screenlines is to determine the future design hour volume of links that exist only in one scenario. This comes up when a new route is added to a scenario. This can occur with both future no-build and build alternative scenarios.

**Example 6-21 Post-Processing – Use of Screenlines**

For example, assume a roadway network in the future no-build year had two north-south links at Main Street and Elm Street, but a build alternative added a new north-south link at Oak Street for a total of three north-south links. The analyst has the model outputs for the scenarios with and without the new connection and the future no-build DHV diagram (without the connection).

1. Draw a screenline across Main and Elm Streets in the future no-build model scenario, and sum up the future no-build model volumes for each street as well as the total north-south future model volume.

**Future No-Build Model Scenario**

```
<table>
<thead>
<tr>
<th>Street</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main St</td>
<td>450</td>
</tr>
<tr>
<td>Elm St</td>
<td>300</td>
</tr>
</tbody>
</table>
```

Main Street Total = 450 + 400 = 850 vph
Elm Street Total = 300 + 350 = 650 vph
Total North-South Volume = 850 + 650 = 1500 vph

2. Draw a screenline across Main, Elm and (new) Oak Streets in the build alternative scenario and sum up the build alternative model volumes for each street as well as the total north-south build alternative model volume. Calculate the street (link) splits and directional (northbound and southbound) splits for all three streets.
Build Alternative Model Scenario

Main Street Total = 350 + 300 = 650 vph
Elm Street Total = 100 + 150 = 250 vph
Oak Street Total = 600 + 500 = 1100 vph
Total North-South Volume = 650 + 250 = 2000 vph

Note: in this example, the build alternative scenario pulls in 33% more traffic (2000 vph vs. 1500 vph) than the future no-build model scenario. This is a result of previously diverting traffic returning to the route that it wants to use. In this case the analyst must use the build alternative model scenario to create the future design hour volumes. If the difference was less than 10%, then the analyst could use the future no-build volume distributed on the build network.

Link Split Calculation:
Main Street split = 650/2000 = 0.325 (32.5%)
Elm Street split = 250/2000 = 0.125 (12.5%)
Oak Street split = 1100/2000 = 0.55 (55%)

Directional Splits Calculation:
Northbound Main Street = 300/650 = 0.46
Southbound Main Street = 1 – 0.46 = 0.54
Northbound Elm Street = 150/250 = 0.60
Southbound Elm Street = 1 – 0.60 = 0.40
Northbound Oak Street = 500/1100 = 0.45
Southbound Oak Street = 1 – 0.45 = 0.55

3. Draw a screenline across Main and Elm Streets in the future DHV diagram, and sum up the total future DHV volumes for each street as well as the total future north-south DHV volume.
Future No-Build DHV

Main Street Total = 610 + 520 = 1130 vph
Elm Street Total = 350 + 390 = 740 vph
Total North-South Volume = 1870 vph

4. Calculate the total north-south build alternative DHV by creating a ratio by dividing the build alternative screenline grand total (Main/Elm/Oak Streets) by the future screenline grand total (Main/Elm Streets) and then multiplying this ratio with the future DHV screenline total (Main/Elm Streets).

General equation form:

\[
\frac{Build \ Alternate \ Model}{Future \ No - Build \ Model} = \frac{Build \ Alternative \ DHV}{Future \ No - Build \ DHV}
\]

Modified equation to solve for the total Build Alternative DHV:

\[
Build \ Alternative \ DHV = \frac{Build \ Alternate \ Model}{Future \ No - Build \ Model} \times Future \ No - Build \ DHV
\]

Build Alternative DHV = \(\frac{2000}{1500}\) x 1870 = 2493 vph

5. Using the Build Alternative DHV (from Step 4) and the link splits (from Step 2), determine the volumes for each of the streets. Oak Street would be calculated by:

Build Alternative DHV (Oak) = Oak Street split (from Step 2) x Build Alternative DHV total (from Step 4)

Build Alternative DHV (Oak) = 0.55 x 2493 = 1371 vph
Build Alternative DHV (Main) = 0.325 x 2493 = 810 vph
Build Alternative DHV (Elm) = 0.125 x 2493 = 312 vph

6. Compute the directional DHV for each street by applying the directional splits from Step 2 to the DHV totals for each street calculated in Step 5.
**6.12.3 Turn Movements**

Once all the link volumes have been determined from the standard or screenline post-processing methods, turn movements need to be calculated for each intersection.

Intersection volumes are represented at the turning movement level. It is important to note that the model is built and calibrated at the link level, not the turn level. Turn movement outputs from the model shall not be used directly in software for analysis. TPAU will not provide turning movement volumes for model requests; as they are typically misused to directly post-process turn movement volumes instead of following the link based post-processing procedure. Turn volumes should be developed from post-processed link volumes according to the procedures below.

Base Year turn movements should follow ground count patterns unless projects or other network differences are present in which case turn percentages are obtained from select-link runs. Future Year Turn movement percentages can be determined from select-link runs.

**Future No-Build Turn Volumes**

The volume of traffic entering each intersection must balance with the traffic leaving the intersection. If an imbalance exists, then inflow/outflow volumes will need to be balanced proportionally.

Typically the future no-build turning movement volumes are the same as the existing volumes.
(base) year movements with a growth factor applied. Impacts from other projects should show up in the future no-build model run, and would impact the growth rate or methodology used to calculate the future no-build design volumes.

There are times when another project is expected to impact the travel patterns in the study area, and the turning movements would have to be manually adjusted to reflect this. The turning movement percentages provided by the Future Year No-Build model select link runs can help point out some of these impacts. *(Note: A capacity constrained demand model should indicate the shift in travel patterns and the directional link volumes from the model should be used as a starting point to arrive at a future DHV. Arriving at a post-processed set of volumes requires a method such as described above or in NCHRP 765).* The origin and destination matrix can also be a helpful tool to obtain the distribution of trips between zones. Model runs with and without committed/STIP projects can be run to determine the impacts, if any, from nearby financially constrained future projects. After turn movements have been developed, the network needs to be re-balanced and volumes rounded to obtain Future No Build DHVs.

**Future Build Turn Volumes**

At this point the directional design hour volumes have been calculated for each link so the intersection approach volumes are known. The volume of traffic entering each intersection should balance with the traffic leaving the intersection. If an imbalance exists, then inflow/outflow volumes will need to be balanced proportionally.

Build turning movements are a combination of the known travel pattern changes and the existing turning movements. Model select-link assignments can be used as a starting place. Select-link plots will need to be requested to verify or modify the turning percentages. Developing the build turning movements in some cases is not a straightforward process. It may involve looking at all the possible movements and using the best judgment and knowledge of the area. Changes to turn volumes are also made as the intersection is balanced to hold the link volumes. The link volumes need to be held as much as possible to preserve the future growth ratios and/or differences. After turn movements have been developed, the network needs to be re-balanced and volumes rounded to obtain future Build DHVs.

There are matrix-based programs such as Turns W32 that assign turning volumes based on the link volume. These automate the [NCHRP Report 765](https://www.trb.org/Projects/765) Chapter 5 (Fratar volume balancing method) turning movement process, which can save considerable time over a hand calculation. The intersection approach link volumes and the exiting link volumes are entered. The programs typically assume that more traffic is attracted to the higher volume links and will weight the movements accordingly. The program goes through an iterative process to closely match the data that was entered. Most of these matrix-based programs require that inflows equal outflows for each intersection. If an imbalance exists, then inflow/outflow volumes will need to be balanced proportionally.

**Turns W32**
Turns W32 is a tool developed by Dowling Associates, Inc., which converts directional link volumes into turn movement volumes at intersections. Prior to use, flows in and out of the intersection must be balanced so that inflows equals outflows.

As shown in Exhibit 6-14, turn percentages are input into the upper part of the screen in Turns W32 rather than actual turn movement volumes. Preliminary future link volumes with balanced inflows and outflows are input on the lower part of the screen. The program will not process unbalanced inflows and outflows. The convergence value should be set to 100 percent. After iterating, the lower screen displays the preliminary future year turn movements. These turn movements need to be adjusted in the final step, which is to re-balance the network while holding the model link growth values as much as feasible.

**Exhibit 6-14 Turns W32 Screen**

![Turns W32 Screen](image)

**Example 6-22 Turns W32**

This example is based on the previous post-processing spreadsheet application shown in Exhibit 6-13. It is desired to determine Future Year turn movement volumes at the
intersection Blackwell Road at Kirtland Road. In this example, Kirtland at Blackwell Road is a tee-intersection. Future year directional link volumes at the intersection have been previously determined and are shown in the intersection diagram below.

### Initial Future Year Directional Link Volumes

<table>
<thead>
<tr>
<th>Initial Future Volumes</th>
<th>Unbalanced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>301</td>
<td>490</td>
</tr>
<tr>
<td>0</td>
<td>547</td>
</tr>
<tr>
<td>0</td>
<td>412</td>
</tr>
<tr>
<td>559</td>
<td>595</td>
</tr>
</tbody>
</table>

The first step is to ensure that the directional link volumes produce equal intersection inflows and outflows at the intersection, and to adjust them if they do not. In this case, the inflows are greater than the outflows. As shown in the table below, the inflows total 1443 and the outflows total 1461. Typically, an average of the two values is used.

In this example, the average of the inflows and outflows is 1452. Individual directional link volumes are then adjusted as follows for the EB outflow.

Initial EB outflow = 412.
Proportion of total outflows = 412 / 1461 = 0.28
Reduction needed = 1461 – 1452 = 9 vph
Adjustment = 0.28 x 9 = 2.5 ~ 3 vph
Adjusted outflow = 412 – 3 = 409

The adjusted intersection inflows and outflows are shown in the table below.

<table>
<thead>
<tr>
<th>Initial Future Volume</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inflow</td>
</tr>
<tr>
<td>EB</td>
<td>0</td>
</tr>
<tr>
<td>WB</td>
<td>547</td>
</tr>
<tr>
<td>NB</td>
<td>595</td>
</tr>
<tr>
<td>SB</td>
<td>301</td>
</tr>
<tr>
<td>Total</td>
<td>1443</td>
</tr>
<tr>
<td>Average</td>
<td>1452</td>
</tr>
<tr>
<td>Difference</td>
<td>9</td>
</tr>
</tbody>
</table>

The next step is to determine the initial turn movement percentages. In this example, the Base Year 2008 turn movement percentages are used. These turn percentages are...
summarized in the table below.

<table>
<thead>
<tr>
<th>Direction</th>
<th>Movement</th>
<th>2008 30 HV</th>
<th>Movement Percent of Approach Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>EB</td>
<td>Left</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>EB</td>
<td>Thru</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>EB</td>
<td>Right</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>WB</td>
<td>Left</td>
<td>215</td>
<td>54%</td>
</tr>
<tr>
<td>WB</td>
<td>Thru</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>WB</td>
<td>Right</td>
<td>180</td>
<td>46%</td>
</tr>
<tr>
<td>NB</td>
<td>Left</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>NB</td>
<td>Thru</td>
<td>220</td>
<td>47%</td>
</tr>
<tr>
<td>NB</td>
<td>Right</td>
<td>245</td>
<td>53%</td>
</tr>
<tr>
<td>SB</td>
<td>Left</td>
<td>95</td>
<td>37%</td>
</tr>
<tr>
<td>SB</td>
<td>Thru</td>
<td>160</td>
<td>63%</td>
</tr>
<tr>
<td>SB</td>
<td>Right</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

The final step is to input the balanced directional link volumes and the turn percentages into Turns W32. As shown in Exhibit 6-14, the turn percentages are entered into the upper half of Turns W32, while the balanced directional link volumes are entered into the lower half. The percent Convergence is set to 100%. Upon selecting Iterate, the program computes and displays updated turn movement volumes and directional link volumes. The analyst may need to make further adjustments to turn movements as part of rebalancing of the network.

6.12.4 Automated Post-Processing

Certain software tools perform post-processing internally. However, no tool can substitute for the need to manually check results for reasonableness. The analyst should have a good understanding of the internal methodology used in the software.

VISUM has an internal post-processing module. TPAU evaluated VISUM 10.0 by comparing its outputs to the manual method. VISUM provides an acceptable level of post-processing to determine preliminary link volumes. These volumes are sufficient for sketch planning level analysis or as input to further manual post-processing of turn movements for facility level analysis. However, VISUM’s internal turn movement post-processor was found to be inconsistent with the manual procedure since it does not balance intersection inflows and outflows prior to determining turn movements. For facility level analysis VISUM internally post-processed link volumes can be used if turn movements are post-processed manually.

There are other proprietary products from consultants (JRHMoves from JRH Engineering and Furness from CH2MHiIl) that have been evaluated and found to be consistent with NCHRP 765 for links and turn moves.
6.13 **Forecasting Truck Volumes for Pavement Design**

Because pavement design is based on the number of axle-loadings experienced on the roadway, heavy vehicle information needs to be furnished in a specific format. The pavement designer will contact the project traffic analyst for this truck information. The Pavement Services Unit (PSU) does all of the pavement designs for all ODOT projects, unless consulted out. Most of these projects are small operational improvements, pavement preservation or bridge replacement projects.

Pavement design volume requests either are at a scoping or project-specific level. All scoping-level requests are done internally by the PSU. A project-level request will need to be done by the project traffic analyst who could be a region project analyst, a consultant, or a TPAU analyst. These requests should be routed through the Transportation Systems Monitoring Unit (TSMU). TSMU will then forward the request to the appropriate project leader and then from there to the project analyst.

Requests of heavy vehicle volumes are e-mailed by PSU. These requests should include the project name, project limits, project type (scoping or project-level) highway name, and route number. They should also include any special needs such as breakouts on one-way facilities. In addition, the analyst should discuss factors that may influence the outputs and therefore the design with the pavement design staff involving the pavement designer. The discussions can help clarify the level and precision of the data required which may streamline the process.

Responses are typically transmitted via e-mails with a spreadsheet-formatted attachment showing: current and 20 year future Average Daily Traffic (ADT), a 20-year growth factor, and the current heavy vehicle volume by class (see Exhibit 6-16). If one-way ADT is requested, state direction and intersection leg, if applicable.

**General information and special considerations**

General truck growth rates are assumed to mirror the overall growth rate on a segment as calculated by methods described previously in this chapter. Vehicle classification specific growth rates are not available due to the lack of commodity and routing information. The trucking industry introduces new products, with different axle configurations, which have insufficient highway count data.

Before reporting out any data, the analyst should verify that there are no special considerations that need to be accounted for such as having count information that may reflect an average and not a typical vehicle mix. Sometimes a specific generator may not be directly accounted for that might require splitting a segment. Other considerations might include:

- Variations in vehicle classifications that are not accounted for such as vehicles with drop-axles that change the vehicle classification or the different configuration for a logging truck – 5-axle loaded logging trucks versus a 3-axle when the empty trailer is piggy-backed.
- Having a count taken in the summer on a route that services a local school, so it is missing the school bus volumes.
- Heavy generators such as mills, industrial areas, distribution centers, truck stops, or intermodal transfer facilities
- Periodic users, such as material/construction sites, logging or agricultural

The Federal Vehicle Classifications are shown in Exhibit 6-15. All vehicles are classified into one of the 13 categories. For example, class 6 is described as 3-axle, single unit which can be reported out as shown in Exhibit 6-16 with the information including the number of axles and trailers of each class. The truck volumes are also shown.
### Exhibit 6-15 Federal Vehicle Classifications

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Motorcycles</td>
<td><img src="image1" alt="Motorcycle" /></td>
</tr>
<tr>
<td>Class 2</td>
<td>Passenger cars</td>
<td><img src="image2" alt="Car" /></td>
</tr>
<tr>
<td>Class 3</td>
<td>Four tire, single unit</td>
<td><img src="image3" alt="Truck" /></td>
</tr>
<tr>
<td>Class 4</td>
<td>Buses</td>
<td><img src="image4" alt="Bus" /></td>
</tr>
<tr>
<td>Class 5</td>
<td>Two axle, six tire, single unit</td>
<td><img src="image5" alt="Truck" /></td>
</tr>
<tr>
<td>Class 6</td>
<td>Three axle, single unit</td>
<td><img src="image6" alt="Truck" /></td>
</tr>
<tr>
<td>Class 7</td>
<td>Four or more axle, single unit</td>
<td><img src="image7" alt="Truck" /></td>
</tr>
<tr>
<td>Class 8</td>
<td>Four or less axle, single trailer</td>
<td><img src="image8" alt="Truck" /></td>
</tr>
<tr>
<td>Class 9</td>
<td>5-Axle tractor semitrailer</td>
<td><img src="image9" alt="Truck" /></td>
</tr>
<tr>
<td>Class 10</td>
<td>Six or more axle, single trailer</td>
<td><img src="image10" alt="Truck" /></td>
</tr>
<tr>
<td>Class 11</td>
<td>Five or less axle, multi-trailer</td>
<td><img src="image11" alt="Truck" /></td>
</tr>
<tr>
<td>Class 12</td>
<td>Six axle, multi-trailer</td>
<td><img src="image12" alt="Truck" /></td>
</tr>
<tr>
<td>Class 13</td>
<td>Seven or more axle, multi-trailer</td>
<td><img src="image13" alt="Truck" /></td>
</tr>
<tr>
<td>Class 14</td>
<td>8 axle B-train double</td>
<td><img src="image14" alt="Truck" /></td>
</tr>
<tr>
<td>Class 15</td>
<td>10 axle resource hauling double</td>
<td><img src="image15" alt="Truck" /></td>
</tr>
<tr>
<td>Class 16</td>
<td>Triple trailer combination</td>
<td><img src="image16" alt="Truck" /></td>
</tr>
</tbody>
</table>
### Exhibit 6-16 Example Response Spreadsheet Attachment

<table>
<thead>
<tr>
<th>Project</th>
<th>Hwy 500 (OR 795) MP 77 - MP 83</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class</strong></td>
<td><strong>Descrip.</strong></td>
</tr>
<tr>
<td>4</td>
<td>buses</td>
</tr>
<tr>
<td>5</td>
<td>2ax</td>
</tr>
<tr>
<td>6</td>
<td>3ax</td>
</tr>
<tr>
<td>7</td>
<td>4ax</td>
</tr>
<tr>
<td>8</td>
<td>4ax trl</td>
</tr>
<tr>
<td>9</td>
<td>5ax trl</td>
</tr>
<tr>
<td>10</td>
<td>6ax trl</td>
</tr>
<tr>
<td>11</td>
<td>5ax dbl trl</td>
</tr>
<tr>
<td>12</td>
<td>6ax dbl trl</td>
</tr>
<tr>
<td>13</td>
<td>7ax dbl trl</td>
</tr>
<tr>
<td><strong>Total Trucks</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### Future Volume Tables

- 2010 AADT = 3000, 2030 AADT = 200

- % Trucks 3.43%
- 20-year growth factor = 1.4

The percent truck calculation is the total number of trucks divided by the base year AADT. For this exhibit this would be 103 / 3000 = 3.43%. The 20 year growth factor is the future AADT divided by the base year AADT or 4200 / 3000 = 1.4.

