ENGINEERING POLICY BALLOT

Effective: January 1, 2022

Level 2

Level two revisions require the approval of the **Assistant Chief Engineer** and the **Federal Highway Administration** only. The **Senior Management Team** is encouraged to review the content and provide comment to the appropriate director. For all other parties, these revisions are posted for information only.

ENGINEERING POLICY BALLOT

Effective: January 1, 2022

Issue 1: New TSMO EPG Article and Related Updates

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Katy Harlan – TS

Summary: Currently Transportation Systems Management and Operations (TSMO) information and guidance is in several EPG articles and may not be clearly defined as a TSMO strategy. These proposed EPG article revisions will bring the existing TSMO guidance up-to-date and assist design teams with incorporating TSMO strategies into projects.

Publication: EPG 104.5, 104.6, 104.7, 130.2.2, 235.6, 616.13, 616.4, 909 & 948

Issue 2: Guard Cable Process Update

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Nick Voltenburg – DE
Tom Honich – TS
Sarah Kleinschmit – DE

Summary: The proposed EPG revision(s) will better define the roles and expectations of guard cable contractors and MoDOT maintenance personnel in the aspects of guard cable installations and repairs. The updated article will also include warrants to better identify when guard cable should be installed along the roadways. This revision also introduces a standardized tension log form for contractors to use when installing guard cable and making repairs. The standard log form provides consistent required information for future referencing.

Publication: EPG 171, 616.2, new Tension Log Form

Issue 3: Transportation Impact Analysis

Approval: **Level 2 – Assistant Chief Engineer**

Sponsor: Ray Shank – TS

Summary: Transportation Impact Analyses can play a vital role in the development of projects. The main purpose of the transportation impact analysis (TIA) is to ensure safety and traffic operations are fully considered during project scoping and development. The proposed EPG article brings all aspects of a TIA together in one place. The article will also identify the tools available for developing the TIA.

Publication: EPG 905.1 and 905.3 (new)

104.5 Items to be Considered and Addressed

At the completion of project scoping all of the items that could possibly affect the scope of the project will have been discussed by the core team. Decisions with regard to how each of these items will be handled shall be documented for future reference. These items not only include the concept of the project but also items such as consideration of ~~how~~ traffic impacts ~~will be handled~~ during construction, any special working restrictions that may be placed on the contractor, incentive/disincentive clauses, contract acceleration clauses, environmental constraints, environmental mitigation commitments, etc. The project scoping checklists described in Project Scoping Checklists provide a summarization of the most common items that may be associated with a project. The items on each of the core team member's checklists and any others pertinent to the project should be addressed prior to completion of scoping.

Most importantly the project manager and core team should ensure that the need has been satisfied.

104.6 Project Scoping Checklists

Efficient use of the project core team is essential in identifying the design elements of the project. When the various disciplines represented by the core team work together, considering as many project development factors as possible, an accurate scope can and will be achieved. There are two main items that can prevent the effective use of core teams: not having the proper members included in the decisions for which they should have input and core members' lack of knowledge of their functional unit.

Checklists for Core Teams

- Bridge Scoping Checklist
- Construction and Materials Checklist
- Design Checklist
- Environmental Checklist
- FHWA Checklist
- Maintenance Checklist
- Planning Checklist
- Design Liaison Checklist
- Project Scoping Checklist
- Public Information and Outreach Checklist
- Railroad Checklist
- Right of Way Checklist
- Traffic Checklist
- TSMO Checklist
- Utilities Checklist

Other Documentation

- Project Estimate Record Sheet

In order to address these issues, two types of checklists have been developed to help ensure the proper factors are being considered through the project scoping process. The checklists are designed to represent the probable issues a core team will address through the process of scoping a project. These lists are not intended to be all-inclusive, but a good representation of the key issues. The checklists are also not intended to be static, but are intended to be flexible in the fact that they can be modified as issues arise and expectations of core team members change.

The checklists are designed to encourage thought upon common development factors as well as those elements that are often overlooked. Strong core team participation is another benefit of the checklists, as they cannot be properly completed without the full commitment of a multidiscipline core team. Finally, the completion of the checklists could act as a signal to the project manager that the project scope is nearing completion.

The Project Scoping Checklist has been developed to assist the project manager in determining the members who are required to be involved in various project decisions. This checklist summarizes the expectations that each type of core team member is trying to meet. The project manager may choose to use this checklist to ensure the scope of a project is as fully defined as possible prior to programming right of way and construction funds.

The other type of checklist that has been developed consists of a list of expectations that each functional unit has for the core team member who will be representing them. With these lists an individual core team member will know the areas of the project scoping process for which they are responsible to provide input to the core team.

Completion of these checklists is important and they ~~not mandatory but can be a useful tool to~~ should be used by the project manager and core team members. These checklists are provided as a tool to help remind the project manager and the core team members to address many of the necessary items during the project scoping process. An electronic version of the Project Scoping Checklists can be found in the Project Scoping category of the design form.

104.7 Scoping Estimates

Estimates based on cost per mile shall in no case be considered to contain sufficient detail to allow their inclusion in the STIP.

The scoping estimate is used to determine solutions for a project. There may be multiple scoping estimates for a project since there are multiple solutions for a project. The district determines which solution best fits the purpose and need of the project and begins preliminary plans stage during which the Program Estimate is complete. The Program Estimate shall not use the cost per mile pricing because there are too many unknowns and assumptions made during the scoping stage of a project to produce an accurate Program Estimate. The Program Estimate shall be at the preliminary plans stage after 30% of the plans are completed.

Resources
Cost Estimate Guide for Scoping
Project Scoping Form
Resurfacing Per Mile Scoping Form

The Project Scoping Form is available for detailed documentation of various project design elements of the project in order to assist the project estimator in covering all applicable project elements while establishing the conceptual estimate. Although not required, the Project Scoping Form can be used to establish a detailed project overview of all likely applicable costs, and while the tool itself does not yield an estimate, it does serve to clearly define and document the various project elements which combine to impact the project cost. This documentation will be beneficial as the project moves forward into preliminary design and programming.

For preventative maintenance treatments, the Resurfacing Per Mile Scoping Form spreadsheet has basic inputs for average unit prices and the applicable work types. The spreadsheet generates a per mile cost for most resurfacing projects based upon the intended project elements to be included. When combined with BidTabs.net, this tool allows the user to quickly compare alternative treatments with costs based upon the specific unit costs for the project specific area. By comparing the specific costs for each alternative, the project staff can select the best overall treatment in terms of cost and benefits for each project.

The cost per mile assumption used to develop the scoping estimate should be derived using data from similar, recently-awarded, projects in the region.