### Process

To prepare the data, knowledge of the highway characteristics in the area is helpful. While a field investigation is likely not practical, use of the ODOT video log, Transviewer GIS or other mapping aide should be used. There likely is more information readily available for use on state highway segments than on local jurisdiction roadways. The general state highway process takes advantage of currently available formatted outputs. The scoping-level process is used for scoping level requests or simpler projects. The project specific process is more detailed. These requests include intersection or straightaway classification counts and may involve local road segments or state highway segments that need special considerations are applied. A spreadsheet calculator, Heavy Vehicle Pavement Design Spreadsheet, has been developed to streamline the process for both scoping and project level request.

#### 6.13.1 Scoping Level

Using the state highway number, milepoint and other locational data, refer to the Traffic Volumes and Vehicle Classification Report available at:

[http://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm](http://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm)

This report provides overall and vehicle AADT volumes and vehicle classification by the Analysis Procedure Manual Version 2 6-85 Last Updated 10/2014
specified segment. The segments are determined by major intersections and other characteristics. Using this information, enter the following into the output spreadsheet (see Example 6-23) for each identified segment:

- Highway/road name
- Beginning mile point
- Effective date of data
- AADT
- AADT 20-YR
- Volumes for Class 4-13

Example 6-23 Scoping Level Project Forecast

As part of a pavement preservation scoping project process, the section of Highway #7 (US20) from M.P. 40 to M.P. 48, heavy vehicle counts were downloaded from http://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm. The AADT Volume, AADT 20-year Volume, Beginning M.P., and the volumes for Classes 4 through 13 were copied into the Heavy Vehicle Pavement Design Spreadsheet in the Scoping Level tab. The data is shown in the next table and the future forecasted results are shown in the following table.

<table>
<thead>
<tr>
<th>Project</th>
<th>Hwy 7 (US20) M.P. 40-48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Descript.</td>
</tr>
<tr>
<td>4</td>
<td>buses</td>
</tr>
<tr>
<td>5</td>
<td>2ax</td>
</tr>
<tr>
<td>6</td>
<td>3ax</td>
</tr>
<tr>
<td>7</td>
<td>4ax</td>
</tr>
<tr>
<td>8</td>
<td>4ax trl</td>
</tr>
<tr>
<td>9</td>
<td>5ax trl</td>
</tr>
<tr>
<td>10</td>
<td>6ax trl</td>
</tr>
<tr>
<td>11</td>
<td>5ax dbl trl</td>
</tr>
<tr>
<td>12</td>
<td>6ax dbl trl</td>
</tr>
<tr>
<td>13</td>
<td>7ax dbl trl</td>
</tr>
<tr>
<td>Total Trucks</td>
<td></td>
</tr>
</tbody>
</table>

AADTs
2013 ADT = 1200, 2033 ADT = 1300

20-year growth factor = 1.08

<table>
<thead>
<tr>
<th>Project</th>
<th>Hwy 7 (US20) M.P. 40-48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Descript.</td>
</tr>
<tr>
<td>4</td>
<td>buses</td>
</tr>
</tbody>
</table>
While the following example used future forecasts from the Future Volume Tables for the purpose of illustration, the volumes could have just as likely been derived from a cumulative analysis or a post-processed travel demand model. Choice of future forecasting methods is dependent on the study area, the project requirements, and the tools available. See earlier sections in this chapter.

Example 6-24 Simple Project Level Forecast

As part of a pavement redesign project, a new pavement structure needs to be designed. The pavement engineer on the project first needs to know the heavy vehicle volumes that need to be designed for. The engineer had a 2011 24-hour traffic count available at the project site and recorded the following data from it. The project base year is 2014 with a 2034 future year. The engineer also recorded the 20-year ADT from the Future Volume Tables.

<table>
<thead>
<tr>
<th>Axle Type</th>
<th>Number of Axles</th>
<th>Future Year Volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2ax</td>
<td>2</td>
<td>134</td>
</tr>
<tr>
<td>3ax</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4ax</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>4ax trl</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5ax trl</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>6ax trl</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>5ax dbl trl</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6ax dbl trl</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>7ax dbl trl</td>
<td>7 +</td>
<td>2 +</td>
</tr>
</tbody>
</table>

Total Trucks: 514
<table>
<thead>
<tr>
<th>Project</th>
<th>Hwy 2 (US730) M.P. 190 - 195</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Descript.</td>
</tr>
<tr>
<td>4</td>
<td>buses</td>
</tr>
<tr>
<td>5</td>
<td>2ax</td>
</tr>
<tr>
<td>6</td>
<td>3ax</td>
</tr>
<tr>
<td>7</td>
<td>4ax</td>
</tr>
<tr>
<td>8</td>
<td>4ax trl</td>
</tr>
<tr>
<td>9</td>
<td>5ax trl</td>
</tr>
<tr>
<td>10</td>
<td>6ax trl</td>
</tr>
<tr>
<td>11</td>
<td>5ax dbl trl</td>
</tr>
<tr>
<td>12</td>
<td>6ax dbl trl</td>
</tr>
<tr>
<td>13</td>
<td>7ax dbl trl</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Future Volume Tables**

2011 ADT = 2500, 2031 ADT = 2600

- % Trucks 42.3%
- 20-year growth factor = 1.04

The count information and Future Volume Tables’ information were entered into the Heavy Vehicle Pavement Design Spreadsheet and the results found recorded from the spreadsheet into the table below.

<table>
<thead>
<tr>
<th>Project</th>
<th>Hwy 2 (US730) M.P. 190-195</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Descript.</td>
</tr>
<tr>
<td>4</td>
<td>buses</td>
</tr>
<tr>
<td>5</td>
<td>2ax</td>
</tr>
<tr>
<td>6</td>
<td>3ax</td>
</tr>
<tr>
<td>7</td>
<td>4ax</td>
</tr>
<tr>
<td>8</td>
<td>4ax trl</td>
</tr>
<tr>
<td>9</td>
<td>5ax trl</td>
</tr>
<tr>
<td>10</td>
<td>6ax trl</td>
</tr>
<tr>
<td>11</td>
<td>5ax dbl trl</td>
</tr>
<tr>
<td>12</td>
<td>6ax dbl trl</td>
</tr>
<tr>
<td>13</td>
<td>7ax dbl trl</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Heavy Vehicle Pavement Design Spreadsheet calculator used in this example is shown below.
### Detailed Process for Local Roads or Highway Segments with Special Considerations

A more comprehensive process is required when pavement traffic data is needed for non-state facilities or when special considerations exist. This process should also be used when recent classification counts are available. This process is based on intersection or straightaway classification counts.

*Note: Additional classification counts may be necessary for longer preservation projects (or where there are no ATR/AVC’s on a particular highway) as counts are not typically obtained for this project type.*
Identifying Segments

To determine segments on state highways, use the Traffic Volumes and Vehicle Classification Report available at:

http://highway.odot.state.or.us/cf/highwayreports/trafficParms.cfm.

Break roadway into segments if AADT volumes change by more than twenty percent (20%). These initial segments need to be reviewed to see if the truck classifications (4-13) change by more than ten percent (10%). The higher classifications have more impacts of the road surface (since these are the heavier vehicles and/or have multiple axles). Note that the review needs to consider where an absolute number versus the percent change is significant. If there are questions whether a change is significant, the analyst should work with the pavement designer to determine if the segment break is necessary. The analyst needs to put greater importance on changes to the higher classifications. For example, an increase of five triple-trailer trucks (class 13) could cause a 50-100% increase with greater impacts than a 50% increase in delivery/panel trucks (class 5). When this occurs, the analyst may need to subdivide the segments to better identify the truck volumes.

For local roads, using the count/classification available, determine volumes at different points in the project. Break into sections if volumes change by more than twenty percent (although this changes on a case by case basis) or the project includes more than one highway. While the project may involve only one road, there may be differences in heavy vehicle volumes on each side of a major intersection or urban/rural environment change. A change, such as road classification, may not be reason to split a section, but may be a good place to look for a difference in heavy vehicle volumes. When a count is not available on a specific roadway, counts from similar facilities that serve the same areas may be used as a basis for an educated assumption of the truck percentages.

Count Data

To forecast truck volumes, obtain a 24-hour (less than three years old) full classification count(s) within or near the project. Since truck volumes typically increase overnight as a percent of total vehicles, every attempt should be made to obtain a 24-hour count. If the project has an Automatic Vehicle Classifier (AVC), then that data can be used as a count. Internal staff may look in the TCM or the count logs on the 6210 share to determine if counts are available. Consultants should contact the TSM staff. If a recent count is not available, and time permits, a full classification count could be requested. Counts on interchange ramps do not have classification data unless specifically requested (such as a freeway to freeway interchange where there are not any ramp terminal intersections), so this is generally obtained from a ramp terminal intersection count.

Determining Classification Volumes

For each intersection count, total the volumes by class for each leg that data is desired.
full classification count is shown in Exhibit 6-17.

### Exhibit 6-17 Traffic Count Sheet

<table>
<thead>
<tr>
<th>Traffic Count Axle Factor Sheet</th>
<th>Site: 2082012</th>
<th>Date: 5/30/2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>County: Benton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>City: RURAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway #:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milepoint: 53.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location: leg 1848 - n leg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count Number: 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather: Clear</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Direction From-To</th>
<th>Car</th>
<th>Li Truck</th>
<th>Sdn Unit Truck</th>
<th>Sdn Trailer Truck</th>
<th>Multi Trailer Truck</th>
<th>Bus</th>
<th>Motorcycle</th>
<th>Total All Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>North-East</td>
<td>31</td>
<td>38</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>84</td>
</tr>
<tr>
<td>North-South</td>
<td>303</td>
<td>437</td>
<td>22</td>
<td>67</td>
<td>1</td>
<td>1</td>
<td>16</td>
<td>671</td>
</tr>
<tr>
<td>North-West</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>East-North</td>
<td>23</td>
<td>48</td>
<td>5</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>88</td>
</tr>
<tr>
<td>South-North</td>
<td>314</td>
<td>363</td>
<td>21</td>
<td>62</td>
<td>9</td>
<td>1</td>
<td>13</td>
<td>850</td>
</tr>
<tr>
<td>West-North</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Total Volume</td>
<td>707</td>
<td>835</td>
<td>50</td>
<td>128</td>
<td>11</td>
<td>47</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Axie Factor</td>
<td>1.1</td>
<td>1.1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>3.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Veh O’Count</td>
<td>776</td>
<td>865</td>
<td>50</td>
<td>192</td>
<td>2</td>
<td>22</td>
<td>118</td>
<td>84</td>
</tr>
<tr>
<td>North-East</td>
<td>31</td>
<td>38</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td>84</td>
</tr>
<tr>
<td>East-North</td>
<td>23</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>85</td>
</tr>
<tr>
<td>South-North</td>
<td>14</td>
<td>28</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td></td>
<td>7</td>
<td>57</td>
</tr>
<tr>
<td>East-West</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>West-East</td>
<td>18</td>
<td>29</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>51</td>
</tr>
<tr>
<td>Total Volume</td>
<td>86</td>
<td>144</td>
<td>9</td>
<td>15</td>
<td>0</td>
<td>2</td>
<td>12</td>
<td>262</td>
</tr>
<tr>
<td>Axie Factor</td>
<td>1.1</td>
<td>1.1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>3.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Veh O’Count</td>
<td>95</td>
<td>158</td>
<td>9</td>
<td>23</td>
<td>0</td>
<td>4</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>North-South</td>
<td>303</td>
<td>437</td>
<td>22</td>
<td>67</td>
<td>1</td>
<td>1</td>
<td>13</td>
<td>871</td>
</tr>
<tr>
<td>East-South</td>
<td>14</td>
<td>28</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
<td>57</td>
</tr>
<tr>
<td>South-West</td>
<td>344</td>
<td>363</td>
<td>21</td>
<td>52</td>
<td>9</td>
<td>31</td>
<td>15</td>
<td>850</td>
</tr>
<tr>
<td>West-South</td>
<td>18</td>
<td>29</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>51</td>
</tr>
<tr>
<td>Total Volume</td>
<td>685</td>
<td>857</td>
<td>45</td>
<td>125</td>
<td>11</td>
<td>35</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>Axie Factor</td>
<td>1.1</td>
<td>1.1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>3.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Veh O’Count</td>
<td>754</td>
<td>343</td>
<td>45</td>
<td>188</td>
<td>2</td>
<td>22</td>
<td>68</td>
<td>84</td>
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<tr>
<td>North-West</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>East-West</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>South-West</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>West-North</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>West-East</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>West-South</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Total Volume</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Axie Factor</td>
<td>1.1</td>
<td>1.1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>3.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Veh O’Count</td>
<td>0</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
</tbody>
</table>
For each leg, there should be a total for each classification (4-13). Note this needs to include both directions (all the “to” and “from”) on the approach. This means that at a 4-legged intersection there are six movements to be summed. Once the table is filled out, the columns must be totaled to report the number of trucks by classification. If the manual count is less than 24 hours, an expansion factor (see Exhibit 5-19) needs to be applied (typically a 1.1 converts a 16-hour count to 24-hour volumes). These classification subtotals are then combined to report the total truck volume(s). The truck total is then divided by the ADT to give the percent trucks. The Heavy Volume Pavement Design Spreadsheet can be used to streamline the individual segment calculations.

**Growth Rate**

For state highways, record each year and its volume for the road segment from the Future Volume Table (FVT) into the calculation spreadsheet which will compute the growth factor. The analyst will need to review the FVT segments to determine which have appropriate r-squared values and can be averaged together to arrive at a segment growth rate (see Chapter 5).

Off-system growth rates would need to be determined with county or city data (off system data source), such as historical tube counts, travel demand model growth rates, similar facilities or other project information in the area (see Chapter 5). If historical data, state highways with similar characteristics, or a travel demand model does not exist for the particular site, use 2% for rural areas and 1% for urban areas per year.
Appendix 6A – Sample Application of Enhanced Zonal Cumulative Analysis (EZCA)
7 NOT YET WRITTEN – SEE APM VERSION 1
8 MESOSCOPIC ANALYSIS

8.1 Purpose

This APM chapter provides fundamental guidance and overview of an array of methods related to mesoscopic modeling. Mesoscopic methods are rapidly changing based on availability of new tools and data sources, such as the move towards activity based travel demand models. This chapter focuses on methods that have previously been applied in projects involving ODOT and is not intended to be comprehensive for all mesoscopic methods and tools. Other methods not documented in this chapter may be applied, if appropriate, through consultation with TPAU staff.

The purpose of this chapter is to provide an overview of methods and tools available to apply mesoscopic analysis. The information provided in this chapter is intended to provide the user with the information required to understand the general approach for scoping project methodology and understanding the differences between various methods along with limitations and advantages of using each method. For more details on many of the methods in this chapter also refer to NCHRP Report 765.

8.1.1 Overview of Chapter Sections

This chapter covers a broad array of topics related to mesoscopic analysis. Topics included cover:

- Scoping – How to identify approach, tools, and effort based on the analysis needs.
- Subarea Analysis – How to develop subarea models that increase the detail from an existing model.
  - Focusing – General procedures for adding detail and creating a focus area model within a regional model.
  - Windowing – General procedures for selecting an area to “cut” or “window” out into a separate model that can then have additional detail.
- Dynamic Traffic Assignment (DTA) – Analysis considerations and triggers that may lead to analysis that considers traffic routes and travel times that vary by time of day.
- Peak Spreading – General concepts and analysis considerations to identify how congestion spreads from peak periods to larger intervals and the impact on vehicle demand during shoulder periods.

Section 8.1.4 includes references to other chapters of the APM that provide material that may be related to mesoscopic methods covered in this chapter.
8.1.2 Key Definitions

Having a common understanding of the terms in this chapter is necessary for proper implementation of methods and tools. Definitions for terms included in this chapter are included in the Glossary. Selected terms that are needed for fundamental content are shown below.

- **Macroscopic** Model—Aggregate models that have a high-level view of the transportation system and do not include many transportation network details. Macroscopic travel demand models are generally large (potentially regional) in size and focus on general vehicle flows and route choice from one area to another. Streets may be approximated by the average number of lanes, a free-flow speed, and approximate vehicle capacity. Vehicle trips are routed through the network based on algorithms that select paths that minimize the travel time.

- **Mesoscopic** Model—A hybrid model that includes combinations or approximations of elements from both macroscopic and microscopic models. Mesoscopic models may include a routable network similar to a macroscopic model (with a supplementary origin-destination matrix), while also incorporating more detailed operational elements of the transportation network to better estimate travel time based on traffic operations similar to a microscopic model. Elements from either the macroscopic or microscopic models may be generalized or simplified.

- **Microscopic** Model—Detailed models that are at a fine scale and typically include all streets and components of the transportation system that impact travel. Such elements can include intersection control and striping, pedestrian crossings, transit stops, and even the inclusion of traffic calming measures. Microscopic models typically refer to simulation models that include randomized characteristics and behaviors of an array of drivers and vehicles as they traverse a network. The performance of these models is typically averaged over several “runs” to account for the randomized driver and vehicle characteristics. Unlike macroscopic models, traffic demand values are generally inputs and typically do not result from path choice within the model, therefore, there may not be a predetermined throughput. As a result, assigned traffic volumes at specific locations such as midblock or a turn movement may not match the input demand due to constraints on the network metering flow. For example, queues will build in a microscopic model and only vehicles that can make it through a bottleneck in a given time period will be observed.

- **Multi-Resolution**—The combined framework of an integrated series of models, each built or scaled for the appropriate level of “resolution” and detail given the context for project application and need. The individual model components (resolutions) each can be integrated for a particular project/analysis that benefits from the data analysis and output of the individual tool and level. General levels, or “resolutions”, that may be used to describe models or application that fit a
general context include microscopic, mesoscopic, and macroscopic models as shown in Exhibit 8-1.

**Exhibit 8-1 Multi-Resolution Spectrum Comparing Various Model Levels**

- **Highest Level (Least Detail) – Typically Regional Application**
- **Intermediate Level – Typically Subarea Application**
- **Lowest Level (Most Detail) – Typically Corridor Application**
8.1.3 Introduction to Mesoscopic Analysis

Transportation analysis methods have traditionally focused on two levels of detail, macroscopic and microscopic. **Macroscopic** analysis is concerned with system-wide travel movements; how much travel, of what types, when, how, and by what modes and major routes. Urban, regional, and statewide travel demand models are the primary tools used to do this level of analysis. These tools facilitate the evaluation of the effects of demographics, economics, land use patterns, transportation network configurations, and prices on travel patterns. These models assess how many trips are moving between areas (zones) and along which routes (links). Because they are not built for focused urban area studies they do not typically account for the influences on delay from turning lanes and signal or stop sign controls at intersections. Likewise, macroscopic models provide no information on the location and duration of queuing. Furthermore, they are not calibrated to the level of local streets and points of access to the network (e.g., parking locations).

**Microscopic** analysis is concerned with the operational performance of transportation facilities; traffic flow rates, queuing, speed, and delay. This level of analysis uses microsimulation models and highway capacity manual methods primarily. These tools facilitate the evaluation of the effects of localized land uses, roadway geometry, and traffic controls on traffic flow characteristics. However, most microsimulation models rely upon fixed post-processed traffic volume inputs from travel demand models to evaluate future year scenarios and are therefore only as good as the volumes put into them. Furthermore, project application of microsimulation models typically requires many hours devoted to model development due to the level of detail incorporated in the models. While these models provide a good estimation of traffic operations, they are often not practical to implement as a tool to evaluate or screen a large number of alternatives or a large analysis area.

One major difference between macroscopic and microscopic analysis is that macroscopic models use land use data as the primary input that dictates demand for travel, whereas microscopic use traffic volumes or vehicle trips as the primary input that dictates the demand for travel. The impacts of land use on travel demand are external to microscopic models and assumed to be already accounted for in the microscopic model’s traffic volume inputs. Likewise travel costs (e.g., fuel prices, the traveler’s value of time, transit fares) are direct inputs to macroscopic models dictating travel mode and route choices. These travel costs and decisions are external to microscopic models, and assumed to be already accounted for in the microscopic model’s traffic inputs.

These two levels of analysis (macroscopic and microscopic) are loosely coupled through the transmittal of link and turn volume data and the use of travel demand model post-processing methods. The flow of the data is from macroscopic to microscopic, and there is typically no feedback from microscopic to macroscopic (e.g. queuing calculations do not affect system travel calculations).

The following diagram illustrates these two levels of analysis and their connection.
Increasing attention is being given to the combination between the macroscopic and microscopic modeling levels, often referred to as “mesoscopic.” While the term “mesoscopic” can have various meanings for users in different fields and even to multiple users within the field of transportation, it generally is used to denote a hybrid of microscopic and macroscopic features. Exhibit 8-3 demonstrates the relationship between these three general fields.

**Exhibit 8-3 Mesoscopic Overlap between (and Potentially Combining) Macroscopic and Microscopic Modeling Process**

Traffic volumes from macroscopic models typically feed into microscopic models; however, these roles can be combined within mesoscopic models.

Exhibit 8-4 lists potential examples that summarize key comparisons among typical microscopic, mesoscopic, and microscopic models. These examples are provided for demonstrative purposes and actual characteristics of these models can differ.
### Exhibit 8-4 Summary of Typical Differences among Microscopic, Mesoscopic, and Macroscopic Models

<table>
<thead>
<tr>
<th>Model Element</th>
<th>Macroscopic</th>
<th>Mesoscopic (Potential hybrid)</th>
<th>Microscopic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Scale (Size)</td>
<td>Region-wide</td>
<td>Varies. Potentially region-wide, but may be smaller, depending on level of network detail and mesoscopic software</td>
<td>Typically a single corridor or small study area</td>
</tr>
<tr>
<td>Network Scale (Detail)</td>
<td>Regionally significant routes (generally collector and higher)</td>
<td>Varies. May include all public streets, but could include less depending on network size</td>
<td>All streets and major driveways</td>
</tr>
<tr>
<td>Intersection Detail</td>
<td>None (typically a simple node junction of streets without time-penalty and without geometric or control characteristics)</td>
<td>Generally includes types of attributes needed for HCM level analysis (intersection control, lane geometry, basic signal timing, etc.)</td>
<td>Full lane geometry and widths, turn bay lengths, traffic control and striping, signal timing detail for individual phases (if applicable)</td>
</tr>
<tr>
<td>Travel Time</td>
<td>Link-based travel times generally rely on volume-delay functions (vdf). Intersection delay is generally ignored or simplified.</td>
<td>Can have a combination of link and intersection travel time, though intersection delay may be less robust than microscopic models</td>
<td>Travel time is based on vehicle interaction and includes acceleration, deceleration, stopped delay and other associated factors</td>
</tr>
<tr>
<td>“Outputs” - Measures of Effectiveness (MOE) / Performance Measures</td>
<td>Vehicle hours of delay, corridor travel time, average distance traveled by users on a link</td>
<td>Provides general MOEs possible in both macro and micro models, without full detail (e.g. queue lengths and impacts) of micro models.</td>
<td>Intersection turn delay, corridor travel time, 95th percentile vehicle queue length, etc.</td>
</tr>
<tr>
<td>Routes / Assignment (Is route diversion possible?)</td>
<td>Yes (routes vary based on relative “cost” of all potential routes, typically travel times)</td>
<td>Yes</td>
<td>No (traffic volumes and route paths are typically a fixed input and route options/diversion are not present)</td>
</tr>
</tbody>
</table>
Needs

Mesoscopic analysis capabilities can help meet emerging analysis needs and overcome limitations of the traditional process and tools (macroscopic forecasts fed into microscopic models). In particular, the following needs can be addressed:

1. Operational Impacts
   - Restricted funding and less interest in making major changes in the roadway system are shifting the focus of planning to system management and leveraging the effects of changes in operations and many small system improvements. In addition, there is increasing interest in modeling operational improvements that improve reliability and reduce incident-related congestion. Macroscopic models are typically not applied in a manner that is precise enough to model the effects of traffic operations or minor improvements. Microscopic model can analyze these effects, but cannot do so at a large-scale systems level. Moreover, microscopic models require a very large amount of data and are impractical to develop for an entire urban road system.
   - The focus on operational improvements and smaller system changes requires the use of more precise performance measures in order to distinguish the relative benefits of alternative choices. Macroscopic models use travel time and speed measures having limited precision (e.g. do not capture the vehicular delays upstream of system bottlenecks). These measures are necessary in order to predict travel patterns, but precision has been limited for reasons of computational tractability and because precision may not have been important for the regional decisions being made. Microscopic models can produce these measures, but only for a relatively small portion of the system.
   - The operational impacts of interactions with other modes (such as bus stops or rail crossings) can impact travel time along a route and thus route choice. For example, the impacts that transit vehicles have on auto travel times are ignored in most macroscopic models (e.g., additional traffic congestion caused by buses on mixed use roadways and vehicular delays occurring at rail crossings). These impacts can be explicitly modeled and evaluated using microscopic models.

2. Congestion Impacts
   - As traffic congestion severity, extent, and duration grow, the travel time and speeds estimated by macroscopic models become less and less able to reflect actual travel conditions. Macroscopic models have a limited ability to account for congestion on adjacent (downstream) links, as well as within (adjacent lanes) a given roadway segment. Consequently, macroscopic models are less able to account for the effect of traffic congestion on travel patterns. This has been a significant consideration in the Portland metropolitan area for some time, and is starting to become an issue in other areas of the state as well.
   - The effects of severe congestion may not be reliably accounted for by microscopic models. How are the system constrained traffic volume and
trip inputs for microscopic models developed for future year scenarios (as the severity, extent, and duration of traffic congestion grows) without the help of macroscopic travel models?

3. Sensitivity/Risk Testing/Alternatives Analysis
   - There is increasing interest in assessing the risks associated with uncertain futures (e.g. amount and distribution of land uses, fuel and other travel costs, government policies, regional economic and funding issues). The assessment of uncertainty and risk requires a more comprehensive analysis than is presently done. In the past, assumptions were made about many factors (such as land use, transportation network changes, etc.) in order to limit the number of alternatives needing to be analyzed. This has been necessary because of the amount of work required to develop models and process outputs from macroscopic models to be input into microscopic models and time required to adequately develop microscopic models.

Mesoscopic modeling has the potential for meeting these emerging needs and overcoming existing limitations by leveraging the strengths of both macroscopic and microscopic modeling:

   - Operational performance can be calculated with more detailed metrics than is currently done by macroscopic models in order to account for the effects of smaller changes to the system and to distinguish smaller differences between alternative improvements. The calculations in mesoscopic models are less precise than those of microscopic models; this reduces the data needs and model run-times so that entire regional transportation systems or large portions of transportation systems can be modeled.

   - Since mesoscopic models can make more detailed calculations of performance, in some cases they may be a substitute for microscopic models for the purposes of uncertainty and risk analysis. For larger systems with severe congestion issues, a mesoscopic model will allow for realistic results to be generated at a lower detail level but still meet the needs of the project development process. The calculation of the performance measures by a mesoscopic model would reduce the need/use of microscopic models for alternatives testing and greatly increase the number of scenarios that could be analyzed within a given amount of time and resources. Microscopic models would continue to be used for more detailed analysis of a limited number of scenarios.

   - Mesoscopic models can provide a mechanism for feeding back better estimates of travel times reflecting very congested conditions to macroscopic modeling processes for forecasting travel demand for successive iterations in the macroscopic models. This might be done by incorporating the mesoscopic model into the macroscopic model, or by using the mesoscopic model as a post-processor of the macroscopic model.
When to Consider Mesoscopic Analysis

Many considerations exist that could lend mesoscopic procedures being applied for an analysis. Some of these considerations for mesoscopic application could include:

- Do a large number of system network alternatives need to be analyzed or screened at a system level? Is it not feasible/cost-effective (or appropriate) to model all alternatives in microscopic analysis? Does macroscopic analysis not provide adequate detail for providing relative comparisons among alternatives?
- Do network alternatives include operational impacts or improvements that may not be captured with a macroscopic model?
- Do network alternatives have the potential to impact system circulation and routing due to the outcome of the resulting traffic operations and flow?
- Does a level of congestion exist that may not be captured with a macroscopic model?

Any of the items listed above may be an indication that mesoscopic analysis would be beneficial for project application. While defined triggers do not exist, generally a mesoscopic approach will provide additional benefit in cases where both macroscopic traits (such as route choice) and microscopic traits (such as traffic operations, performance measures on duration and severity of congestion and queuing) are desired in a hybrid environment.

8.1.4 Related APM Chapters

Several other chapters provide related guidance. These chapters and the relation each has to this chapter are listed here.

- Version 2 Chapter 3: Transportation System Inventory – Includes information about data collection that may be needed for application of the methods covered in this chapter.
- Version 2 Chapter 5: Developing Existing Year Volumes – Includes information about volume development that may be needed to estimate demand for some of the tools and methods covered in this chapter.
- Version 2 Chapter 6: Future Year Forecasting – Provides information about developing future forecasts and includes subarea assignment methods. The chapter also describes multiple forecasting methods, including use of travel demand models.
- Version 1 Chapter 8: Traffic Simulation Models - Procedures for microsimulation model development and calibration.
- Version 1 Chapter 10: Analyzing Alternatives – Includes information about developing sets of alternatives that may be analyzed or screened using the tools and methods covered in this chapter.
8.2 **Subarea Analysis**

This section provides an overview of types of subarea analysis and general considerations for application. Two types of subarea analysis, focusing and windowing, are covered in greater detail in following sub-sections.

8.2.1 **General Considerations**

The analyst has a number of tools and methods available for application. A critical component of any project is first selecting an appropriate tool and then determining how to best apply that tool. In many cases, the best tool available may not be adequately refined for the intended application. In the case of a regional travel demand model, the model may be constructed and calibrated to a regional scale. However, with the appropriate additional refinement, the model (tool) may be applicable to additional uses. Creating a subarea model is a common example of applying model refinement for more rigorous use beyond the original scale of the model.

This subsection describes general subarea refinement and considerations. A *subarea* is a specified area that is identified for refined analysis. This may require a model or tool that includes additional detail beyond what is used for areas outside the subarea in order to adequately capture the desired level of analysis. The subarea may be similar to a “study area” identified through the analysis as the general area included in the analysis, but often these areas differ based on the degree of analysis needs and tools present.12

Once an analyst is aware of pre-existing models, the decision about model applicability and potential to use the model for another purpose must be made. While this decision process should be coordinated with TPAU and documented, the following considerations may indicate the potential for applying subarea analysis:

Is the “base model” (agency or regional model) appropriate for further project use?
- Does the model boundary fully include the study area?
- Does the model consider the appropriate time period (hour of day, season, etc.)?
- If land use changes are being investigated, are the scale and type of uses appropriate for the model? Smaller magnitude areas, such as some traffic impact analysis (TIA) for the development review process, may not require land use adjustments in the model if it is being used to forecast background growth. However, larger magnitudes may require land use adjustments or even be beyond the scope of the model. Additional documentation on this matter is provided separately.13
- Does the model boundary include key locations outside of the study area that may influence operations within the study area (downstream interchanges, over capacity intersections, etc.)?

Is subarea refinement needed for model application?

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12 Considerations for identifying subarea boundaries are presented later in this section.
13 Modeling Procedures Manual for Land Use Changes, TPAU, February 2012.
Does the model include all transportation facilities relevant to the study? This may include study intersections as well as parallel facilities or alternate routes, which may be needed for gauging traffic diversion.

Is the zone structure detailed enough for the analysis and are centroid connectors placed in a way that will not impact the outcome of the results?

Is the model sensitive enough to test the range of alternatives under consideration, such as intersection control and geometry or signal timing changes?

Is a specific zone or unique land use not adequately captured due to the regional scale of the model?

Is the zone and centroid connector structure detailed enough to perform Origin-Destination (O-D) matrix estimation procedures if needed?

What will be the ultimate use of the model data? Do HCM procedures need to be performed on study intersections? Will the model be exported to microsimulation?

Do other modes of travel need to be considered that are not included in the regional model? For instance, do a significant amount of trucks or heavy vehicles need to be analyzed separately and/or account for restricted routes? Are there other modal network elements?

Is a more realistic assignment needed due to extensive peak period congestion?

The considerations above are intended to serve as a general guide for determining model application potential. However, other given project context, other considerations may exist and coordination with TPAU is needed. The following sections explore these general considerations in more detail.

8.2.2 Overview of Focusing and Windowing

Focusing and windowing are two general types of subarea models that are commonly applied. These approaches can be applied for both macroscopic and mesoscopic analysis models. While each of the two methods shares similarities, there are also distinct differences.

**Focusing** is the practice of adding additional refinement and detail to a model within the structure of that model. The additional resolution may be added to the supply (transportation network) or the demand (zone structure or loading). In either case, the full function of the model is maintained.

**Windowing** involves cutting out a portion or component of a model. Often, this will include a “window” of the transportation network in the subarea that then creates cordon (external) areas at the edge of the subarea. Windowing, like focusing, is applied to allow additional refinement or modification. However, because windowed models are separate from the original model, they are not held to the same requirements for consistency and integration with the full model. This allows for testing changes from the original model.

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14 Coordination with TPAU is necessary to determine if the level of adjustments are appropriate and reasonable for the windowed area model.
such as travel demand intensity or trip assignment technique). Results of the windowed model are specific to the window itself and are not necessarily relevant to the original model. In some cases, the entire model area may be windowed in order to test scenarios (or framework) that differs from the base regional model.

Exhibit 8-5 demonstrates the general differences in network refinement that a focus and window subarea model would add to a base model network.
Exhibit 8-5 Comparison of Base/Regional, Focused, and Windowed Models

Regional Model

Focus Model

Window Model
### 8.2.3 Scoping

The following sections provide an overview of scoping subarea modeling efforts, including general considerations for selecting windowing and focusing methods and level of effort for subarea application.

#### Tool Selection

In some instances either windowing or focusing may be an appropriate approach for refining the model area. However, in other cases one approach may be preferred due to limitations or flexibilities built into each method. Exhibit 8-6 highlights some situations to guide the analyst in selecting an appropriate methodology.