Where similar projects are not found, the Cost Estimate Guide for Scoping may be used. The Cost Estimate Guide for Scoping includes cost per mile factors derived from similar projects as well as the generic factors. These factors typically are for the major items of work and do not include other anticipated work that would be required to construct the project. All other anticipated construction costs should be included in the scoping estimate which is typically assumed at 20% but may be more or less depending on the project.

For Advanced Work Zone traffic techniques, refer to EPG 616.13, Work Zone Capacity, Queue and Travel Delay, and utilize Section B of the Enhanced MoDOT Work Zone Impact Analysis Spreadsheet for cost estimates.

County

Route

Job Number

Core Team Member

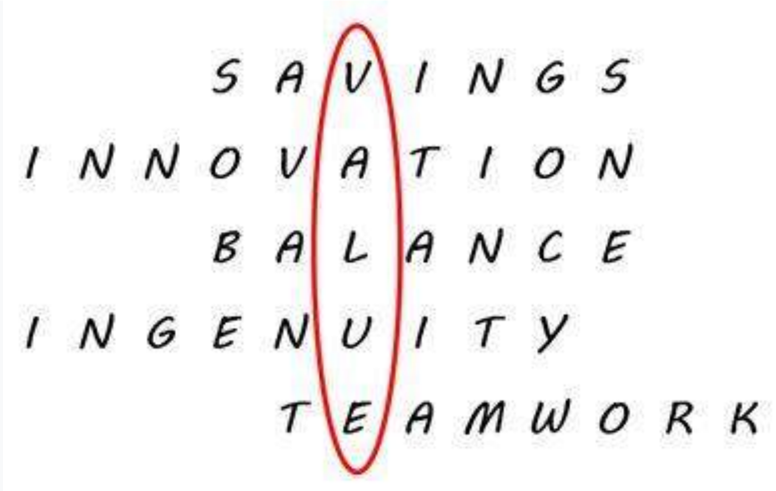
TSMO
(Transportation Systems Management and Operations)
SCOPING CHECKLIST

A project's scope can be defined as the set of design parameters that precisely satisfy the purpose and need of the project. A poorly identified scope that is broader than the purpose and need will result in an unnecessarily high project budget and schedule, while a scope which falls short will yield a project that accomplishes little of significance. While an accurate project scope is difficult to identify early in the development, a careful, multidisciplinary examination of the purpose and need will produce a solid foundation upon which project development can occur.

This checklist is designed to stimulate thought on those project parameters that are sometimes overlooked and whose omission can jeopardize the integrity of the scope. At the initial scoping meeting, the appropriate core team member should fill out the checklist as completely as possible. As project development progresses, the core team member should continue to update the checklist and coordinate with the project manager. In this manner, potential changes to the project scope can be dealt with as they emerge, and the scope represented by the preliminary plan will be as accurate as possible.

- ☐ Evaluate traffic queuing and delay of each design alternative. Refer to EPG 616.13, Work Zone Capacity, Queue and Travel Delay and utilize the Enhanced MoDOT Work Zone Impact Analysis Spreadsheet.
- ☐ Ensure additional delay due to the project design is 15 minutes or less.
- ☐ Consider need for contract incentives or disincentives to minimize construction time.
- ☐ Ensure existing ITS and TSMO strategies are maintained in the project design.
- ☐ Determine appropriate Advanced Work Zone traffic techniques to be included in the project. Refer to EPG 616.13, Work Zone Capacity, Queue and Travel Delay and utilize Section B of the Enhanced MoDOT Work Zone Impact Analysis Spreadsheet.
- ☐ For projects on interstates and major freeways, develop a traffic incident management (TIM) plan to ensure incidents are cleared quickly and traffic safety is maintained. Refer to District Incident Management Coordinator or District TIM Coordinator.

Category:130 Value Engineering



Continually Searching for Value

Contents

130.1 Discussion

Value Engineering (VE) is a systematic method of examining performance to improve the value of projects or processes. Value is defined as the ratio of performance to cost and thus capable of being increased by either lowering the cost or improving the performance. MoDOT's values and tangible results place increased importance on value-based, practical design. While VE, in the classic sense, tends to be somewhat more structured, VE and Practical Design are intended to achieve the same goal. The goal of VE is to build the right project at the right time, achieving delivery of project purpose and need with proper project scope.

Practical Design
Summary 2007
See also: Research Publications

Additional Information
District Value Engineering Coordinator's Responsibilities
Project Manager's Guide
Value Engineering Team Leader Guide
VE Training Evaluation Form
Construction Value Engineering Change Proposal (C-104)
Evaluation Procedures for Construction Value Engineering Change Proposals
MoDOT Value Engineering Contacts

MoDOT uses VE to ensure that the public receives full value for every tax dollar invested in Missouri's transportation system. VE techniques are used to improve productivity in nearly every aspect of MoDOT's operation, including practices, processes, and procedures. In highway construction, VE encourages contractors to submit proposals for modifying the plans, specifications or other requirements of the contract to deliver improved projects of the best possible value.

MoDOT's goal is to have some form of Value Analysis on every project.

The FHWA's *Value Engineering for Highways* provides further details on the VE technique and its applicability to highway projects and functions. AASHTO's *Guidelines for Value Engineering, 2nd Edition* provides an excellent description of VE and the process steps.

130.1.1 Study Timing

VE studies are performed to add value to a project, not to simply reduce costs. VE studies should challenge project scoped that exceed the minimum necessary to deliver the project's purpose and need. As stated in the law, VE studies are conducted "to provide suggestions for reducing the total cost of the project and providing a project of equal or better quality."

Although only a single study during preliminary design is generally required for a project, VE studies can be performed any time prior to letting or after award, and even multiple times on an individual project. A study can be conducted at any stage during the design life of the project; however, priority is given to performing the study as early as feasible to maximize the opportunity to implement developed alternatives. During the study, all aspects of the project may be considered including, but not limited to, location, geometrics, final vertical and horizontal alignments, drainage, construction staging, traffic impacts, TSMO strategies, traffic control, and signalization, pavement and structure details. In addition, studies in the later phase should consider what additional flexibility can be added and what adjustments can be made to "fine tune" the project prior to letting.

Additional VE analysis should be considered if, during a project's design, the scope of work is changed significantly from that which was studied previously. In addition, consideration should be given to an additional study if the previous study will have been conducted more than 10 years prior to the projects letting.

130.1.2 VE Organization

Value Engineering is a critical program and requires statewide participation in order to accomplish the program goals. The Policy and Innovations Engineer manages the overall operation of MoDOT's VE program. The Policy and Innovations Engineer is responsible for tracking the VE program and reporting its progress to both management and the FHWA. The Policy and Innovations Engineer leads studies and may assist with the initial selection of teams for district VE studies, and provides training guidelines and facilitation.