#### Exhibit 8-6 Considerations to Guide Selection of Subarea Model Methodology

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Focusing</th>
<th>Windowing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternate Traffic Routes</td>
<td>• If alternate (or parallel) traffic routes exist outside the subarea, they may be affected by non-uniform refinements made to the model within the focus area.</td>
<td>• Routes from the regional model will be fixed and constrained at the location of subarea boundary or cordon “cut” lines (outside the windowed area)</td>
</tr>
<tr>
<td>Assignment</td>
<td>• Constrained by base (regional) model</td>
<td>• Adjustments to assignment type and parameters allowed</td>
</tr>
<tr>
<td>Demand Intensity</td>
<td>• Constrained by base (regional) model</td>
<td>• Adjustments to demand intensity of zones allowed</td>
</tr>
<tr>
<td>Model Size</td>
<td>• Can be applied for any size model</td>
<td>• Applying a “cut” of the model and creating new cordon zones may be desired to reduce run time</td>
</tr>
<tr>
<td>Model consistency</td>
<td>• Edits require consistency within the framework of the regional model and running the full 4-step model</td>
<td>• Edits are allowed to deviate from regional model framework, however do not provide the ability to re-run the full 4-step model directly.</td>
</tr>
<tr>
<td>Future Work</td>
<td>• May be used for future projects</td>
<td>• Generally can only be used for the subject analysis</td>
</tr>
<tr>
<td>Intersection Control</td>
<td>• Typically not available in regional models</td>
<td>• Intersection control through nodal delay-based assignment</td>
</tr>
<tr>
<td>Level of Effort</td>
<td>• (Varies – see Exhibit 8-7)</td>
<td>• (Varies – see Exhibit 8-7)</td>
</tr>
<tr>
<td>Full 4-Step Model Runs</td>
<td>• Full model could be rerun with the additional detail of focus area</td>
<td>• Model generally reassignment only. A full model run (trip generation, distribution and mode choice) is not performed.</td>
</tr>
<tr>
<td>Transit</td>
<td>• Typically not affected in subarea focus model.</td>
<td>• Transit assignment and route functionality may break due to unique nature of coding.</td>
</tr>
</tbody>
</table>
Data

Types of data that are necessary to perform subarea analysis (such as focusing and windowing) may include:

- Traffic volumes – Needed to validate the model traffic volumes, particularly if new network is being added
  - Roadway tube counts
  - Intersection turn counts
  - Truck percentages
- Land use – Provides guidance for refining zone structure to allocate land use or trips to new zones.
  - Zoning map
  - Detailed land use metrics (in size of building and/or number of employees)
  - Aerial photos
- Network geometry – Characteristics needed to reflect infrastructure and control
  - Intersection and corridor geometry (lane use and channelization)
  - Posted speed
  - Capacity
  - Intersection control – type, orientation, signal timing plans, etc.
- Traffic operations – Existing traffic operations for model validation/calibration.
  - Speed
  - Travel time
- Traffic patterns – What is the distribution and what routes are being used?
  - Origin-destination patterns
  - Routes

Some data may only be needed depending on the detail of the subarea model (such as intersection control and geometry), while other data may only be needed if the subarea model will be later converted to microsimulation.

Resource Needs

The ability to scale the tool for the analysis is an important benefit of subarea modeling. The degree of effort needed to apply a subarea model can vary greatly based on the amount of detail that is put into refinement of the key model elements. Various model elements that may be refined for subarea analysis are listed in Exhibit 8-7 along with a sample of “low”, “medium”, and “high” levels of effort. For the purposes of this table, these levels are defined (as approximations) to be:

- Low Effort – Typically completed within a couple hours
- Medium Effort – Can be completed within a day
- High Effort – May require several days or more to complete
## Exhibit 8-7 Subarea Scalability to Identify Resource Needs

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Range of Effort (Refinement and Application)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network Refinements</strong></td>
<td><strong>Low</strong> Add a link in study area or adjust speed/capacity</td>
</tr>
<tr>
<td></td>
<td><strong>Medium</strong> Review and refine all existing links and link properties for advanced street network detail. Add key missing links.</td>
</tr>
<tr>
<td></td>
<td><strong>High</strong> Review and refine all links in model and add any missing public streets (local, collector, arterial, etc.)</td>
</tr>
<tr>
<td><strong>Zone System</strong></td>
<td><strong>Low</strong> Use existing zone system or split a single zone</td>
</tr>
<tr>
<td></td>
<td><strong>Medium</strong> Split zones (5 or less) in the immediate study area</td>
</tr>
<tr>
<td></td>
<td><strong>High</strong> Split zones (5+) over a broad area that may expand beyond the study area</td>
</tr>
<tr>
<td><strong>Connectors</strong></td>
<td><strong>Low</strong> Use existing connectors, add connectors, or adjust placement to be loading to optimal roadway in study area</td>
</tr>
<tr>
<td></td>
<td><strong>Medium</strong> Review and refine placement and potentially weights of connector loading in general study area</td>
</tr>
<tr>
<td></td>
<td><strong>High</strong> Review and refine placement and weights of connector loading in broader area</td>
</tr>
<tr>
<td><strong>Assignment Method</strong></td>
<td><strong>Low</strong> Use existing assignment method. May still require subarea “cut” of windowed area.</td>
</tr>
<tr>
<td>(Window only)*</td>
<td><strong>Medium</strong> Modify assignment method to incorporate other considerations (such as fixed intersection delay by movement)</td>
</tr>
<tr>
<td></td>
<td><strong>High</strong> Implement detailed intersection operations elements that incorporate HCM intersection turn delay.</td>
</tr>
<tr>
<td><strong>Intersection Control</strong></td>
<td><strong>Low</strong> No control setting, or simple node type of signalized/unsignalized</td>
</tr>
<tr>
<td></td>
<td><strong>Medium</strong> Control includes intersection geometry, specific control type and orientation</td>
</tr>
<tr>
<td></td>
<td><strong>High</strong> Control includes detailed type, geometry, and settings such as signal timing</td>
</tr>
<tr>
<td><strong>Data Mining</strong></td>
<td><strong>Low</strong> Daily or peak hour link volumes</td>
</tr>
<tr>
<td></td>
<td><strong>Medium</strong> Peak hour/period link and turn volumes at key locations in study area</td>
</tr>
<tr>
<td></td>
<td><strong>High</strong> Peak hour/period link and turn volumes at locations in and beyond study area (and cordon zones if they exist)</td>
</tr>
<tr>
<td><strong>Validation/Calibration</strong></td>
<td><strong>Low</strong> Check/observe regional links in study area.</td>
</tr>
<tr>
<td></td>
<td><strong>Medium</strong> Check/observe regional links and additional subarea link network</td>
</tr>
<tr>
<td></td>
<td><strong>High</strong> Check/observe and plot the differences for all link and turn count locations to measure model calibration</td>
</tr>
</tbody>
</table>

Note: *Applies to Window models only since focus area models do not change assignment methods.*
8.3 **Focusing**

The following sections provide an overview of how to apply focusing:
- Process – What steps are involved?
- Potential Issues – What are issues that may occur?
- Calibration – How to know when the model is “ready”?
- Application – When is this tool needed?
- Examples – When has this tool been used?

8.3.1 **Process**

The following steps, simplified in Exhibit 8-8, are used to apply focusing:15

1. **Refine Transportation Analysis Zone (TAZ)/network** - The standard TAZ system and network are refined in the subarea. This may include adding elements that were not included in the base model (such as additional roads), or adjusting elements that were in the base regional model (such as modifying link capacity).
2. **Allocate origins/destinations to new TAZs** - The origins and destinations for the original or “parent” TAZs from the model run are allocated to the disaggregated TAZs using one of several possible weighting schemes (Section 8.4.4).
3. **Expand matrix for new TAZs** - The assignment trip matrix from the model run is expanded to reflect the revised TAZ system.
4. **Balance matrix** - The expanded matrix is balanced using the disaggregated origins and destinations from Step 2.
5. **Run assignment** - A new trip assignment is run with the trip matrix from Step 4 and the refined network.
6. **Error checking** – Compare model output to check for consistency with base model.

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**Exhibit 8-8 Focusing Process**

Refine TAZ/network → Allocate origins/destinations to new TAZs → Expand matrix for new TAZs → Balance matrix → Run assignment → Error Checking

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8.3.2 Potential Issues

The following potential issues may arise with a subarea model that uses focusing:

- Additional detail or street network may attract/detract travel demand from the study area. Creating additional transportation system links in the study area may increase the total capacity, thus attracting additional trips. Conversely, adding additional detail (nodes/intersections, traffic control, etc.) may disproportionately increase the travel time through the study area and detract traffic. These potential issues may indicate that windowing is more appropriate.
- Data may not be readily available to validate the traffic volumes on street network that is vital to the focused area.

8.3.3 Calibration (Model Checking)\(^\text{16}\)

Analysis Procedure Manual Version 2 Chapter 6 includes additional information on model checks. It is assumed that the subarea models are based on regional travel demand models that have already been subject to a formal calibration and validation process. The following information is provided for calibration of subarea models for project application and may not be appropriate for regional models.

The calibration process is a critical step to ensure that the focused subarea model is compatible with the base model. If issues arise during the calibration process, it may be indicative that another method (such as windowing) may be more appropriate. The calibration process should generally include the following considerations, at minimum:

- Confirm the focus model is consistent with the base model
  - Is the overall demand matrix sum unchanged? There is risk of modification to the overall matrix demand when splitting the zone structure and creating new TAZ. Any change in overall demand (which may result when splitting zones with internal trips) should be minimal (typically less than one percent, unless documented otherwise).
  - Do links outside the focused area generally retain the same assigned traffic volumes? Significant shifts in traffic volumes may indicate incompatibility with the base model and a need to perform windowing as an alternate approach.

- Confirm the focus model is compatible with the base model
  - For a given screenline, do links within the focus area carry the same total assigned traffic as the base model? If the network was refined, traffic assignment may shift within the focus area, but the overall assigned volumes across a screenline should not significantly differ.

\(^{16}\) The following material includes components of both a validation and calibration process. It is assumed that the regional demand models would have been formally validated and calibrated during model development. The information in this section focuses on the calibration of subarea models for project application.
• Confirm the focus model is providing realistic results
  o Do the sums of connector volumes for a zone match the total zone demand?
  o Does the routing for traffic into and out of new zones make sense? Common checks include a select zone analysis (Emme traffic assignment software) or a zonal flow bundle analysis (Visum traffic assignment software).
  o Do the routes, origins, and destinations for traffic using a new link make sense? Common checks include a select link analysis (Emme) or a link-based flow bundle analysis (Visum).

• Confirm the model reflects existing traffic data
  o Does the magnitude of resulting traffic demand match base year traffic count data? Differences in data are typically present due to:
    - Difference in model year/period and date of data collection (e.g., average weekday model for year 2010 compared to July 2013 count data).
    - Count data collected from various source and time periods. Assigned traffic volumes in the subarea model must balance (unless there is a connector between locations), so unbalanced count data can lead to incompatibility of the data set and create more difficulty for the calibration process.
    - The amount of driveway trips related to pass-by and retail use, or the detail of street network included in the subarea model, may not be captured in the regional travel trends present in the regional travel demand model.
  o If assigning multiple vehicle classes, does the traffic demand match classification data?
  o Does the distribution of traffic match O-D patterns anticipated from license plate, Bluetooth, cell-phone, or other data survey means?

8.3.4 Key Considerations (Application and Issues)

In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements.

The following questions and considerations are intended to help guide decisions regarding application of focus models. In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements. These considerations are not absolute but are intended to function as a general guidance when developing an approach and methodology.

Study Area Size/Boundary
When selecting an area of the model to focus, consider the following:
• Larger focus areas provide more opportunity to refine the model, but also require additional effort.
• Smaller focus areas may limit the effects of focusing.
• Having a constrained focus area with limited connectivity to surrounding areas helps to retain consistency with the base model assignment.
• A focus area should be adequately large that changes within the focus area do not impact areas outside of the focus area.

Network Link (Street) Refinements
• When refining the attributes of the street network, parameters should be consistent with assumptions made about the rest of the network. For example, streets within the focus area should have compatible capacity to similar streets outside the focus area.
• Is the structure of the focus area street network appropriate for the level of detail that is needed for the analysis? Are key streets missing from the model? These may include facilities that affect circulation as well as locations that require detailed traffic forecasts.
• Are the attributes that are used in the regional model appropriate for the focus area? Models are often calibrated to a regional scale and may not include unique details that reflect specific locations. Attributes such as speed or capacity may need to be refined to better reflect true conditions.

Network Zone Refinements
• Can a zone be split based on different land use types? This often can help to allocate the portion of trips from the original zone to the split zones.
• Are there constraints that affect connectivity (such as rail, topography, water, etc.) that drive the need to split a zone to better control loading?

Network Connector Refinements
Depending on the modeling platform, treatment of connectors may be used as a substitute for splitting zones. However, some modeling platforms may not provide the flexibility for multiple connectors per zone with different weighting allocations.
• Location of connector loading should best represent the real-world condition (location of internal streets, driveways, or parking) as is feasible given the model detail. Exhibit 8-9 provides an example of using connector loading to better represent actual network conditions. In this example, each connector for Zone 11025 is placed to represent approximate driveway locations and is given a relative weight based on the amount of trips that are served by the land uses at each driveway. In some cases additional link network and detail may be needed for realistic connector loading.
The amount of connectors may need to be increased depending on the magnitude of zone trips and the uniformity of real-world loading throughout the zone. Commercial zones typically have less loading points due to the location of specific (high volume) driveways. Residential zones that may not require specific loading points that represent major driveways but instead multiple connectors that distribute these trips along the edge of the zone as local street circulation would provide.

The weighting or portion of trips loading to each connector may be set based on the configuration and available data. A common case may be a commercial zone that includes multiple driveways. If traffic counts are available for the driveways, connectors can be weighted to replication these driveways and better reflect actual conditions. In other cases it may make sense to uniformly load (equal weight) connectors across the zone area to distribute demand more evenly – as in the case of a residential zone with uniform house coverage.

What is the real-world circulation within the zone and should all connectors be used? Is internal circulation possible and is connector (driveway) use based on driveway delay or some other attribute? If so, movement within a zone may occur and trips (in some cases) may not use a given connector and/or connector weights may change. The level of internal circulation also may impact the amount of crossing driveway traffic (e.g., traffic from an eastern driveway heading to the west and traffic from a western driveway heading toward the east, versus all
western driveway traffic heading to the west and all eastern driveway traffic heading to the east).

**Intersection Control**
- What methods are applied to determine intersection capacity and impedance (delay) in the regional model? If none are applied, application of intersection control is likely beyond the scope of focusing and may be better suited for windowing (which provides more flexibility and deviation from the regional model).
- What level of detail is appropriate given the fidelity of other model elements? Models generally fit into one of the following levels of intersection control:
  - Level 1 – intersection control is ignored
  - Level 2 – some control types are coded (e.g., signalized intersections are flagged) with an equal delay given to all movements
  - Level 3 – all control types are coded and a look up delay is applied for all/some turns. This may consider influences of major and minor street approaches.
  - Level 4 – all control types (and potentially geometric details) are coded and delay is calculated at each intersection movement by a method such as HCM.

**Ramp Meters**
- Ramp meters can create bottlenecks that can significantly restrict the throughput based on timing parameters. To reflect this “hard” capacity restriction, a volume delay function that has significantly more delay when over capacity may be an option for emulating a ramp meter.
- Additional solutions for reflecting ramp meter impacts may be available depending on the presence of intersection control elements in the model.
8.3.5 Examples and Scaling

As listed in Exhibit 8-7, the focusing methodology can be applied in varying degrees and scaled to fit the needs of each project and analysis. The following examples demonstrate different scales of application. For reference, Exhibit 8-10 provides a sample of a typical regional base model. This model includes a sparse system of links that represent the major roads (typically collectors and arterials), a zone network, and limited connector loading.

Exhibit 8-10 Base Network Model (Example)

Examples for different scales of applying focusing are shown in Exhibit 8-11 and Exhibit 8-12.
Focus Model Example 1: Low Effort

A low effort application may include making a minor refinement to the travel demand model, including any combination of the following:

- Add a new link or adjust the attributes of a link
- Add connector location or weighting
- Split a zone

Exhibit 8-11 shows an example of adding an additional link and centroid connector to refine the network. The new link (relative to the base network shown in Exhibit 8-10) is shown in red. These two refinements (new link and new centroid) may be all that are needed to focus the subarea model, and represent a minimal, low effort application. Low effort applications may also involve adjustments to the zone system (disaggregation), or minor additional link and centroid connector edits.
Focus Model Example 2: Moderate Effort

A moderate effort application may include making refinements to several elements in the travel demand model, including any combination of the following:

- Adding several new links or adjust the attributes
- Add connector location or weighting for several zones
- Split several zones

Exhibit 8-12 shows an example of adding several additional links and centroid connectors to refine the network. Similar to the previous example, the new links (relative to the base network shown in Exhibit 8-10) are shown in red. These additional refinements (beyond the level of detail shown in Exhibit 8-11) represent a moderate effort application and would further refine the assignment of traffic in this subarea. Moderate effort applications may also involve adjustments to the zone system (disaggregation).
Windowing is primarily intended to be a motor vehicle reassignment exercise to improve traffic circulation routing and analysis within a subarea. It is likely that continuity of certain elements of the full regional model, such as the ability to perform full 4-step model runs and assigning transit, will be broken by windowing a subarea model. If these components are critical for the application, consider performing a focus model or other methods.

The following sections provide an overview of how to apply windowing:

- Process – What steps are involved?
- Potential Issues – What are issues that may occur?
- Calibration – How to know when the model is “ready”?
- Application – When is this tool needed?
- Examples – When has this tool been used?

### 8.4.1 Process

The following steps, simplified in Exhibit 8-13, are used to apply windowing. Note that the windowing process contains more steps than the focusing process shown in Exhibit 8-8. Steps that are also included in the focusing process may have more details in Section 8.4. Additional information, including key considerations and checks, is provided in the following sections.

1. **Determine subarea boundary and “cut”** – Identify locations (links) that will become “cordon” zones with fixed demand from the regional model run. The selection of the boundary is a key decision since demand will be fixed.
2. **Refine TAZ/network** - The standard TAZ system and network are refined in the subarea. This may include adding elements that were not included in the base model (such as additional roads), or adjusting elements that were in the base model (such as modifying link capacity).
3. **Allocate origins/destinations to new TAZs** - The origins and destinations for the original or “parent” TAZs from the model run are allocated to the disaggregated TAZs using one of several possible weighting schemes.
4. **Expand matrix for new TAZs** - The assignment trip matrix from the model run is expanded to reflect the revised TAZ system.
5. **Balance matrix** - The expanded matrix is balanced using the disaggregated origins and destinations from Step 3.
6. **Adjust gateway (cordon) demand** – Adjust the demand at the windowed gateways as appropriate for analysis needs (such as adjustment to another analysis year or season).
7. **Modify assignment framework** – Adjust the assignment parameters\(^{17}\) (such as assignment type and method for determining cost or travel delay), as appropriate, to meet the analysis needs.

8. **Run assignment** - A new trip assignment is run with the trip matrix from Step 5 and the refined network.

9. **Adjust TAZ (internal zone) demand** – Adjust the demand for internal zones as appropriate for analysis needs (such as scenario testing and scaling for additional growth or development). Verify that the resulting demand matches the target values.

10. **Rerun Assignment** - A new trip assignment is run with the updated demand parameters.

11. **Error checking** – Compare model output (such as link and/or turn assignments and general routing patterns between zones) to check for consistency with base model.

12. **Calibration** – Compare model output to data sources and make adjustments to calibrate model.

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\(^{17}\) While windowing provides some flexibility to add additional detail and refinements that may support using different assignment techniques than the regional model (such as moving from a link-based volume-delay function to an intersection turn-based delay calculation), it is critical to coordinate with TPAU and ODOT regional staff to confirm these methods and assumptions are appropriate for the network detail.
8.4.2 Potential Issues

The following potential issues may arise with a subarea model that uses windowing:

- The subarea needs to be sufficiently large to capture variations in traffic circulation patterns among alternatives. Since the edge of the subarea becomes fixed demand, traffic circulation that may be impacted outside the study area is not considered.
- The additional flexibility (“more knobs to turn”) with windowed models can require more care and make them more difficult to calibrate. The iterative process that considers adjustments to the network, demand, assignment parameters, and other elements, often requires that those elements are revisited after subsequent adjustments have been made to other parameters. Conceptually-sound adjustments are critical.

8.4.3 Demand Adjustments

Demand adjustments (scaling or changing the demand for a zone or specific O-D pairs) allow a layer of flexibility not present in focus area models that can be used to account for subarea demand magnitudes and traffic patterns that may not be captured in a regional scale model. While subarea models should typically stay consistent with the regional demand model, there may be cases where demand adjustments are needed. Section 8.5.5 includes additional considerations for demand adjustments.

- Demand adjustments may be needed for a number of reasons (including, but not limited to, adjusting to count data for another analysis period/year, or capturing internal trips ends and driveway counts along a corridor) to represent demand well enough that the model has the ability to adapt to network modifications and alternatives.
- A sample application of a demand adjustment could include the following analysis scenario:
  - The purpose of the analysis is to test a variety of transportation improvements, which include operational improvements such as intersection control and lane configurations.
  - A windowed area model is created that includes a high level of detail for the traffic network in order to capture the operational behavior and impacts in the model. This model uses intersection-level turn delay based on HCM methodology.
  - Traffic circulation in the model depends on the delay calculated for turn movements in the system. In order to capture existing traffic flow patterns, a realistic approximation of the travel demand between zones is needed to produce accurate turn delays in the model.
  - A comparison of the subarea model and traffic count data indicates that some of the gateway (cordon) traffic volumes in the model do not match well with count data.
  - A demand adjustment is performed in order to scale the gateway traffic volume (or other isolated internal demand that is not related to routing errors) closer to actual count data. By having a model demand that reflects actual count data, the model will be able to better account for traffic...
circulation patterns that result from changes in the transportation system. By better estimating the traffic circulation, the model will also better estimate actual traffic volumes on the road system.

- Demand adjustments typically rely upon having traffic count data that demonstrates the basis for the adjustment. However, it is important to be mindful of daily traffic fluctuations, which may be 10% on a day-to-day basis.
- Demand adjustments (as noted in Section 8.5.4) should only be performed after exhausting other model checks and calibration items related to assignment routing in the model.
- Demand adjustments should not be performed indiscriminately without a conceptual basis for why the adjustments are being made.
- Demand adjustments require existing year count data or similar thresholds to act as constraints to determine the degree of adjustment. Demand adjustments made to future year models should be applied in such a way that the resulting model growth (difference between the original base and future models and differences between the adjusted base and adjusted future models) does not change. Demand adjustments are performed to better fit traffic data and routing behavior in the model, not to influence the growth projected by the model (unless analysis year is changed).

8.4.4 Calibration (Model Checking)

The calibration process is a critical step to ensure that the focused subarea model is compatible with the base model. If issues arise during the calibration process, it may be indicative that another method (such as focusing) may be more appropriate. The calibration process for windowing is similar to the process used for focusing (Section 8.4.3); however, some key differences exist due to additional allowances and flexibility that the modeler has through the windowing process. The calibration process for windowing should generally include the following considerations, at minimum:

(Before demand adjustments or network refinements)
- Confirm the window model is consistent with the base model
  - Are demands at cordon zones or gateways on the edge of the windowed model consistent with the assigned link volumes at these locations in the base regional model?
  - Do internal TAZ retain their original scale of demand (total trips in and out)?
- Confirm the window model is compatible with the base model
  - Does rerunning the assignment procedure for the windowed area give similar assignment results as the regional base model?

(After network refinements)
• Confirm the window model is providing realistic results
  o Do the sums of connector volumes for a zone match the total zone demand?
  o Does the routing for traffic into and out of new zones make sense?
    Common checks include a select zone analysis (Emme) or a zonal flow bundle analysis (Visum).
  o Do the routes, origins, and destinations for traffic using a new link make sense? Common checks include a select link analysis (Emme) or a link-based flow bundle analysis (Visum).

• Confirm the model reflects existing traffic data
  o Does the magnitude of resulting traffic demand match base year traffic count data?
  o If assigning multiple vehicle classes, does the traffic demand match classification data?
  o Does the distribution of traffic match O-D patterns anticipated from license plate, Bluetooth, cell-phone, or other data survey means?

(After demand adjustments)
• Confirm the demand adjustments had the intended effect
  o Are adjusted totals for in and out trips by zone consistent with the targets?
  o Does the overall matrix sum change by the intended amount (if applicable)?
  o Do demand levels at zones that weren’t intended to change remain the same?

• Confirm the window model is providing realistic results (again)
  o Do the sums of connector volumes for a zone match the total zone demand?
  o Does the routing for traffic into and out of new zones make sense?
    Common checks include a select zone analysis (Emme) or a zonal flow bundle analysis (Visum).
  o Do the routes, origins, and destinations for traffic using a new link make sense? Common checks include a select link analysis (Emme) or a link-based flow bundle analysis (Visum).

Given the unique characteristics and applications of subarea models, an appropriate level of calibration (e.g., metrics such as $R^2$ values for observed versus modeled link or turn volumes) for one model may not be sufficient for another model. For that reason it can be difficult to determine when a model is calibrated “enough”, since it ultimately depends on how the model is applied and the decisions that will be made with the analysis. However, at a minimum, the above process and qualitative checks should be followed to ensure that due-diligence is performed, though additional checks and actions may be required. In addition, the analyst/modeler should provide documentation that shows that convergence criteria (such as $R^2$) were tracked through the calibration process.
8.4.5 Key Considerations (Application and Issues)

The following considerations are intended to help guide decisions regarding application of window models. In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements. These considerations are not absolute but are intended to function as a general guidance when developing an approach and methodology.

Study Area Size/Boundary
When selecting an area of the model to window, consider the following:
- The boundary of the windowed area creates gateway or cordon zones that have fixed demand based on the assigned link traffic in the regional base model.
- Refinements to the regional base model may be needed before applying the windowed cut in order to refine demand at the cordon zone locations.
- Since demand is fixed at cordon locations, ensure that the model is sufficiently large to test the set of alternatives that will be analyzed. Running a sensitivity test in the regional base model that includes the most extreme network alternative can be used to determine the area of impact and potentially the size of windowed area model that may be needed.
- Since demand is fixed at cordon locations, it is generally beneficial to minimize the number of cordons and select a boundary that has less network redundancy. Constraints to network connectivity (rail, water, extreme topography, etc.) can provide physical boundaries that serve windowed models well.

Network Element Refinements (Links, Zones, Nodes)
When adding refinement to the network elements in a windowed subarea model, many of the same considerations for focusing should also be applied and are provided in Section 8.2.4. Additional considerations that result from the added flexibility that windowing allows:
- Do other attributed need to be considered and coded in the windowed area that may not be included in the regional base model? Unique elements within the windowed area (downtown parking, pedestrian activity, etc.) may be considered and added to the network attributes. These elements may also need to be accounted for in the assignment process.

Demand Adjustments
When applying demand adjustments, consider the following (and items noted in 8.5.3):
- Applying network refinements before demand adjustments aids in error-checking these edits before introducing additional changes (demand).
- What is the demand adjustment trying to achieve and what is the appropriate level of detail to meet this need? Some adjustment scenarios may require simply applying a factor to a single zone, while other adjustment scenarios may include a more elaborate process that considers changes to distribution.
- What type of demand needs to be adjusted? Will all model trips be adjusted, or will adjustments be made to specific internal zones and/or cordons?
- Do the trip length frequencies of the adjusted demand matrices remain similar to the original demand matrices?
Future Year Scenarios
When preparing future year scenarios, consider the following:

- What is the most appropriate method for combining the windowed area network with the future year demand? The most efficient process often includes windowing the future demand matrix and inserting it into the windowed base year model network and then adding additional improvement projects (if any) to reflect the future model road network.
- Were demand adjustments made to the base year model that needs to also be applied to the future year model? Section 8.5.2 provides additional information about conducting demand adjustments and application for future year models.

8.4.6 Examples and Scaling
As listed in Exhibit 8-7, the windowing methodology can be applied in varying degrees and scaled to fit the needs of each project and analysis. The following examples demonstrate different scales of application.

Window Model Example: Astoria Downtown

The Astoria-Warrenton model was windowed to capture potential circulation impacts related to potential traffic control changes in the Astoria downtown area. The base regional model is shown in Exhibit 8-14 and includes Astoria, Warrenton and the surrounding rural areas.

Exhibit 8-14 Astoria Warrenton Regional Model

Exhibit 8-15 shows the Astoria downtown area in the regional model, as well as a sketch showing the proposed window boundary and cordon zones. This area was selected to
minimize the amount of streets in the regional travel demand model that would be cut, while allowing for a large enough area to sufficiently capture potential traffic circulation changes due to future transportation network alternatives. Specifically, the window boundary was selected to account for and balance the following needs:

- Adequate size to include subset of study intersections and circulation impacts
- Minimize the number of cordon zones (cut base regional links)
- Zone boundaries were retained and not split (windowed matrix retained total trips for internal zones)

Exhibit 8-15 Astoria Warrenton Regional Model and Sample Window Area

The resulting windowed area model is shown in Exhibit 8-16. The windowed model included the following refinements to capture circulation impacts:

- Assignment – Incorporated HCM intersection delay for intersection turns.
- Link Network – Added all public roadways in windowed area
- Zone Network – Added centroid connectors to reflect major driveways and parking locations.
8.5 **Dynamic Traffic Assignment (DTA)**

This section provides an overview of Dynamic Traffic Assignment (DTA) concepts and general considerations for application in Oregon. DTA tools and software packages are still relatively new, emerging tools that have the potential to improve forecasting and analysis and are becoming more widely used around the country. Due to the potential benefits of these tools, they may become more prevalent as they become better known and understood. While this section provides a general overview of DTA, additional information about DTA is provided by the Transportation Research Board18.

8.5.1 **DTA General Concepts**

Traditionally, travel demand models have generally included a “static” assignment – one that provides a fixed path (or paths) for each origin-destination (O-D) pair during a given time interval. The time interval is generally the duration of the model period (such as a full day or a one-hour evening peak hour), or may be divided into shorter durations (such as one hour intervals within a day, or 15-minute periods within an hour). Generally, these static models have four common characteristics:

1) The O-D trips for each time interval are a function of input static time-of-day factors that are unrelated to the modeled assignment results. This means that the trips planned for each time interval are largely insensitive to how congestion varies through time.

2) All O-D trips are assumed to be completed during the time interval. That is, the travel time for each O-D pair is less than or equal to the time interval (generally one hour). In the event that a trip exceeds the time interval, demand is still forced through the system, leading to unreasonable demand-to-capacity (d/c) in highly congested networks.

3) The assigned path (or paths) for each O-D pair are not affected by the volumes in earlier time periods. Therefore, preexisting congestion on the roadway (from previous time periods) is ignored.

4) The representation of intersection LOS is very simple (or non-existent) as the network usually lacks intersection geometry and signal timing. This significantly limits the static assignment model in its usefulness for traffic operations analysis.

Such static assignment models tend to work fairly well as long as recurring congestion is not present in a network with multiple alternatives routes (i.e. a redundant network). In addition, static assignment models are not able to fully capture additional details related to the complex effects of congestion that causes traffic to:

- Divert to another route (spatial spreading),
- Leave earlier or later (during another time period – peak spreading), or
- Travel through the congestion (with a significantly higher realized travel time).

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Beyond traditional aggregate trip-based demand models, activity-based demand models (ABM), are a better framework for integration with DTA. ABMs microsimulate a day’s worth of travel for each individual in a region, operate at a finer temporal resolution (such as 30 minutes), and include improved models for scheduling trips (both departure and durations). Unlike aggregate trip-based models which output matrices by time period, ABMs output a list of individual trips with departure times. Integrating an ABM with a DTA therefore looks significantly different than integrating with a trip-based model. Currently, ODOT is in the process of developing ABMs.

In addition, static assignment models are not designed for dynamic changes in network capacity related to temporary closures, changes in traffic control, or non-recurrent diversion related to an incident. Other tools are needed for application in these scenarios. To better understand the potential impacts of the above cases, DTA can provide a more comprehensive assessment.

Unlike static models, DTA models allow travel routes to change through time. Traffic that is existing on the system (and its impacts on travel time) is considered, much like a seeding interval for a traffic simulation model. While there are many differences between different DTA platforms, the following general characteristics are common:

- Time-dependent paths; the path through the network is influenced by travel times that vary depending on when travelers arrive at a given network link, as opposed to assuming that travel times are constant throughout the period being simulated.
- Travel routes typically change at shorter intervals than static models (typically minutes instead of hours).
- Network congestion estimates, which are often based on traffic operations, are typically more detailed than a static model to account for travel time difference between routes.
- Vehicles queue on the network and are not forced through over-capacity conditions due to a timer interval constraint. Thus some demand may remain unserved during the analysis period.
- Individual vehicle “simulation” (whether visualized or not) is generally present to account for vehicle interaction and operational impacts.
- Like static assignment, multiclass assignment (including trucks) can be captured in DTA tools, which allow for different path sets and attributes among vehicle classes.
- Transit elements are included in varying degrees based on each DTA tool, but may include the ability to include service information including routes, stop locations, and schedules. Next generation DTA tools are starting to model individual transit persons as well.

DTA models assign demand in a much shorter time interval than static equilibrium traffic assignment models; often demand must be segmented into 15, 10 or even 5 minute time slices. This shorter interval duration is a feature that allows for better reflection of traffic flows, but it is also a requirement that necessitates better trip estimates than typically provided by demand models. Developing the initial set of OD trip tables by time period that are fed into the DTA is an important task that needs to be done with care, and is
discussed later in this section.

In mesoscopic modeling, DTA models represent the application that comes closest to achieving the same details that microsimulation models achieve. While microsimulation models maintain more advanced driver behavior algorithms and settings, DTA models usually provide individual vehicle simulation, car-following logic, intersection delay and queuing components, and the ability to introduce vehicle and/or driver profiles, all while maintaining trips to load onto a routable network.

A key differentiator among DTA models is the overall fidelity and detail for which traffic flows are captured along a road. The two types of models are referred to as “link-based” and “lane-based.”

- **Link-Based Models** – Traffic flow along a roadway is analyzed macroscopically, where the total number of lanes is considered as an overall link capacity. Differences among individual lanes (including the amount of traffic demand for an individual lane), interactions among individual vehicles, and friction related to movement and lane changing are not directly modeled.

- **Lane-Based Models** – Traffic flow along a roadway is analyzed for each lane, using car-following algorithms that account for interactions among vehicles and flow differences in each lane. Storage of vehicles related to turn bay lengths and other differences between lanes along a given link may influence operations at the adjacent node/junctions/intersections.

As discussed in later sections, the fundamental differences between these model types should be considered when selecting a DTA tool for project application.

### 8.5.2 DTA Scoping

The following sections provide an overview of scoping DTA modeling efforts and an introduction to various tools and software packages.
Tool Selection
Unlike static demand models that typically can achieve similar analysis under different graphical user interface (GUI), DTA models generally have many more fundamental differences related to model structure, network detail, and assignment algorithms. Section 8.5.3 provides an overview of DTA tools and includes additional information comparing key differences among some of the DTA tools and software packages. It is important to consider these fundamental differences when selecting the correct tool (among DTA software or other tools) to address the transportation question.

Data
The general types of data needed to code and calibrate a DTA model are similar to a subarea model (Sections 8.2 through 8.4) and require the following general types of data:

- **Network Data** – Attributes of the transportation network such as traffic control, lane geometries, and signal timing information.
- **Demand Data** – Data such as initial O-D trip matrices by time period, land use inventories and/or traffic counts to estimate the level of overall traffic demand.
- **Calibration/Validation Data** – Data that can be used to compare traffic flows and operations from the model, such as tube or intersection turn counts, and travel time runs along a corridor.

However, the key differences are that DTA traffic datasets (demands, flows, and operations) typically need to address finer-grained resolutions of traffic volume and travel time data over sequential time periods. For instance, data (such as traffic volumes, speeds, etc.) may be needed for individual 15-minute intervals (3:00 to 3:15 p.m., 3:15 to 3:30 p.m., … 6:45 to 7:00 p.m.) rather than a single, aggregated 5:00 to 6:00 p.m. one-hour time interval.