Each District Engineer selects a district value engineering coordinator (DVEC) to coordinate VE activities in that district. The DVEC is responsible for the district's VE program. The DVEC should be at a level consistent with the supervision and management responsibilities of the VE effort. The DVEC is responsible for scheduling the study and making appropriate accommodations for the participants. The DVEC serves as a team member on the VE study to become familiar with the process and leads VE studies, as required, to meet the demands of the program. The DVEC is also responsible for tracking the district led value engineering studies and ensuring the study results are forwarded to the Policy and Innovations Engineer and entered into the SIMS database for each studied project.

In any case, the facilitator of the study compiles recommendations from the VE study and submits them in a VE report, for approval as follows:

- The lowest level decision maker within the project hierarchy can approve and implement VE recommendations that do not change policy, standards, or scope of the original project. A copy of the VE study and the Project Manager's, District Design Engineer's or District Engineer's approval is retained by the district and the Policy and Innovations Engineer. The Policy and Innovations Engineer notifies the team members of the study results and tracks results of each study.

- The approval of a District Engineer or division engineer is required to approve and implement VE recommendations that change the scope of the original project. A copy of the VE study and the District Engineer or division engineers' approval is retained by the district and the Policy and Innovations Engineer. The Policy and Innovations Engineer tracks results of each study.

- The approval of the Chief Engineer, or his representative, is required to approve and implement VE recommendations that affect more than one division/district or change policy or standards. The Policy and Innovations Engineer notifies affected divisions, districts and the team members and tracks results of each study.

Approved recommendations are incorporated in the project design. If an approved recommendation cannot be included, the Project Manager must document the justification for eliminating the recommendation. This documentation should be submitted with the PS&E and a copy is sent to the Policy and Innovations Engineer.

130.1.3 Consultant Led VE Studies

When consideration is given to using a consultant for conducting a VE study, the Policy and Innovations Engineer should be contacted. If the State Design Engineer approves the use of consultant services for a VE study, the Policy and Innovations Engineer will work with the district to ensure that the selected consultant is qualified and has no conflict of interest for the proposed work.

130.2 Design Phase Value Engineering

Design phase VE studies can be conducted during any phase of the project design process but prior to PS&E submittal. These studies can also be traditional or non-traditional, depending on the project. District should work with the Policy and Innovations Engineer to determine their VE needs.

130.2.1 Design Phase Project Selection and VE Workplan

Each year, a value engineering work plan for the federally required Value Engineering Studies is completed after approval of the MoDOT highway right of way and construction program.

The federal requirements are:

- Projects on the National Highway System (NHS) receiving federal assistance with an estimated total cost of $50,000,000 or more.
- Bridge project on the NHS receiving federal assistance with an estimated total cost of $40,000,000 or more. (A bridge project is defined as any project where the primary purpose is to construct, reconstruct, rehabilitate, resurface or restore a bridge).
- Any other project designated by the Secretary of Transportation.
- Design/Build projects do not require a VE study.

Please note, total cost is defined as the cost of all phases of a project including environmental, design, right of way, utilities and construction.

Projects meeting the minimum federal requirement are identified and submitted to FHWA for their concurrence in the form of a VE work plan. The VE work plan will identify all of the projects requiring a study and the anticipated date of those studies (if known). In addition, the work plan will identify each of projects for which a VE study is required for which value analysis has already been conducted along with the date of that study. The DVECs will assist the Policy and Innovations Engineer in identifying the appropriate projects.

A district value engineering workplan will be created by each DVEC to identify the district's projects which will be the priority on which to conduct a VE effort. The DVEC may use the VE project selection criteria to aid in determining which projects have the greatest potential for study. The DVEC sends the district's annual study schedule to the Policy and Innovations Engineer for retention and to supplement the MoDOT VE work plan.

Divisions or districts may also request VE studies at any point throughout the year. These design phase VE studies are generally done at the district level. VE studies on procedures, processes, specifications, standard plans and details of statewide impact are generally done at the division level.

The VE study report and recommendations are conveyed to the appropriate staff upon completion of the study. Affected districts and divisions will receive copies of the study as soon as practical after its completion. The DVEC works with project managers to evaluate the recommendations of the VE team. The project managers submit responses to the study recommendations to the Policy and Innovations Engineer.

130.2.2 Design Phase VE Study Process

The formal VE process entails a systematic process of review and analysis of a project during its design/project development phase, resulting in recommendations to improve value while addressing the project's purpose and need. The study consists of the following, which is also known as the job plan:

- **Pre-Study Phase:** The Policy and Innovations Engineer works with the project manager and DVEC to set up the study (see the Project Manager's Guide for additional information).

- **Study Phase:** A multidisciplinary team not directly involved in the planning or design of the project, conducts the VE review by: investigating and analyzing the planning, design, and constructability of a project.

    - Informative Phase - identifying project functions and costs and worth;
    - Creative Phase - creatively speculating on alternate ways to perform the various functions;
    - Evaluation Phase - evaluating the best and/or least life-cycle alternatives;

Related Information Video
Life Cycle of a Highway

- Development Phase - developing acceptable alternatives into supported recommendations; and
- Presentation Phase - presenting the team's recommendations to the appropriate staff.

- **Post Study Phase (or Resolution Phase):** Approval and implementation of VE recommendations and finalizing the VE Report. The VE Report should consist of:

  - The names and contact information for the participants
  - A description of the project
  - A summary of the functional determination or consideration given for the project.
  - A listing of the generated alternative solutions
  - The traffic impacts of each alternative
  - The anticipated savings costs associated with each alternative
  - A copy of the district's or division's response indicating accepted alternatives and anticipated savings.
  - Any additional pertinent information associated with the study.

In addition, required VE studies for bridge projects should include the following:

- A review of the bridge substructure and superstructure requirements with consideration for alternative construction materials.
- An engineering and economic assessment with consideration of acceptable designs.
- A life-cycle cost analysis and consideration of construction duration.

130.2.3 Design Phase VE Study Types

There are several types of studies:

130.2.3.1 Traditional VE Studies

A traditional study is typically used on required studies, however as each project is unique, each phase of the study can be scaled to meet the needs of the individual project.

- **Concept Stage VE (CSVE).** The focus is on coming up with many alternates, the goal being to choose the best alternate to accomplish project P&N. It works best for the CSVE to be conducted prior to signing DEIS or before conceptual submittal if a CE. (3- to 5-day study). A full VE report is prepared.

- **Preliminary Stage VE (PSVE).** The traditional VE study conducted prior to preliminary plan submittal. The focus here is usually on improving the existing design, often, by this stage, the footprint is usually set and it may be too late for major functional enhancements. (3- to 5-day study). A full VE report is prepared.

- **Final Design Stage VE (FDVE).** A traditional VE study conducted near the end of the design process. The focus here is on improving the design, providing flexibility and considering alternatives that meet the purpose and need. This is likely the least effective phase to conduct the study as most of design features will have been committed to and significant changes may be required to implement new alternatives, however project improvement is still possible. A full VE report is prepared.

235.6 Approval of Preliminary Plan

The preliminary plan for projects designated for federal involvement for preliminary plans on the PODI Matrix must be approved by the FHWA. The district submits the preliminary plan to Design for review and approval and once obtained Design submits the preliminary plan to the FHWA for approval. An updated cost estimate of the project is included in the transmittal letters.

For all other projects, the district engineer may approve the preliminary plan as long as established design guidance and policy are followed. If design exceptions (signed by the district engineer) are necessary, they must accompany the submittal of the approved preliminary plan to Design.

~~In both situations, the district will provide Design with three (3) copies of the approved preliminary plan.~~

The NEPA process must conclude, resulting in FHWA approval of a CE, Finding of No Significant Impact (FONSI), or a Record of Decision (ROD), prior to approval of the preliminary plan for any project. The process to obtain this approval is described in EPG 127.14 National Environmental Policy Act (NEPA) Classification Documents. Final design cannot begin until this step is complete.

The district completes an electronic request for environmental services (RES) at each project development milestone, or at least at the Location/Conceptual state and final design (see EPG 127.1.1.2 Process). Submission of the RES at this stage will enable earlier initiation of cultural resource compliance procedures and possibly prevent future project delays.

The letter of transmittal shall contain the following information:

- Passing sight distance controls and data.
- Existing pavement type together with thicknesses of surfacing and base at the connecting ends of the project.
- Brief statements on borrow or excess material requirements.
- Utility concerns.
- The results of traffic capacity studies.
- TSMO Evaluation and Analysis
- Ideas for traffic control.
- Any information necessary to explain items not self-explanatory on the preliminary plan itself.

616.13 Work Zone Capacity, Queue and Travel Delay

When lane closures are required for road construction, rehabilitation, or maintenance activities, the capacity of the roadway may be greatly reduced. Capacities differ for interstates, freeways, multiple-lane routes and two-lane roadways due to the number of closed lanes, how the project will affect the surrounding roadways, and geometrics of the roadway. When the reduction is too great the traveling public may experience unacceptable travel delays through the work zone, vehicles queuing (a line of vehicles) upstream of the work zone and possible frustration of the motorist.

Typical estimation for capacity restriction is outlined in the MoDOT Work Zone Guidelines. To help MoDOT personnel view capacity restrictions and cautionary zones, the Transportation Management System (TMS) provides the restrictions in a color coded *Traffic Segment Hourly Volume* (TSHV) table. Directions of how to use the TSHV table are available.

Hourly volumes - IS 70 E Begin Log:114.717 End Log: 136.582

Period	12	1	2	3	4	5	6	7	8	9	10	11	Total ADT
Segment: MO 179 S **Roadway:** FREEWAY **Date:** 04/20/2016 **Lanes:** 2/1 **Cap:** 1240 **Cautionary:** 1000 **Logs:** 111.458 to 114.717													
AM	262	181	155	186	236	428	991	1595	1203	1000	1039	1095	17586
PM	1057	1048	992	1023	1046	968	818	622	548	445	374	273	17586
Segment: .394 mile(s) after FWS CUMBERLAND CHURCH RD S **Roadway:** FREEWAY **Date:** 04/20/2016 **Lanes:** 2/1 **Cap:** 1240 **Cautionary:** 1000 **Logs:** 114.717 to 115.508													
AM	262	181	155	186	236	428	991	1595	1203	1000	1039	1095	17586
PM	1057	1048	992	1023	1046	968	818	622	548	445	374	273	17586
Segment: RT BB E **Roadway:** FREEWAY **Date:** 04/20/2016 **Lanes:** 2/1 **Cap:** 1240 **Cautionary:** 1000 **Logs:** 115.508 to 117.69													
AM	268	185	159	191	242	438	1014	1632	1231	1024	1064	1120	17989
PM	1080	1071	1015	1047	1069	989	837	637	560	456	383	279	17989
Segment: RT J S **Roadway:** FREEWAY **Date:** 04/20/2016 **Lanes:** 2/1 **Cap:** 1240 **Cautionary:** 1000 **Logs:** 117.69 to 120.962													
AM	280	163	138	176	222	381	921	1540	1224	1107	1141	1256	18475
PM	1147	1137	1093	1141	1198	1051	912	630	565	427	362	267	18475
Segment: US 40 E **Roadway:** FREEWAY **Date:** 04/20/2016 **Lanes:** 2/1 **Cap:** 1240 **Cautionary:** 1000 **Logs:** 121.182 to 124.406													
AM	281	189	156	204	247	508	1351	2265	1681	1384	1331	1382	23655
PM	1433	1304	1434	1424	1477	1542	1060	868	785	556	402	387	23655
Segment: MO 740 E **Roadway:** FREEWAY **Date:** 04/20/2016 **Lanes:** 2/1 **Cap:** 1240 **Cautionary:** 1000 **Logs:** 124.406 to 125.547													
AM	300	195	174	163	281	564	1528	2829	2303	1700	1665	1720	31847
PM	1810	1862	1998	2188	2345	2317	1737	1231	1143	821	585	390	31847

Page 1 of 3 (42 items) [1] 2 3 Page Size: 18

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Fig. 616.13, Traffic Segment Hourly Volume Table: I-70 Eastbound Example.

The TSHV table provides time periods when lane closures are in a cautionary zone or a capacity restriction, which are color coded blue and red, respectively.

The cautionary zone is a triggering point for a review of the location or area the work will be performed. Normally, there should not be a capacity or travel delay concern, but due to history, narrow lanes, climbing grades, etc., the capacity may be reduced to a level of concern for delays or queuing. If there is a queuing or delay concern, work may be required to be performed during off-peak hours (i.e., nighttime and/or weekends) when necessary.

When the hourly volume reaches the capacity restriction level, work should be scheduled during off-peak hours. Off-peak hours could consist of the time between rush-hour, per example; some locations only work between the hours of 9 am and 3pm. Many locations are taking advantage of nighttime or weekend hours due the lower volume of traffic.