---

hour period. Key differences in the type and resolution of data needs include:

- **O-D Trips (travel demand)**
  - Finer time resolution trip matrices
  - Trips matrices that will not overload the DTA network (i.e. the overall magnitude of traffic demand is appropriate for the network)

- **Traffic Volumes (intersection turn or roadway tube)**
  - Flow profiles that cover the modeled time period (which may exceed a simple peak hour)
  - Flow profiles in time intervals of an appropriate resolution to be compared to the DTA model (such as 15-minute periods)
  - Flow profiles at key locations upstream, downstream and/or within bottleneck areas to understand differences in traffic demand and actual supply output

- **Traffic Operations**
  - Average speed profiles along a corridor (may come from Bluetooth and/or third party vendor speed data such as INRIX or TomTom)
  - Average delay for intersection movements (may be compared to an HCM intersection model)
  - Actual signal timing (such as observed average phase durations and cycle lengths) to develop the network model (traffic control details).
  - Queue lengths to understand the vehicle spacing and jam density

Given the duration and resolution of datasets identified above, it can be difficult (if not cost-prohibitive) to acquire complete data coverage of the model area. For that reason, it is important to strategically make use of existing data sets and focus new data collection efforts on key locations that capture real world behavior and attributes that need to be reflected in the model. The following types of answers should be addressed in model validation and calibration and may guide the collection of data:

- **Is the overall magnitude of traffic demand appropriate?** If not, then a common correction (for current and short term forecast years) is to adjust the O-D trip matrix to better match traffic counts (see Section 8.5.3) (Check volumes at network entry points and/or screenlines)\(^\text{19}\)
- **Is the correct routing being reflected in the model?** (Check volumes on screenlines and turn movements at key junctions)
- **Is the correct volume profile (and peaking) being realized on key network links?** (Check volume profiles at key locations as well as upstream/downstream of bottlenecks)
- **Is the correct travel time profile being realized on key network links?** (Check traffic volumes and determine if delay estimates are being applied appropriately)

### Resource Needs

Section 8.3.3 reviewed the level of resources needed to apply windowing and subarea models. In many cases a DTA model may be applied as a windowed model. For

\(^{19}\) There are some DTA model development projects that rely upon activity-based demand, provided in the form of trip lists (simulation output) rather than an ODO matrix.
reference, application of a DTA windowed model will generally fall under the “high” range of effort listed in Exhibit 8-7.

Due to the additional refinements and details available in a DTA model, the time needed to set up a DTA model (like a microsimulation model) is probably best summarized as weeks or months, rather than hours or days.

Since DTA models typically require additional effort to build and calibrate beyond a typical static macroscopic model, it can be helpful to approach the process from the perspective of scoping a microsimulation model. While DTA models may be used for a variety of purposes ranging from developing better demand volumes for microsimulation to using operational measures to screen alternatives, the details and data needed to build and calibrate the models can emulate a microsimulation model. ODOT has developed a process\textsuperscript{20} for building Vissim microsimulation models that provides a general structure for how to approach and scope a microsimulation effort. Depending on the DTA application and similarity to a microsimulation model, some of the framework of this approach may be able to provide a generalized resource for a DTA modeling endeavor.

8.5.3 Overview of DTA Tools and Software Packages

There is a wide array of tools available to perform DTA at varying scales and resolution levels. These tools range from enhancements of macroscopic models to application within microsimulation – essentially covering the full spectrum of mesoscopic modeling in terms of network detail and level of effort. The various types of tools available and the range of these tools allows for broad application ranging from enhancing volume development for separate traffic analysis to performing the actual traffic analysis in place of microsimulation. The following section provides an overview of some of tools used in the Portland metropolitan area. This list is not meant to be a review of all the DTA tools on the market; instead it is meant to illustrate the spectrum of DTA tools. Exhibit 8-18 summarizes the DTA tools that have been applied in the Portland metropolitan area.

\textsuperscript{20} Protocol for Vissim Simulation, Oregon Department of Transportation, June 2011.  
The following tools are grouped along the spectrum of mesoscopic modeling, ranging from those closer to macroscopic models to those that are more similar to microscopic models. Each tool has numerous features and fundamental differences that provide opportunities and limitations that ultimately impact the analysis results. This list is grouped for demonstrative purposes only and analysts are encouraged to understand the full abilities and limitations of these tools before project application. Groups closer to macroscopic models would require less detail and resources to use, while those closer to microsimulation would be more data and labor intensive to apply.

DTA tools within **macroscopic framework** (individual vehicles are not modeled):
- Visum Dynamic User Equilibrium (DUE) – A model within PTV’s macroscopic Visum model that constrains vehicle flow due to out-link intersection capacity and allows spreading of vehicle demand to adjacent routes. If other routes are at capacity (for a given time period), demand can be spread to originate during adjacent time periods. DUE is a link-based model and does not require coding intersection geometry or signal timing.

DTA tools with **link-based traffic flow** (individual vehicles modeled):
- DynusT – An open-source stand-alone DTA package that models individual vehicles but does not model individual travel lanes. Because of its simplifications in network representation, it can be applied to larger network sizes. See Exhibit 8-18 for additional details.

DTA tools with **lane-based traffic flow** (individual vehicles modeled):
- Dynameq – This stand-alone DTA package developed by INRO models individual vehicles and lanes, includes car-following logic that (due to the lane-based nature) models interactions in a more advanced manner than the link-based models but is more simplified than a microsimulation model. See Exhibit 8-18 for additional details.

DTA tools within **microscopic framework** (individual vehicles modeled):
- Vissim DTA – A model within PTV’s Vissim microsimulation package that allows for dynamic routing of individual vehicles. This application makes use of the fine-grained car following logic within the microscopic model.
Exhibit 8-17 Continuum of DTA Tools and Typical Level of Detail

<table>
<thead>
<tr>
<th>Increasing Level of Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>(MACRO)</td>
</tr>
</tbody>
</table>

## Exhibit 8-18 Comparison of DTA Tools Applied in Portland Metropolitan Area

<table>
<thead>
<tr>
<th>Element</th>
<th>DynusT</th>
<th>Dynameq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment Geometry and Control</td>
<td>Link-based (overall capacity of the cross-section is considered)</td>
<td>Lane-based (individual capacity for each lane and interaction with adjacent lanes and vehicles are considered)</td>
</tr>
<tr>
<td>Intersection Geometry and Control</td>
<td>Intersection turn bays are based on single global distance parameter.</td>
<td>Allows specific lane storage via creation of new links at any change in cross section.</td>
</tr>
<tr>
<td>Traffic Signals</td>
<td>Includes general traffic signal settings as well as actuated timing on a cycle by cycle basis.</td>
<td>Includes general traffic signal settings as well as actuated timing on a cycle by cycle basis. (beta feature)</td>
</tr>
<tr>
<td>Typical Model Size/ Application</td>
<td>Regional application for major roads is common.</td>
<td>Typically more restrictive model size that may be smaller scale subarea due to increased detail (all streets).</td>
</tr>
<tr>
<td>Includes Vehicle Simulation</td>
<td>Vehicles simulated at specific time steps (every 3 seconds or other duration)</td>
<td>Vehicle interaction is simulated for events and calculation is performed when there is a change</td>
</tr>
<tr>
<td>Visualization</td>
<td>Synthetic visualization of individual vehicles based on link-level information.</td>
<td>Macro flow (density, speed, etc.) at link level - individual vehicles not shown (but are simulated).</td>
</tr>
<tr>
<td>Randomness</td>
<td>Stochastic – allows multiple runs to reflect system variability (similar to microsimulation)</td>
<td>Deterministic model (profiles are applied for characteristics)</td>
</tr>
<tr>
<td>Ability to Import and Export Data</td>
<td>Allows network import/export with travel demand models and microsimulation. Direct integration may be difficult since network may be modified based on geometries.</td>
<td>Allows network import/export with travel demand models and microsimulation. Direct integration may be difficult since network may be modified based on geometries.</td>
</tr>
<tr>
<td>Output</td>
<td>Data/Measures can be visualized in GUI or raw data exported for processing.</td>
<td>Data/Measures can be visualized in GUI or raw data exported for processing.</td>
</tr>
<tr>
<td>Scripting / Application Programming Interface (API)</td>
<td>Custom dynamic-link library (DLL) for ramp metering and signal control; full API planned</td>
<td>Python API</td>
</tr>
<tr>
<td>License</td>
<td>Open source without support; support for a fee</td>
<td>Purchase (includes software updates and support)</td>
</tr>
</tbody>
</table>
8.5.4 DTA Calibration

Model Checking
An important aspect of DTA calibration is finding and fixing network coding problems and performing a model checking process. In the case of a DTA model, miscoding signal timing, approach geometry, intersection connectivity, turn prohibitions, etc. can have major impacts on the simulation. Very often the calibration process requires detailed network coding checks, and network defaults must be revised where they are found to be insufficient to reflect true operations in key locations. In addition, any O-D demand adjustment should be re-done if significant network errors are corrected.

Calibration
In general, the following broad observations are common to DTA model calibration:

- DTA models include more settings and “knobs” to turn (which may or may not be appropriate to adjust) than a traditional static assignment model. This makes the calibration process more complex, costly and time consuming.
- More data is needed than a typical static model (see Section 8.6.2)

Due to the varied level of detail and application of DTA tools, it is important to consider the resolution of the model and what is an appropriate level of calibration. In addition to information provided for calibration subarea models, some strategies for calibrating DTA models include:

- If specific targets are used for traffic volumes and/or travel times, consider thresholds that vary by project priority. Corridors that are the primary focus of the analysis should have the tightest calibration targets while other roads in the model that compose the supporting network may not be as critical. These targets should be developed through coordination with agency staff.
- Signal timing can be a critical element that affects calibration on non-freeway facilities. Spending the time to code signal timing at an appropriate level of detail will facilitate calibration.
- Flow models (relationship of vehicle speed, density and flow) are an important component of freeway segments. Be sure that the settings are reasonable and appropriate for the model area.
- Understand the basis, limitations, and location-dependency of data that was used to develop the model, specifically in regards to if data represents a total traffic demand or an actual (potentially capacity-restricted) traffic volume that is realized in the network.
- Consider if bottlenecks and capacity constraints are being correctly reflected in resulting flow profiles. Gateway adjustments may be necessary to approximate bottleneck effects.
Some parameters (such as vehicle flow densities and signal timing) have the potential to greatly influence the model network capacity and the resulting traffic assignment and overall results. These parameters should be verified before focusing on and adjusting gateways or micro-level details for calibration.

8.5.5 Measures of Effectiveness (MOE)

The fundamental nature of DTA models and core differences from traditional static models allows for an expanded set of model data and reportable measures of effectiveness. The increase of available measures reflects the key differences introduced by DTA models in level of detail (such as intersection operations) and changes over time that are typically not available in static models.

The amount of MOE that are available directly through the GUI of the DTA platform may vary by software version and type of DTA model (link-based versus lane-based, see Section 8.5.3). However, additional measures are typically available indirectly by processing raw data that is produced through the model runs. These possibilities leave the analyst with a wide selection of potential MOEs. It is important to select MOEs that are relevant for the decisions being made and are appropriate for the level of detail coded into the model.

Some potential types of MOEs include:
(Note: additional detail may also be available for individual lanes in lane-based DTA models when denoted with *)

- MOEs typically produced by a static model
  - Roadway segment (link) traffic volume during a time period *
  - Roadway segment (link) average travel time during a time period *
  - Roadway corridor average travel time during a time period *
  - System MOEs (vehicle hours of delay, etc.)
- MOEs typically produced by a DTA model
Some MOEs or outputs that are commonly produced using static models (such as model difference plots) may not be as easy to reproduce in DTA packages. The summary of this output may require additional processing rather than being directly available/automated through the model interface.

The following exhibits demonstrate some of the MOEs that are possible with DTA models.
Exhibit 8-19 DTA MOE Sample 1 – Map-based Shockwave Animation (Regional or Subarea) Shown for Four Sequential Time Periods

Exhibit 8-20 DTA MOE Sample 2 – Travel Time Profile along a Corridor

Corridor travel profiles for one month of Average Weekdays (20 days)

Change in total travel time through corridor from 15:00 to 18:00
8.5.6 Key Considerations (Application and Issues)

The following considerations are intended to help guide decisions regarding application of DTA models. In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements. Since application of a DTA model may be applied as a windowed subarea model to a regional static model, many of the same considerations for windowing would apply. However, due to the fundamental differences for DTA models (including increased resolution for traffic operations), additional considerations would apply. These considerations are not absolute but are intended to function as a general guidance when developing an approach and methodology.

General considerations related to windowing a DTA subarea from a regional static model (see Section 8.5.5 for additional detail)

- Study Area Size/Boundary
- Network Element Refinements (Links, Zones, Nodes)
- Demand Adjustments
- Future Year Scenarios

The following considerations reflect those that are introduced by DTA models that may not be primary issues when dealing with static models.
• Balancing model refinements with overall purpose - The ultimate purpose of the DTA model will application will vary from project to project and will ultimately guide the level of refinements needed in the model. Some examples of the range of typical applications include:
  • Volume development (may include higher level model)
    o Developing base year alternative volumes for operations analysis
    o Forecasting future year volumes
  • Operations analysis (may include finer resolution and detail)
    o Screening alternatives within the DTA model (relative comparisons)
    o System measures
    o Corridor/Intersection measures

• Understanding Traffic Flow Theory and Operations Concepts - DTA models introduce traffic flow details that are not generally present in static models. These elements may vary from those that are simplified in static models (such as traffic control types), to those that are non-existent in static models (flow model and jam density values). In order to correctly understand and use the models, the analyst needs to have an understanding of traffic flow theory that goes beyond what is generally needed for regional-scale travel demand modeling using static models. Some of these key concepts include:
  • Intersection control and movement priority
  • Traffic signal timing (and realistic settings)
  • Speed/Flow/Density relationships (including jam density$^{21}$)

Fundamental knowledge in these areas is needed to correctly code operational elements in the model and to consider the reasonableness of model results.

• While DTA software generally include the ability to import and export data, these abilities, and the differences in the underlying network data models, vary by platform and can make it difficult to transfer data between packages in an efficient manner. For this reason, the analyst should consider these differences when considering application of multi-resolution models and combinations of DTA platforms for project application.

• Applying DTA models for future conditions introduces several other considerations for the future year model:
  o Assumptions for traffic control, specifically future traffic signal timing parameters for existing or proposed traffic signals. In some cases (such as a fixed timed grid network or along a coordinated corridor) it may not be reasonable to assume that signal timing parameters would change in the future. However, depending on the intersection location, ownership, and potential for growth, it may be reasonable to anticipate that traffic signal timing would be updated in the future to reflect changing needs. For example, an intersection on the urban fringe that currently runs free and

$^{21}$ Jam densities vary by location and vehicle mix but generally range from a spacing of 25 to 30 feet per vehicle or 175 to 210 vehicles per lane per mile)
has low average splits and cycle lengths may have longer average splits and cycle lengths as demand increases in the future. However, for intersections that are part of a coordinated system, particularly when located along a highway route that maintains a green band, future signal timing modifications may not be as likely. These assumptions should be coordinated with TPAU and/or ODOT Region traffic group.

- Adjusting demand through O-D matrix demand adjustment is problematic for future year models because it assumes the relationships that exist between the seed demand matrices from a regional travel demand model and the traffic counts hold true in the future (see Sections 8.5.3 and 8.6.4)
- Method used for developing traffic analysis volumes. Many factors (such as the type of DTA model used, the amount of data available, the effectiveness of the calibration process, the amount of pre-processing of traffic demand, etc.) will influence the balance of traffic analysis that is performed within the DTA model versus the use of external tools (including HCM or microsimulation).
8.6 Peak Spreading

This section describes the concept of peak spreading and summarizes different analysis methods, needs, and considerations based on location and context (type of study and implications such as short term development impacts for a TIA or long-term regional planning needs). Peak spreading (as described in the following sections) occurs when there is travel demand for a sustained period that exceeds the available capacity of the transportation network. For this reason, peak spreading is unique to congested conditions, and is unlikely to exist for an extended period in a relatively uncongested network.

While peak spreading methods can be used to estimate how traffic routing, assignment, and/or travel time may be influenced by congestion during different periods of the day, the existence of peak spreading may indicate that other facets of the travel estimation (such as trip generation and trip distribution) may need to be reconsidered. As Oregon moves towards activity based models (ABM) and Dynamic Traffic Assignment (DTA) models the integrated abilities of these tools will limit the need for separate peak spreading processes described in this section.

8.6.1 Peak Spreading General Concepts

The following sections provide an introduction and overview of general peak spreading concepts. For the purposes of the following material, it is important to understand the differences between two terms that are commonly used interchangeably but have very different meanings:

- **Travel demand** – the amount of unconstrained traffic that wants to travel on a road or make a turn movement during a specified period of time. An example of traffic demand would be the amount of traffic that a static travel demand model reports wants to use a road in the future. In reality, there may be constraints (such as capacity of a downstream intersection) that prevent this amount of travel demand from being achieved in the real world. However, this demand” can still provide insight for planning purposes. Travel demand is sometimes reported as a ratio to available capacity as demand/capacity (D/C), which can exceed a value of 1.0.

- **Traffic volume** – the amount of traffic that is actually served on a road during a specified period of time. An example of a traffic volume would be the number of cars that are observed travelling in a lane or making a turning movement during a vehicle count data collection. These volumes are the actual amount of vehicles that are able to use the system, given constraints that exist. The traffic volumes may be equal to the travel demand, but in congested conditions the traffic volumes will be less than the travel demand due to constraints (insufficient green time at the signal, downstream bottlenecks, etc.). Traffic volumes are commonly
reported as a ratio to available capacity as volume/capacity (V/C). By definition, these ratios cannot exceed a value of 1.0.

**How Travel Demand Models Deal With Time-of-Day**
Before defining peak spreading in detail, it is important to understand how travel demand models generate traffic demand forecasts since traffic demand is often revised during peak spreading procedures.

Aggregate trip-based models create time period specific travel demand trip matrices based on static user defined time period factors. These factors usually vary by trip purpose and direction of travel (production to attraction and attraction to production). By applying these time-of-day factors, the estimated daily travel demand is split into time period specific demand. As a result, travel demand models are largely insensitive to peak spreading since the user specifies how demand is spread across the hours of the day.