Due to different types of work, there may be times when lane closures are necessary during the hours exceeding the Capacity Restriction levels. The TSHV table does not provide information about possible delays or queuing of traffic due to capacity restrictions.

Over the years, software programs have been developed to estimate the length of vehicles queued upstream from the work zone taper. The queue length is normally calculated in miles. The queue length is based on the number of vehicles in the number of open lanes upstream of the work zone taper. These software programs may also provide an estimate of travel delays in minutes.

Contents

616.13.1 Urban and Rural Significant Projects with Major Surrounding Network Systems

Depending on the location and duration, urban and rural significant projects may entail an in-depth analysis of the surrounding network of roads. Due to the complexity, project analysis of these larger projects should start as early in the planning phase as practical. With early analysis, the planner or designer can make an appropriate cost estimate for traffic management to the early budget requests and the appropriate temporary traffic control devices to mitigate possible traffic concerns. Various traffic analysis tools and techniques can be utilized to evaluate these situations. The district Traffic offices should be able to help determine an appropriate analysis methodology and support any technical analysis to determine the potential work zone impacts.

616.13.2 Interstate, Freeways and Multi-lane Roadways

Due to MoDOT's large highway system, interstate, freeway, and multi-lane work zones may be located anywhere from the rural and urban areas to the flat and hilly terrain. Normally, these roadways have larger volumes and higher speed limits. When volumes exceed the capacity restriction level, ideally work should be performed when the volumes are lower, such as, off-peak, nighttime, weekends, etc. However, there are times when work has to be performed through the capacity restriction time periods, due to the type of work, longevity of the project, etc. Whenever a lane closure is performed during the capacity restriction time period, a potential for queuing and delays may occur. To assist the planner, designer, construction inspector, contractor work zone specialist, and maintenance personnel, the University of Missouri-Columbia has helped developed a user-friendly software program, MoDOT Work Zone Impact Analysis Spreadsheet, to provide an estimate of queues and delays to the traveling public.

For contract projects, work zone capacity should be analyzed early in the planning and design stages so enough time will be provided for designing the work zone and budgeting for possible use of advance warning strategies.

For maintenance projects, history may have shown locations that do not queue or delay due to the type and location of work, percentage of trucks, etc. If the work area has not shown queue and delays, the spreadsheet analysis may not be warranted.

MoDOT Work Zone Impact Analysis Spreadsheet

To provide user friendly features, the spreadsheet uses an excel database program, which requires a limited amount of data from the user. The spreadsheet has color-coded (blue, orange and yellow) fields that require information which can be obtained from the TMS database.

The WZ Impact Analysis Spreadsheet Directions provides guidance on how to use the spreadsheet.

The spreadsheet consists mainly of two parts: existing conditions and work zone details. When calculating the capacity of the work zone, the program accounts for different factors that affect the capacity (ex. location of workers and/or equipment to the travel lane, travel lane width, and number of trucks). The spreadsheet is used to calculate the queue lengths, delay of travel, and cost of the travel delay based on the estimated capacity.

616.13.2.1 Work Location

Studies have shown that the location of the physical work (workers/equipment) to the traveling public may adjust the base work zone capacity (1600 passenger car/hour/lane) as much as ±10%. The MoDOT Work Zone Impact Analysis Spreadsheet provides capacity based on worker/equipment locations, worker protection, or moving traffic away from the work area (ramp by-pass, crossover on divided highway).

616.13.2.2 Travel Lane Width

Reducing the travel lane width will reduce the free-flow speed, which will cause a decrease capacity through the work zone. Currently, speeds are not used to estimate capacity within the work zone, but an adjustment factor is used to calculate the capacity based on the different lane widths. The MoDOT Work Zone Impact Analysis Spreadsheet includes a reduction factor based on the travel lane width.

616.13.3 Capacity Restriction for Different Climbing Grades

Interstate, freeway and multi-lane roadways with a continuous climbing grade may reduce the work zone roadway capacity, especially when large percentages of heavy vehicles (trucks, buses, RV, etc.) are present. If the grades are steep and long enough, the heavier vehicles speed may be reduce to a “crawl” speed.

Due to the length and weight of the larger vehicles, they cannot be compared with passenger vehicles (cars/small trucks). Large vehicles are normally calculated as equivalent trucks.

616.13.4 Capacity Guidelines for Ramps

Ramps located near work zones may disrupt traffic flow due to the interaction of traffic entering or exiting the on/off ramps.

MoDOT’s spreadsheet does not address individual ramps. If the work zone is located 500 ft. upstream or downstream of the on/off ramps, the TMS hourly volume should be based on the highest upstream or downstream volumes from the ramp.

Closing ramps may be an option to reduce the volume into the work zone, which may relieve queuing and delay concerns. When closing ramps, the traveling public should have a detour route.

616.13.5 Travel Delay or Travel Time

Travel delay or increased travel time may be calculated within the different work zone software. There may be times that queue lengths and travel delays develop on projects that were not calculated within the software programs.

When delays occur in the field, delay time will be calculated by the following equation:

Delay Time = $T_{wz} - T_p$

Where:

T_{wz} = Time to travel through WZ
T_p = Time to travel through area at posted WZ speed limit

Project personnel will determine these travel times and update DMS/CMS messages, as needed, at regular intervals and as conditions change. Possible methods to estimate travel times include:

- driving the limits of the work zone,
- establishing times based on predetermined queue lengths,
- monitoring travel times of vehicles traveling through the work zone or
- automated means.

The spreadsheet, Travel Time for Work Zones, calculates the delay time within the advance warning area or the activity area (buffer and work space and end taper). You are invited to field test Travel Time for Work Zones and forward your comments to Highway Safety and Traffic Division – Work Zone Section (573) 526-0123 or (573) 526-4329.

616.13.6 ~~Strategies for~~ Advance Warning and Advanced Work Zone Traffic Strategy Selection

Below are several examples of strategies to inform the public or reduce work zone queues and delays, but they are not all inclusive.

616.13.6.1 Temporary Traffic Control Devices

Proper set-up of the temporary traffic control (TTC) devices is designed to provide the maximum safety and mobility through a work zone. Through the years, studies have been conducted to design the different components of the work zone. There are times (geometrics of roadway, etc.) when the work zone may have the speed limit reduced, but the amount of spacing and location of the TTC devices should be based on the posted speed limit (before the work zone).

616.13.6.2 Changeable Message Signs (CMS) and Dynamic Message Signs (DMS)

CMS are portable signs and DMS are stationary signs both of which are capable of displaying several messages in a sequence and display pertinent traffic operational and guidance information as well as advising drivers of unexpected work zone traffic and routing conditions.

CMS and/or DMS depending on the location may alleviate driver frustration with queues and delays by informing the traveling public with pertinent information.