Activity-based models (ABM), such as those being developed for the Portland metropolitan area regional government (Metro) and ODOT, take a much different approach to modeling time-of-day. ABMs have explicit trip departure time and duration models that operate at the hourly or half-hour time period that are sensitive to a much more comprehensive set of information, including differences in network congestion by time-of-day. As a result, ABMs can produce more reasonable travel demand by time period and are much more able to model peak spreading.

**What is Peak Spreading?**
Traffic demands and traffic volumes constantly fluctuate based on many factors. While traffic is always changing, traffic analyses generally consider peak traffic conditions to assess the needs of the roadway system. Traffic analyses commonly account for traffic peaks or profiles in three general ways.

1) Annual traffic profile - Daily traffic volumes for a given location may be assessed to determine how they change over the year. These considerations are used to adjust for seasonal factoring, which account for changes in daily traffic demand throughout the year. (see APM Section 5.4 for additional information)

2) Daily traffic profile and “peak hour” occurrence - Traffic volumes by time of day (generally divided into an hour) are considered to determine at what time the traffic is generally highest. These periods are commonly referred to as peak periods and (based on land use and transportation factors) generally occur during a “peak hour” in both the morning and evening periods that correspond to commute patterns. In order to account for this peaking, traffic counts may be conducted during both periods for a traffic impact analysis, such as the 7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 6:00 p.m. periods to identify the peak hour.

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22 Such as proximity to land uses that may have atypical trip generation peaks (schools, major employment centers with off-peak shift changes) or variable elements of the transportation system (time of day control or meters that influence other network options) that cause routing patterns to change.
3) Traffic peaking during the highest hour and peak 15-minutes\textsuperscript{23} – Traffic analysis following Highway Capacity Manual procedures further accounts for peak traffic demands during a peak 15-minute period. This is measured as the peak hour factor (PHF), which corresponds to the ratio of: \((\text{peak hour volume} / (4 \times \text{peak 15-minute volume}))\). A PHF of 1.0 indicates a uniform traffic volume during each 15-minute segment of the peak hour, while lower values indicate a sharp peak (such as a shift change near a major employer or end of school day near a school).

On a smaller scale, the example of a PHF at or near 1.0 is indicative of the general concept of peak spreading within the peak hour. **Peak spreading** is when traffic demand exceeds capacity and the resulting traffic volumes are served over a longer peak duration (temporal spreading) or may shift to other routes (spatial spreading).

Exhibit 8-22 demonstrates temporal peak spreading along a corridor. First, the x-axis represents the hour of the day and the y-axis represents the traffic on the freeway segment. The example includes four primary elements:

- The capacity of the segment is approximately 6,100 vehicles per hour (VPH), represented by a dashed red line.
- The unconstrained traffic demand (shown in dashed blue) is the amount of traffic that wants to travel on the corridor. This demand may be the result of applying a growth factor (resulting from historical trend or travel model forecast to an existing profile). The unconstrained demand is highest around 3 p.m. with a value of 8,200 vehicles. This unconstrained demand is well above the capacity of 6,100 vehicles per hour.
- The constrained traffic volume (shown in solid red) is the amount of traffic that can actually use the corridor given the capacity constraints. The constrained traffic volume does not exceed the capacity of 6,100 vehicles per hour. During early hours of the day and late hours of the night (when traffic demand is low), the traffic volume is the same as the traffic demand. However, when traffic demand exceeds the capacity, the traffic volume is limited at the capacity.
- The peak spreading (shown as the area above the unconstrained demand and below the constrained volume) is traffic volume that is using the system earlier or later than the unconstrained peak in order to be accommodated by the capacity. In this case, some of the traffic volume would occur later (approximately between 6 p.m. to 9 p.m.) due to congestion and longer travel times. In addition, some of this traffic may have desired to use the system between 2:00 p.m. and 5:00 p.m. but may have chosen to plan their route differently to leave later. In addition, the peak spreading shown to occur between 5:00 a.m. and 11:00 a.m. would be caused by traffic that would be leaving earlier to avoid congestion later in the day.

\textsuperscript{23} Refer to APM Chapter 3 for additional information regarding traffic counts and congested conditions.
Exhibit 8-22 Temporal Peak Spreading Example along a Corridor

![Diagram showing temporal peak spreading example along a corridor with columns for Time (Hour of day), Vehicles per Hour (VPH), Unconstrained Demand (no Spreading), Constrained Volume (with Spreading), and Shifted Traffic (Peak Spreading).]
What Causes Peak Spreading?
As demonstrated in Exhibit 8-23, peak spreading is generally caused by one or both of the following conditions related to congested traffic conditions:

- Driver decision making - A driver changes their travel behavior to leave before/after the peak conditions to decrease the overall travel time and avoid waiting longer in congestion.
- Bottleneck capacity - A driver does not change their travel behavior and leaves at the desired time to start their trip. However, congestion prevents the driver from completing their trip in a timely manner and they do not reach a downstream location until later due to upstream bottlenecks.

Exhibit 8-23 Types of Temporal Peak Spreading along a Corridor

Why Does Peak Spreading Matter?
Peak spreading as an outcome of congested traffic conditions can influence the amount and distribution of actual traffic on the system. In some cases, the traffic volumes may be less than the travel demand that was projected (during the peak period), but in other cases the traffic volumes may be greater than the projected travel demand due to the effects of peak spreading. In cases where actual traffic volumes are required for an analysis (which is the majority of all traffic analysis), and there is potential for congestion and peak spreading, considerations for peak spreading are important to ensure that findings are reasonable.
In particular, peak spreading considerations are critical for the following use cases:

- **Realistic operational analysis (including microsimulation analysis)** – Realistic traffic demands are necessary to produce realistic traffic operations results. In order to derive more realistic operations (such as v/c or LOS), appropriate consideration needs to be taken for other network elements and behavior that may influence the traffic demand. Microsimulation models generally function poorly (and may reach a gridlock state) when estimates of O-D trips are not reasonable to account for upstream metering or capacity constraints. In addition, by not correctly accounting for peak spreading, the analysis may lead to unrealistic conditions, misidentification of traffic impacts and queues, and poor design decisions.

- **Understanding duration of congestion (and implications of potential improvements)** – As new performance measures and policies are explored, it is critical to have a better understanding of what congested conditions will result. By portraying the actual conditions that people will experience, analysts and decision-makers will have a better context for choices related to transportation improvements and policy needs. This consideration will also provide a means for assessing the implications for potential improvements outside the traditional design hour case.

### 8.6.2 Peak Spreading Scoping

The following sections provide an overview of scoping peak spreading considerations.

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**Peak spreading analysis and approach depends highly on the preexisting tools (such as the type of travel demand and assignment model) that exist for a location as well as the level of detail needed. Some sketch level analysis may be completed in a matter of hours while more in-depth questions may require additional travel surveys and/or (further) development of a travel demand model.**

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### Identifying Analysis Needs

When analyzing congested conditions, peak spreading may need to be accounted for in the following conditions:

- Developing travel demand volumes for microsimulation
- Determining peak hour factors for future intersection capacity analysis
- Evaluating compliance with OHP mobility targets and possibly identifying alternate mobility targets

### Tool Selection

Ultimately, the tools and methods available to assess peak spreading will vary greatly for each unique application based on a variety of factors, including:

- **Purpose of the analysis**
  - What questions are being asked and what level of detail and precision is needed? Having a sketch level estimate of congestion duration at one
location is much different than producing peak period travel volumes along a corridor for microsimulation analysis.

- **Location and context**
  - Single road location versus network level demand
  - Commuter travel base that may adjust travel patterns and driver behavior versus recreational trips that may not have information (the knowledge of regular occurrence) to change travel behavior.

- Availability of existing data sources (see Data section)
- Availability of existing modeling tools (travel demand models or other tools)

Exhibit 8-24 provides an overview of peak spreading tools and methods that are covered in additional detail in the following section.

### Exhibit 8-24 Overview of Peak Spreading Tools and Methods

<table>
<thead>
<tr>
<th>Element</th>
<th>Cursory Method (No Model)</th>
<th>Travel Demand Model (OSUM(^1)/JEMnR(^2))</th>
<th>Metro Hours of Congestion (HOC)</th>
<th>Metro Peak Spreading</th>
<th>DTA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area</strong></td>
<td>Areas without models</td>
<td>Urban areas with models (outside Portland)</td>
<td>Portland region</td>
<td>Portland region</td>
<td>Portland region</td>
</tr>
<tr>
<td><strong>Location Scope</strong></td>
<td>Manually applied on link by link basis</td>
<td>Systematic for model area</td>
<td>Systematic for model area</td>
<td>Systematic for model area</td>
<td>Systematic for model area</td>
</tr>
<tr>
<td><strong>Data Needed</strong></td>
<td>Existing traffic counts and profile</td>
<td>Depends on application and post-processing</td>
<td>Depends on application and post-processing</td>
<td>Depends on application and post-processing</td>
<td>Depends on application and post-processing. See Section 8.6.2</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td>Scaled volume profile for a location</td>
<td>With additional processing - regional matrix and systematic link level travel demand by hour</td>
<td>Systematic link level travel demand by hour</td>
<td>Regional hourly demand matrix from 2-7 p.m. that can be assigned</td>
<td>Link by link or O-D pair travel time for time intervals</td>
</tr>
</tbody>
</table>

1. Oregon Small Urban Models (OSUM) - Population under 50,000
2. Joint Estimated Model in R (JEMnR) Population over 50,000 (MPOs)

**Data**

The following types of data may be useful or necessary to conduct peak spreading analysis:

- Existing travel profiles – existing profiles can provide some insight into how peak spreading currently occurs or could develop given additional traffic growth or transportation network changes.
The following section provides an overview of a cursory method to estimate peak spreading in the absence of a travel demand model. While this method can provide useful estimation on peak spreading potential, locations that are projected to be congested to the degree that trip generation, distribution, or route choice are affected may require a travel demand model to better assess this impacts.

8.6.3 Peak Spreading Application and Procedures

The following sections provide an overview of tools and methods available to analyze peak spreading. Each tool is location-based and therefore options and methods may be limited. In all cases, it is appropriate to coordinate with TPAU or Region 1 Traffic staff to ensure that the method and application is appropriate based on the analysis requirements. In some cases existing tools and data may limit the degree and certainty of peak spreading analysis.

Areas without Travel Demand Models (Cursory Method)

At a cursory level, peak spreading can be assessed for locations that do not have a travel demand model. The application may vary based on the specific location, context or purpose of the analysis (such as short-term analysis or long-range planning needs), and availability of data. However, the general process would be the same. While additional processing and adjustments may be needed and applied, the following method is intended to be applied at a cursory level as an informative approximation of peak spreading.

To manually assess peak spreading, three elements are needed to first develop the un-

- Bottleneck data – data that indicates the maximum capacity for bottlenecks such as intersections. Saturation flow studies may be needed to determine actual capacities.
- Travel survey – Driver decision making has the potential to influence peak spreading characteristics. The decisions people make related to how much congestion they are willing to endure, the flexibility of their schedule, and the likelihood to leave earlier or later to avoid congestion can all affect the degree of peak spreading.
- Travel time data – The collection of existing travel time data may be used to calculate a travel time index (TTI) or other measure to better understand existing congestions levels (the degree to which travel time is impacted by existing congestion) and consider when estimating driver sensitivity and the future potential for peak spreading.
- Seasonal count data – In absence of specific data about the share of system users that are aware of recurrent system conditions (such as commuters) and those that are not (such as recreational travelers), a comparison of seasonal count data may provide insight into the portion of travelers that are seasonal users. This data can be used to inform assumptions about whether trips would occur at other periods in the presence of congestion. (See Section 8.7.3).
spread profile, including:

- **Reference traffic volume at location to be analyzed** – This may be an existing traffic count or a projected future traffic volume, typically for a peak hour. This value is needed to determine how to appropriately scale the traffic profile.

- **Traffic profile at a generally representative location** – This may be data from an ATR or data collected from a multi-hour (typically 16-hour or daily) traffic count. The location would optimally be at the same location that is studied for the effects of peak spreading. However, it may be determined that other locations may be representative (or may be all that is available) and may be sufficient for analysis. Other representative locations would typically be along the same corridor either upstream or downstream of the analysis location. Depending on the use of the cursory analysis, other locations may be considered.

- **Relative comparison (or scaling factor) to adjust (“fit”) the traffic volume to the representative location on the profile** – A factor to convert the traffic profile to the profile for the analysis condition is needed. This factor is derived from the following method and will generally vary by location:
  - Reference volume / Profile volume during period = Profile Factor
  - For a like time period (such as 5-6 p.m.) (Exhibit 8-25):
    - **For same location** - This factor may be equal or near 1.0 depending on when the profile data and reference data were collected. However other values may result from impacts such as seasonal factors or annual growth.
    - **For different location** - This factor may be more or less than 1.0 depending on where the data was collected and the relative difference between the two locations (e.g., the profile data may be located upstream of the study location in an area that generally has higher traffic volumes). Like data collected from the same location, variability also may result from impacts such as seasonal factors or annual growth.

**Exhibit 8-25 Profile Factor Calculation**

<table>
<thead>
<tr>
<th>Profile Factor = Volume (Reference) / Volume (Profile)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Profile Factor</strong>: Scalar factor that will be applied to each hour of the existing profile to achieve the demand profile, which is representative of another location or another analysis period (or year).</td>
</tr>
<tr>
<td><strong>Volume (Reference)</strong>: Volume that represents the analysis volume (peak count or post-processed) for a given time reference time period. This may be the 30HV traffic volume.</td>
</tr>
<tr>
<td><strong>Volume (Profile)</strong>: Volume that is indicated in the daily profile during the same reference time period as the Volume (Reference).</td>
</tr>
</tbody>
</table>

In addition, a general assumption about spreading behavior is needed to determine how the excess demand will be spread:
• **Capacity or maximum traffic flow that can be served** – At the location being analyzed, determine the maximum traffic flow. This may be based on an HCM intersection or other types of capacity analysis.

• **Seasonal data/user system familiarity, or assumptions related to the propensity for drivers to shift earlier, later, or not at all** – Roadway context, location, and fluctuation in seasonal demands have an influence on peak spreading. The decisions made by a traveler (destination, route choice, and time of departure) have the potential to greatly influence the observed peak spreading trends. The outcomes of these decisions can vary greatly based on the characteristics of the travelers, particularly with respect to how familiar the traveler is with the system condition and their level of flexibility. Commuters or other drivers that know the system conditions may choose to leave earlier or later, or may select a different route, based on their expectation of the system condition. This could include unfamiliar drivers if they have access to traveler information on congested conditions. Thus, they may tend to make peaking spread both earlier and later. However, trips made by users that are not familiar with the system (such as regional/recreational trips) may not have the ability to leave at a different time (being committed to a longer regional or interstate trip) or may not be aware of the local conditions before committing to a route. These users would tend to cause peak spreading to occur with a bias towards later. Therefore, the types of drivers on the system and the mix of seasonal and daily users can have an influence on how peak spreading occurs. Related discussion about data is provided in Section 8.7.2. In the absence of other data, the following spreading trends could be applied based on the traffic user:
  - Commuters – Assume that these users that are familiar with the reoccurring system conditions would be evenly likely to change their daily behavior to leave before and after the peak period - half of the travelers would leave before the peak and the remaining half would leave after the peak.
  - Recreational Users (Portion derived from seasonal data) – Assume that these users, which are not familiar with the reoccurring system conditions, would not spread to other periods (i.e., these users would not leave before or after the peak period in order to reduce their overall travel time).

To manually apply the cursory method, the following two steps are needed:
1) Determine the projected (un-spread) traffic profile (each hour) of the profile
2) Determine the method used to develop the adjusted (spread) traffic profile by the following method::
   a. No shifting - Trips leave at original times, but take longer to complete due to congestion. (Trips over capacity will be shifted to later period of arrival)
b. Shifting – A share of commuter or other users may shift their trip-making to an earlier and/or later period. (Determine portion to shift)
   i. Identify the portion of trips that will be shifted earlier or later based on the familiarity with the system.
   ii. Based on the split of excess demand that will be shifted earlier and later than the peak, identify when this period occurs. This will serve as the “divide” where excess demand is shifted before or after the peak.

Example 8-1 Cursory Method for Estimating Peak Spreading (To Determine Duration of Congestion)

In this example, the Cursory Method is applied to determine the duration of “congestion” at the US 101/D River intersection in Lincoln City. This example assesses the southbound direction in the peak summer month (August). The duration of congestion, accounting for peak spreading, is estimated using the following steps:

- **Step 1: Determine the base year volume profile.** An Automatic Traffic Recorder (ATR) exists near the study intersection (D River Wayside ATR) and used to determine the base year volume profile. To determine the summer volume profile, each hourly volume is averaged for the entire month of August. The resulting profile is shown below.

**Existing Year Traffic Profile**

![Existing Year Traffic Profile](image)

- **Step 2: Factor the volume profile to the year 2035 p.m. peak hour volumes.** Through the forecasting process, the resulting year 2035 p.m. peak hour volume for the southbound approach is 2,145 vehicles/hour; the peak hour is 4 p.m. The corresponding base year volume at 4 p.m. (determined in Step 1) is 1,279 vehicles/hour. The resulting factor is 1.68 (i.e., 2145/1279). To determine the
2035 volume profile, each hour of the base year volume profile is multiplied by 1.68. The resulting year 2035 volume profile is shown below.

**Factored Future Year Unconstrained Demand Profile**

![Year 2035 (30HV) Volume Profile](image)

- **Step 3: Determine capacity constraint.** Through HCM analysis (e.g., Synchro HCM report), the southbound mainline approach capacity is 2,091 vehicles/hour. The same value of capacity is assumed for each hour of the 24-hour volume profile.