When used, distance to end of work zone, in miles, with estimated travel times, in five-minute increments, will be displayed on a properly delineated CMS or DMS board. These boards will be located in advance of any potential traffic queue. Additional boards may be used as needed. The recommended display for these messages is as follows:

Unless travel time is provided through automated means, CMS and DMS boards will display the following recommended messages when workers are not present and traffic delay can be expected.

CMS and DMS boards may display meaningful messages when workers are not present, no traffic delay can be expected, and travel time is not provided through automated means.

When needed, commission-owned CMS and DMS units should be used unless justified otherwise. The core team should review the districts quantity of CMS boards to verify the district's ability to supply the project before plans are finalized.

616.13.6.3 ~~Work Zone Intelligent Transportation Systems (WZITS)~~ Smart Work Zone (SWZ) Strategy Selection

Through the years, the advancement of technology has produced a variety of strategies and techniques to provide improved warning and real-time work zone traffic information to the traveling public. MoDOT is committed to providing safe and efficient movement of traffic through work zones and protecting workers within the work zones.

The MoDOT Work Zone Impact Analysis Spreadsheet, referenced above, has been enhanced to also provide guidance in the selection of the appropriate smart work zone (SWZ) strategies (listed below) for a given work zone. The enhancements to the spreadsheet also include preliminary cost estimates for each SWZ strategy. This was done as part of MoDOT's TSMO initiative. More information about TSMO can be found in EPG 909 Transportation Systems Management and Operations.

To assure the safety of traffic and workers in work zones, the enhanced Work Zone Impact Analysis Spreadsheet should be utilized during the project planning and scoping phase of project development. Performing this exercise at this stage allows for the appropriate strategies and costs to be included in the project scope and STIP.

The enhanced MoDOT Work Zone Impact Analysis Spreadsheet can be found above or clicking on the link below:

https://epg.modot.org/files/0/04/616.13_WZ_Impact_Dec_2016.xlsm

Smart Work Zone Strategy Description

The smart work zone strategies described below are:

- Construction Vehicle Warning System
- Dynamic Late (Zipper) Merge System
- Queue Warning System
- Portable Rumble Strips
- Road Closure
- Speed Warning System
- Work Zone ITS and Temporary Traffic Incident Management System
- Travel Time Advisory System
- Travel Time Advisory System with Alternate Routes

work zone intelligent transportation systems (WZITS) that can provide real-time data to the traveling public.

Instead of having a person being present to change the CMS or DMS through notification, the WZITS may be equipped with sensors, communication technology, computers, internet connection, etc. This technology can collect traffic volume, speed, etc. and then provide the traveling public with the accurate and real-time information for that particular work zone.

The nonstandard Work Zone Intelligent Transportation System special provision is available as a guide for use in a project.

The WZITS can provide travel time, travel delay, congestion concerns, speed advisory information, etc. Minnesota Department of Transportation (MnDOT) and American Traffic Safety Services Association (ATSSA) have the following documents that describe installation and use of the different WZITS products.

- **http://www.dot.state.mn.us/trafficeng/workzone/iwz/MN-IWZToolbox.pdf**
- **http://www.dot.state.mn.us/trafficeng/workzone/wzmanual.html**

MnDOT and ATSSA examples show the use of either CMS boards or static signs. The use of static signs with lights or small displays may save significant saving compare to using contractor furnished CMS boards, but the CMS board can be readily moved to different locations. If MoDOT has adequate number CMS boards with the capabilities to be used on projects, rental saving could be offset. The district core team should review the CMS quantities to verify the district's ability to supply the project before plans are finalized.

Dynamic Late Merge/Zipper MergeConstruction Vehicle Warning System

One of the crucial aspects of the establishment and maintenance of a work zone is safe access and egress points for construction vehicles. These points are key determinants when it comes to ensuring the safety of both the traveling public and construction workers on a project.

The usage of detectors and CMS helps in notifying the motorists when a construction vehicle is planning to enter or exit from work zones. This display of messages can prepare travelers for a slowdown or potential merging conflicts due to construction vehicles. These warnings also reduce the frequency of incidents where motorists following work vehicles.

Dynamic Late Merge/Zipper Merge

One strategy that is available for 4-lane divided facilities in heavily congested areas (volumes greater than 1500 vehicles per hour) is the Dynamic Late Merge, which is more commonly referred to as the Zipper Merge. The Zipper Merge can increase work zone safety by reducing queue lengths. The Zipper Merge JSP contains all of the specifications for this WZITS tool along with the Dynamic Late Merge/Zipper Merge Figure showing the standard layout of the merge along with the appropriate messaging.

The Zipper Merge system should be considered for temporary traffic control situations where a lane closure reduces the mainline roadway from two continuous lanes to one lane. Considerations include the estimated traffic volumes, duration of the lane closure and the effects of congestion and large traffic queues at the particular -project location.

The Zipper Merge system should be considered for deployment as part of a project's temporary traffic control plan when the following conditions are anticipated:

- The lane closure will be in place for 2 or more days in a static work zone i.e. not in a mobile operation.
- The traffic volumes exceed 1500 vehicles/hour for at least 2 hours per day.
- During congested periods, the estimated traffic queue lengths (without the zipper merge implemented) will potentially encroach on upstream intersection/interchange operations.

The Central Office Traffic Division Work Zone section is available as a resource for the use of the WZITS technology.

Queue Warning System

A Queue Warning system is used to inform travelers about upcoming congested or stopped traffic conditions. The queue warning system informs drivers of an impending traffic situation and to avoid emergency braking and queue-related collisions.

This system typically consists of roadside sensors and Portable Changeable Message Signs (PCMS) placed upstream of the work zone. The basic principle of this system is when sensors detect slowing or stopped vehicles, it sends signals to the PCMS where warning signs are displayed advising travelers about an impending traffic queue. The sensors and PCMS should be placed in such a way that if the queue reaches within 1-2 miles (based on the speed and length of work zone) of PCMS, it should start displaying the warning signs alerting the approaching motorists of queue conditions.

Temporary Rumble Strips

Temporary rumble strips are a strategy for reducing distracted driving and achieving MoDOT's work zone safety goals. Temporary rumble strips are comprised of a series of raised elongated bumps placed upon the surface of the roadway to provide an audible and vibratory alert to drivers of the upcoming work zone.

Speed Warning System

The regulation of speed during construction is necessary to maintain travelers' and workers' safety as well as making sure of timely completion of the road work. Speed warning systems are speed displays using intelligent transportation system (ITS) technologies that give the driver information about their speed as well as ~~safe driving speeds~~the posted advisory speed. The speed displays are portable and can be used in the work zone wherever excessive speeding is a problem.

Work Zone Intelligent Transportation System and Temporary Traffic Incident Management System~~Speed Feedback:~~

A sensor-based speed warning system used in a work zone is the Speed Advisory display, which informs the approaching motorists of the posted advisory speed and their current speed to warn them if they are driving above the speed limit defined. This speed displays are portable and can be used in the work zone wherever excessive speeding is a problem.

Through the years, the advancement of technology has produced work zone intelligent transportation systems (WZITS) that can provide real-time data to the traveling public.

Instead of having a person being present to change the CMS or DMS through notification, the WZITS may be equipped with sensors, communication technology, computers, internet connection, etc. This technology can collect traffic volume, speed, etc. and then provide the traveling public with the accurate and real-time information for that particular work zone.

The nonstandard Work Zone Intelligent Transportation System special provision is available as a guide for use in a project.

A WZITS will improve detection in work zones, both by use of CCTV cameras and traffic sensors to monitor traffic flow and determine problem areas.

The prompt detection and clearance of traffic incidents in a work zone aids in avoiding secondary crashes and minimizes associated delays.

A Temporary Traffic Incident Management (TTIM) system can be defined as the coordinated, preplanned use of technology, processes, and procedures to reduce the duration and impact of incidents in a work zone. By significantly reducing the time to assess the incident details and needs, and to notify the appropriate responders, the clearing of the incident will be performed much more expediently.

Travel Time Advisory System

A travel time advisory system consists of travel times through a work zone. Travelers seek accurate, timely, and reliable information regarding their travel routes in a convenient form. Apart from benefitting the individual motorist, travel time information can lead to system-wide benefits when many users respond in a predictable way to the information they received.

The benefits of travel time information for work zones include less stressful conditions for the motorists and more predictable and safe travel conditions.

Work zones are infamous for travel delays and lead to traffic conditions that violate traveler’s expectations. Hence, the usage of travel times becomes important rather than a good-to-have for work zones. Travel time systems gather real-time traffic information in work zones with the help of sensors, video cameras, and communicate the scenario to upstream motorists with the help of portable Changeable Message Signs (PCMS).

The messages of travel time are displayed on CMS activated by the sensors. This information helps drivers understand the magnitude of delay they will encounter and to make an informed decision in how to conduct their travels.

Probe data may be used for travel time measurement where available and volumes provide sufficient sample size.

Travel Time Advisory System with Alternate Routes

On projects where there is an alternate route available which has adequate capacity and minor out-of-distance travel, it may be advantageous to install travel time advisory systems both on the route under construction as well as the alternate route.

This information helps drivers understand the magnitude of delay they will encounter and to make an informed decision in how to conduct their travels. Alternate route travel times can aide travelers in determining whether to travel through a work zone or utilize the designated alternate route.

Travel time information is trip-related information provided to a traveler. This information usually consists of travel times through a work zone and/or on a designated alternate route for the work zone. Travelers seek accurate, timely, and reliable information regarding their travel routes in a convenient form. Apart from benefitting the individual motorist, travel time information can lead to system-wide benefits when many users respond in a predictable way to the information they received.

The benefits of travel time information for work zones and related designated alternate route include reduced trip time, less stressful conditions for the motorists and more predictable and safe travel conditions.

Work zones are infamous for travel delays and lead to traffic conditions that violate traveler's expectations. Hence, the usage of travel times and alternate route travel time advisories becomes important rather than a good-to-have for work zones. Travel time advisory and alternate route travel time advisory systems gather real-time traffic information in work zones and on designated alternate routes with the help of sensors, video cameras, and communicate the scenario to upstream motorists with the help of portable Changeable Message Signs (PCMS).

The messages of travel time are displayed on CMS activated by the sensors. This information helps drivers understand the magnitude of delay they will encounter and to make an informed decision in how to conduct their travels. Alternate route travel times can aide travelers in determining whether to travel through a work zone or utilize the designated alternate route.

Probe data may be used for travel time measurement where available and volumes provide sufficient sample size.

One WZITS tool that is available for 4-lane divided facilities in heavily congested areas (volumes greater than 1500 vehicles per hour) is the Dynamic Late Merge, which is more commonly referred to as the Zipper Merge. The Zipper Merge can increase work zone safety by reducing queue lengths. The Zipper Merge JSP contains all of the specifications for this WZITS tool along with the Dynamic Late Merge/Zipper Merge Figure showing the standard layout of the merge along with the appropriate messaging.

The Zipper Merge system should be considered for temporary traffic control situations where a lane closure reduces the mainline roadway from two continuous lanes to one lane. Considerations include the estimated traffic volumes, duration of the lane closure and the effects of congestion and large traffic queues at the particular project location.

The Zipper Merge system should be considered for deployment as part of a project's temporary traffic control plan when the following conditions are anticipated:

- The lane closure will be in place for 2 or more days in a static work zone i.e. not in a mobile operation.
- The traffic volumes exceed 1500 vehicles/hour for at least 2 hours per day.
- During congested periods, the estimated traffic queue lengths (without the zipper merge implemented) will potentially encroach on upstream intersection/interchange operations.

The Central Office Traffic Division Work Zone section is available as a resource for the use of the WZITS technology.

616.14 Work Zone Safety and Mobility Policy

616.14.3.2.4 Project Core Team

Project core teams will review all projects before they are awarded to reduce work zone impacts on the public. Responsibilities of the project core team includes:

- Review Work Zone Questions for the Core Team with the entire core team from the scoping stage through final plans.
- Conducting traffic analyses to identify work zone impacts to traffic flow and safety.
- Identifying strategies to minimize impact and maximize awareness.
- Developing a traffic control, traffic management, and public information plan, as needed.
- Scheduling lane closures during off-peak and/or at nighttime hours when capacity is an issue.
- Using innovative contracting and bidding options, when possible, to reduce project completion time.
- Evaluating and implementing schedules to reduce the number of working days needed to complete projects quicker.
- Using road closures and/or signed detours, when possible, to complete projects quicker.
- Considering the traffic effects of major sporting events and other special activities when planning work zones.
- Opening additional through lanes to reduce traffic effects when possible.
- Determining work zone speed limits are appropriate in active and non-active work zones.
- Incorporating provisions for real time travel information to the public through the use of changeable message signs (CMS), dynamic message signs (DMS), highway advisory radio, ITS, etc.
- Include appropriate Advanced Work Zone traffic strategies as indicated by the Enhanced Work Zone Impact Analysis spreadsheet (refer to EPG 616.13).