- **Step 4: Apply Peak Spreading by Shifting Demand to Determine the Volume Served.** First, for this analysis, it was assumed that due to the high amount of recreational traffic during the seasonal peak that no trips would shift before the peak. Therefore, all peak spreading would occur by shifting to a later period. This exercise included comparing each projected (unconstrained) hourly demand to the capacity. When an hourly volume exceeds capacity, the difference is added to the demand of the next hour. After shifting demand, demand is capped at capacity (2,091 vehicles/hour in this example). The following table shows the original demand projected for each hour as well as the resulting shifted capacity. Time periods where the ultimate volume is different than the original demand are shaded.
Shifted Volume Constrained by Capacity

<table>
<thead>
<tr>
<th>Time</th>
<th>Demand</th>
<th>Capacity</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 AM</td>
<td>275</td>
<td>2091</td>
<td>275</td>
</tr>
<tr>
<td>1:00 AM</td>
<td>189</td>
<td>2091</td>
<td>189</td>
</tr>
<tr>
<td>2:00 AM</td>
<td>110</td>
<td>2091</td>
<td>110</td>
</tr>
<tr>
<td>3:00 AM</td>
<td>103</td>
<td>2091</td>
<td>103</td>
</tr>
<tr>
<td>4:00 AM</td>
<td>73</td>
<td>2091</td>
<td>73</td>
</tr>
<tr>
<td>5:00 AM</td>
<td>95</td>
<td>2091</td>
<td>95</td>
</tr>
<tr>
<td>6:00 AM</td>
<td>197</td>
<td>2091</td>
<td>197</td>
</tr>
<tr>
<td>7:00 AM</td>
<td>365</td>
<td>2091</td>
<td>365</td>
</tr>
<tr>
<td>8:00 AM</td>
<td>671</td>
<td>2091</td>
<td>671</td>
</tr>
<tr>
<td>9:00 AM</td>
<td>940</td>
<td>2091</td>
<td>940</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>1416</td>
<td>2091</td>
<td>1416</td>
</tr>
<tr>
<td>11:00 AM</td>
<td>1927</td>
<td>2091</td>
<td>1927</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>2226</td>
<td>2091</td>
<td>2091</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>2263</td>
<td>2091</td>
<td>2091</td>
</tr>
<tr>
<td>2:00 PM</td>
<td>2178</td>
<td>2091</td>
<td>2091</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>2140</td>
<td>2091</td>
<td>2091</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>2145</td>
<td>2091</td>
<td>2091</td>
</tr>
<tr>
<td>5:00 PM</td>
<td>2036</td>
<td>2091</td>
<td>2091</td>
</tr>
<tr>
<td>6:00 PM</td>
<td>1831</td>
<td>2091</td>
<td>2091</td>
</tr>
<tr>
<td>7:00 PM</td>
<td>1549</td>
<td>2091</td>
<td>1731</td>
</tr>
<tr>
<td>8:00 PM</td>
<td>1219</td>
<td>2091</td>
<td>1219</td>
</tr>
<tr>
<td>9:00 PM</td>
<td>925</td>
<td>2091</td>
<td>925</td>
</tr>
<tr>
<td>10:00 PM</td>
<td>676</td>
<td>2091</td>
<td>676</td>
</tr>
<tr>
<td>11:00 PM</td>
<td>457</td>
<td>2091</td>
<td>457</td>
</tr>
</tbody>
</table>

- **Step 5: Determine “congestion.”** Congestion can be defined many ways, but in this example, congestion is assumed as volume/capacity (v/c) of 0.90 or higher. To determine the equivalent volume at which the approach becomes congested, the v/c ratio is multiplied by capacity: 0.90*2,091 = 1,882 vehicles/hour.

- **Step 6: Determine hours of congestion.** For 8 hours of the day (11 a.m. to 7 p.m.) the volume of the southbound approach exceeds 1,882 vehicles/hour. This information is summarized in the figure below.
Cursory Method for Estimating Peak Spreading

![Graph showing vehicle demand and hours of congestion]

- 2035 Demand
- Capacity
- Congestion
- Served

Hours of Congestion

Graph shows the comparison between vehicle demand and the capacity of the system, highlighting the hours during which congestion occurs.
Areas with Travel Demand Models (excluding the Portland Metropolitan Area)

Travel demand models have been developed for a number of areas around the state. These models generally fit into one of two categories, each with distinctions that may provide ability to estimate peak spreading.

- Oregon Small Urban Models (OSUM) - Population under 50,000
- Joint Estimated Model in R (JEMnR) Population over 50,000 (MPOs)

The following sections provide an overview of peak spreading available with each type of model. These methods could be applied systematically over the entire model area. Additional post-processing and refinements that incorporate more real-world data (such as spot location use of actual traffic profile data) and/or use of subarea modeling methods could provide information for peak spreading and traffic profiles on other network locations.

In addition, there is the potential that Metro’s methods for pre-processing the trip table (shifting the demand of O-D pairs to other adjacent time periods based on a TTI ratio), described later in this section, could be applied to these other models with additional effort and coordination. In these urban areas, the modeler would need to identify whether there is systematic peak spreading, or if spreading is limited to a specific corridor through investigation of the variability of the TTI. This endeavor (and travel time data collection) would require further discussion and scoping with TPAU and Region traffic to determine the extent of the analysis based on the unique characteristics of the urban area. Application of this method would require development of a TTI ratio based on a perceived accepted maximum level of congestion (and travel delay) that currently occurs.

OSUM

The OSUM models can produce hourly trip matrices based on static input factors that can be assigned for each hour of the day. These trip matrices provide the ability to determine raw, model level demand profiles for links in the transportation model network. Additional post processing of these demands using real-world traffic data (depending on analysis need) has the potential to readily provide information about peak spreading. A key limitation for this method is that reliability would be a question for time periods that haven't been validated (e.g., 10 p.m. to 11 p.m.). Metro’s method of pre-processing the trip table and subarea model may provide a solution to this shortcoming.

24 For more information: [http://www.oregon.gov/ODOT/TD/TP/Pages/Tools.aspx](http://www.oregon.gov/ODOT/TD/TP/Pages/Tools.aspx)
25 The Eugene-Springfield travel demand model is not a JEMnR model, but it shares many of the same features as it relates to modeling time-of-day and (the lack of) sensitivity to peak spreading.

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trip table (shifting individual demand of OD pairs to adjacent time periods) may be an option, as noted in the previous section.

JEMnR (MPO)
The JEMnR model by default does not produce hourly matrices. Instead, the model is typically set up for the daily, a.m., and p.m. peak periods. It may however be set up for different time periods if desired. To develop matrices for other time periods, static input factors would be needed to split the daily person trip matrices by time-of-day and direction. Separate factors are used for each trip purpose. Once individual matrices were developed, the tool could be applied in a similar method as the OSUM models – with assignment of individual time periods and additional post-processing (using real-world traffic data), as needed, based on specific application needs. Metro’s method of preprocessing the trip table (shifting individual demand of O-D pairs to adjacent time periods) may be an option, as noted in the previous section.
Portland Metropolitan Region

There are two recent tools that have been developed to analyze peak spreading in the Portland metropolitan region. A summary of each of these tools is presented in the following section, but additional documentation for each tool may be available.26

Hours of Congestion (HOC) Tool [Interim Method]
ODOT Region 1 developed this tool as an interim method to assess the duration of congestion in the Portland region. The following excerpts summarize the purpose and methods used to develop the tool. Additional documentation is available from ODOT.

The tool is in the form of a spreadsheet that imports and processes data from the travel demand model to calculate hourly demand for every link in the model. The following excerpts from the documentation provide an overview of the procedures used by the tool:

“The purpose of this study was to develop a method to address peak hour spreading given the limitations of a traditional four-step travel demand model. This was accomplished by using a link-based approach that post-processes travel demand model outputs to generate peak-spreading measures at the link level. The link based approach is viewed as an interim method for addressing hours of congestion where a more robust method would adjust the travel demand model trip tables. However, the link based approach is viewed as a reasonable estimate that will allow the congested hours on freeways and arterial roadways in the Portland metropolitan area to be approximated for purposes of policy discussions and project prioritization.

Hours of Congestion Application
To capture peak spreading on a corridor with a link based approach, traffic volumes produced from a travel demand model need to be post-processed to reveal an hourly volume profile. For this study, an application was developed that accomplishes this process in three basic steps, as shown in Figure 1 [Exhibit 8-26]. The first step involves gathering Metro’s model data for the AM, midday, and PM peak periods. Next, the model data is used to estimate Average Daily Traffic (ADT) and hourly traffic volumes for the entire 24-hour period. Finally, the hourly volumes are compared to the link capacity and, where volumes exceed capacity, peak spreading is applied to spread the volume into shoulder hours.

26 For additional information, contact ODOT Region 1 Traffic Unit for the Hours of Congestion study or Metro’s Transportation Research and Modeling Services for information related to regional model peak spreading.
Exhibit 8-26 HOC Figure 1: Tool Development Process Summary

**Methods**
To determine the congested hours on roadways in the Portland metropolitan area using the link based approach described above, a data mining effort was undertaken to build the Hours of Congestion application based on observed traffic characteristics in the Portland area. The following sections describe the four major components of the data mining.

**Data Collection**
Data for ODOT facilities in the Portland area were collected for the most recent four years from PORTAL, ODOT Automated Traffic Recorders (ATRs), available 24-hour tube counts, and TriMet GPS bus travel time records. Reality checks and data quality screenings were performed on the PORTAL, ATR and tube-count data to remove data from outside the area of interest, incomplete or suspect data, and/or data that did not meet data quality diagnostics. For an example, of the original 665 PORTAL detector locations, 455 remained in the database after the data screening and quality checks were performed.

**Volume Profile Analysis**
Metro’s regional travel demand model provides forecasts for a 2-hour AM period, a 1-hour midday period, and a 2-hour PM period. Daily traffic volumes are not directly forecasted. To estimate a 24-hour vehicle volume profile, regression analysis was conducted to first develop estimation factors for the total daily volume (ADT). With the predicted daily volumes and the peak period volume forecasts, a 24-hour volume curve was estimated to represent an “unconstrained” forecast for each link.

**Peak Spreading Analysis**
To develop an application that can spread excess volumes in peak periods, existing peak spreading in the Portland area was investigated in the PORTAL

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27 It should be noted that while Metro’s model does not provide temporal spreading of the traffic volumes in the peak periods when congestion occurs, it does spatially spread volumes to parallel corridors when possible to balance travel times in the system.
traffic volume database. Traffic volume data was examined to essentially identify congested vs. uncongested traffic flow days at locations where peak spreading was found to occur. At these locations, AM and PM peak periods were examined to determine how spreading occurs (i.e., which direction traffic shifts relative to the peak hour). These volume shifting factors were then used in the Hours of Congestion application to adjust 24-hour profiles when demand was forecasted to be above capacity. This shifting of traffic volume is an important distinction, as total daily traffic volume is conserved whereas some methods used by other agencies for similar efforts “trim” peak period volumes and do not maintain ADT.

**Congestion Threshold Analysis**

Review of Hours of Congestion analysis compared to speed data in the PORTAL system found that the congestion threshold (where vehicle speeds are significantly reduced from free-flow speed) may be well below the ODOT mobility standard, which is essentially where volume reaches capacity. An evaluation of speed congestion information compared to link v/c estimates was conducted, which found that a v/c ratio of 0.80 (instead of 1.00) would be a reasonable threshold for congestion. Therefore, the Hours of Congestion application was built to track both how many hours exceed a v/c ratio of 0.80 and how many hours reach a v/c ratio of 1.0.”

The output of the Hours of Congestion tool is link-level traffic volumes for each hour of the day as shown in Exhibit 8-27. This example demonstrates a case where the link demand during the evening peak approaches the link capacity (4,000 vph) shown by the red line but does not reach the capacity. If the demand had exceeded the capacity, the tool would process the demand to the shoulder periods.

**Exhibit 8-27 HOC Output Example (Link Volume by Hour of Day)**
Metro Travel Demand Model with Peak Spreading

Metro has developed a methodology for pre-processing raw demand volumes from the static travel demand model to feed into dynamic traffic assignment (DTA). The output of the tool is an adjusted origin-destination matrix for each hour between 2:00 p.m. to 7:00 p.m. The following text is an excerpt for Metro’s tool documentation, which is distributed with other travel demand model assignment tools:

“Metro's peak spreading algorithm is a method for measuring congestion through a travel time index (TTI), which is simply travel time / free flow travel time. For example, if the free flow travel time between an O-D pair is 10 minutes and the peak period travel time is 15 minutes, then the O-D pair has a TTI of 1.5 (15 minutes / 10 minutes).

A proxy 'threshold' for congestion is based on the highest TTI corridor in our region within Existing Year (2010) regional model--I-5 NB from 5pm to 6pm. It’s a corridor that currently experiences a good deal of peak spreading, which is represented in the relatively long congested peak (3pm – 6:30pm or later on most work nights). The TTI for this corridor is 1.6, and establishes a threshold for comparing all other congestion against. It is assumed that travelers are willing to accept congestion up to a TTI of 1.6 before they begin peak spreading.

The TTI threshold is used to adjust future year demand for each hour in the PM peak period. Since congestion is widely prevalent in the future, the peak period is measured from 3pm-6pm. Hour-long shoulder periods are also produced, resulting in a full 5 hours of PM peak period trip tables (2pm-7pm).

To begin the peak spreading algorithm, a 5pm-6pm (peak of the peak) hourly static assignment is run, and the TTI for each O-D pair is then calculated. For each O-D pair in which the TTI exceeds the TTI threshold (1.6), trips are removed based on how much the TTI exceeds the threshold. For example, if an O-D pair has a 2.0 TTI, and the TTI threshold is 1.6, the difference is 0.4. This number is 25% above the TTI threshold (0.4 / 1.6), therefore 25% of the trips from this O-D pair are removed from the 5pm-6pm trip tables (SOV and HOV only) [Note that latent demand for other O-D pairs may potentially be reassigned to links belonging to paths and O-D pairs that were adjusted].

The trips that are removed from the 5pm-6pm hour are added to the 4pm-5pm and 6pm-7pm trip tables. For each of these hours, the above process is repeated:

28 Contact Metro’s Transportation Research and Modeling Services for additional information.
29 Application of this methodology to areas outside of the Portland metropolitan region would require assumptions about an appropriate TTI to use.
30 The spreading is applied to the O-D matrix itself and not the assigned link volume. Therefore, after the O-D matrix has been adjusted it will need to be reassigned. The reassignment may result in different paths than the original assignment and (while the demand for the original O-D pairs using a link will be reduced) other latent demand from other O-D pairs may shift to the link that was originally over capacity. Therefore, reducing all O-D pairs assigned to a link by 25% may not ultimately result in a 25% demand reduction.
Produce hourly static assignments with the new trip tables, calculate the O-D TTIs, and remove excess trips based on the TTI-to-threshold ratio. The excess trips get added to the next shoulder hour (e.g., 3pm-4pm for the 4pm-5pm hour). The process is continued on through every hour of the 5-hour PM peak period.

There are a few additional rules that are observed during the process, such as never removing more than 50% of the trips in an O-D pair for the 5pm-6pm hour and never reducing the O-D trips in subsequent shoulder hours to values less than the final 5pm-6pm peak spread tables.

The final result is a set of hourly trip tables encompassing the 2pm-7pm time period, with O-D pairs reflecting different degrees of peak spreading depending on the initial amount of 'congestion' (i.e., comparison against the TTI threshold) measured during each hour.”

Additional frequently asked questions for Metro’s peak spreading methodology are available in Appendix 8A.

8.6.4 Key Considerations for Peak Spreading Application

Policy and Performance Measures
While accounting for peak spreading generally improves the reasonableness of traffic volumes, it may not be compatible with some performance measures and policies that are based on those performance measures. For example, mobility targets in the Portland region are based on V/C ratios, which for some locations (such as a Town Center) exceed 1.0. These policies are based on traditional tools that do not fully account for limitations related to peak spreading and capacity constraints within congested systems. Peak spreading methods have the potential to greatly improve the reasonableness of reported measures; however, it is important to understand the limitations and differences between policy measures and the tools that are used to analyze them.

Existing and Future Year Methods
Projecting peak spreading for future year conditions adds another aspect of uncertainty. Given limited resources and data, one approach may be to scale an existing demand profile to a forecasted future magnitude. However, assuming that existing year demand profiles (shape, not magnitude) are similar in the future may be affected by the following:

- Location of future growth areas and travel patterns on the facility
- Traveler decision making based on future changes to society and technology
- Future conditions on other areas of the travel network, including upstream/downstream bottlenecks and adjacent routes
Appendix 11A – Procedure for Analysis and Design of Weaving Sections, A User’s Guide

Appendix 12A – Preliminary Traffic Signal Warrant Analysis Form

Addendum 12B – Two-Way Stop Control Intersection Queuing

Addendum 13A – Progression Analysis
Addendum 14A – Multimodal Analysis

15 NOT YET WRITTEN – SEE APM VERSION 1

Addendum 15A – Protocol for Vissim Simulation

Note: The Protocol for VISSIM Simulation provides practitioners with ODOT expectations, guidelines, and requirements when considering and performing traffic simulation analysis with VISSIM. The protocol shall be followed on all ODOT plans and projects.

16 NOT YET WRITTEN – SEE APM VERSION 1

Appendix 16A – Noise, Air and Energy Traffic Requirements Checklist

17 NOT YET WRITTEN – SEE APM VERSION 1

18 NOT YET WRITTEN – SEE APM VERSION 1

19 NOT YET WRITTEN – SEE APM VERSION 1

Appendix 19A – Example Tech Memos
Appendix 19A.1 – Fern Valley Interchange Existing Conditions Technical Memo

Appendix 19A.2 – Constitution Area Refinement Study Future No-Build Technical Memo

Appendix 19A.3 – Grandview – Nels Anderson Traffic Analysis Technical Memo

Appendix 19B – Example Narratives

Appendix 19B.1 – US 97 Bend North Corridor Solutions Project (Example of a System Project)

Appendix 19B.2 – Constitution Area Refinement Study (Example of a Point Project)

Appendix 19B.3 – US 199 Expressway Upgrade Project (Example of a Linear Project)