616.14.3.2.5 Field Operation Forces

EPG 909
Transportation Systems Management and Operations (TSMO)

Transportation Systems Management and Operations (TSMO) consists of operational strategies and systems that cost-effectively help optimize the safety, reliability, and capacity of the transportation system. MoDOT is continuously working to improve safety and alleviate congestion on its roadways; the effective application of TSMO strategies will help to further improve MoDOT's roadways by directly addressing many of the root causes of recurring and non-recurring congestion.

Related Information
MoDOT's STIP website

Recurring congestion occurs in numerous locations in the interstate and state highway system and is typically the result of inadequate capacity of the existing highway facilities. Recurring congestion occurs most often during peak traffic periods. MoDOT is not funded to construct sufficient highway facilities to address all areas of recurring congestion.

Non-recurring congestion occurs throughout the interstate and state highway system at any given time and is typically the result of:

- Work Zones (road construction and maintenance activities, permit work, etc.)
- Traffic Incidents
- Special Events

Recurring and non-recurring congestion both result in delay to motorists, adversely affect travel time reliability, and diminish highway safety.

MoDOT is committed to integrating TSMO in all aspects of managing and operating the transportation system in Missouri.

<u>Recurring Congestion</u>

Highway segments with recurring congestion are candidates for highway improvements. While adding capacity by constructing additional lanes may not be feasible, other TSMO strategies should be considered as alternate solutions which are often more economical than traditional construction solutions. Strategies such as integrated corridor management (ICM), active transportation and demand management (ATDM), ramp metering, and lane management may provide substantial improvements to recurring congestion.

<u>Non-recurring Congestion</u>

Non-recurring congestion can occur at any location at any time and results in delay to motorists as well as a potential for subsequent traffic incidents. TSMO strategies should be utilized to address each type of non-recurring congestion generator.

Construction:

- As an initial step, a project design should be selected to eliminate or minimize additional delays and traffic queueing during construction. The guidance in EPG 616.13 provides tools to access the traffic impact of the proposed project design(s).
- Once a project design has been determined, the smart work zone spreadsheet (EPG 616.13) will assist in determining which smart work zones strategies should be included in the project to provide information and warnings to motorists to improve work zone safety and traffic mobility.
- When traffic incidents occur within a work zone, it is imperative to clear the incident and restore traffic as quickly as possible. To aid in this effort, a project-based traffic incident management (TIM) plan should be developed for all significant projects on interstate and freeways.

Traffic Incidents:

Traffic incidents occur without warning at any time and location on the highway system. On all segments of the interstate and freeway highway system, traffic incident management (TIM) plans should be developed in coordination with law enforcement and local responders to:

- Reduce response and clearance times
- Develop alternate plans for handling affected traffic
- Communicate and coordinate between responders
- Communicate traffic impacts to motorists

MoDOT's Strategic Traffic Incident Management Plan can be found in EPG 948.

Category:948 Incident Response Plan and Emergency Response Management

From Engineering_Policy_Guide
Jump to navigationJump to search

MoDOT's Safety and Emergency Management Unit supports the core value of "Moving Missourians Safely" by providing planning, training, exercise and implementation of the MoDOT Incident Response Plan. In addition, the Emergency Management staff work to coordinate with internal and external partners while supporting MoDOT's Emergency Operations Center and providing staffing for the State Emergency Operations Center Transportation Emergency Support Function.

The Incident Response Plan directs the actions of MoDOT personnel in the event of an incident or emergency situation. The plan establishes procedures for conducting effective and coordinated response and recovery operations using resources available to MoDOT. The Incident Response Plan includes chapters regarding Command and Management, Resource Management, Communications and Information Management, Supporting Technologies, and Ongoing Management and Maintenance.

Supplemental Plans include Continuity of Operations, Severe Weather Response, Hazardous Materials Response, Radiological Response, Terrorism Response, Pandemic Influenza Response, Earthquake Response and a Workplace Security Plan.

Additional responsibilities of the Emergency Management staff are:

Disaster Recovery and Reimbursement

Disaster Recovery and Reimbursement includes evaluating damages received from natural and man-made disasters for possible reimbursement from the Federal Highway Administration and the Federal Emergency Management Agency. Staff members may coordinate the gathering of data and costs related to disaster repairs, report to state and federal entities to be included in disaster declarations or reports and oversee the process to request and gain reimbursement for costs incurred from multiple disasters each year.

MoDOT Traffic Incident Management (TIM) Training Program

Keeping MoDOT employees and responders safe while working on our roadways is a top priority in Missouri. The number of highway workers and responders who are injured or killed on the highways continues to rise each year. Emergency Management staff are responsible for implementation of the MoDOT's Strategic Traffic Incident Management Plan and the Traffic Incident Management Training Program. They oversee the curriculum, qualified trainers, and delivery of courses throughout the state. In addition, this staff provides guidance to several agencies and committees on how to further protect our responders and public when they are impacted by an accident or response on our roads or highways.

One tool that is very beneficial is the MoDOT Strategic Traffic Incident Management Plan. This plan establishes MoDOT's vision, goals, and objects for traffic incident management throughout the state as well as a history of how the program has developed. This plan is used throughout the TIM training and was developed as part of MoDOT's TSMO initiative. More information about TSMO can be found in EPG 909 Transportation System Management and Operations.

MoDOT Statewide Communications System

MoDOT also operates a statewide two-way radio communications system. This system is licensed in the Highway Maintenance and Local Government Public Safety Radio Service and may be referred to as a "dual use" system. Normally it is used for routine highway business but during times of declared emergency it augments Emergency Management and response capabilities. The MoDOT Communications Standard Operating Guideline provides detailed information regarding use of this system.

MODOT STRATEGIC TRAFFIC INCIDENT MANAGEMENT PLAN

March 2021

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Traffic incident management (TIM) is a planned and coordinated multi-disciplinary process to detect, respond to, and clear traffic incidents so that traffic flow may be restored as safely and quickly as possible. TIM partners include law enforcement, fire and rescue, emergency management services (EMS), public safety, and towing and recovery. Effective TIM improves the safety of emergency responders, crash victims, and motorists, as well as reduces the duration and impacts of traffic incidents. As part of transportation systems management and operations (TSMO), traffic incident management is consistent with MoDOT's mission and strategic initiatives by providing a safe and reliable transportation system.

MoDOT and its partners have successfully implemented a number of TIM strategies and practices on Interstates and highways in Missouri over the years. In order to further advance TIM in Missouri, this plan identifies goals, objectives, strategies, and action items that can be practically implemented and prioritized by MoDOT. Best practices including the National Unified Goal (NUG) established by the National Traffic Incident Management Coalition (NTIMC) are used to guide the content of this document.

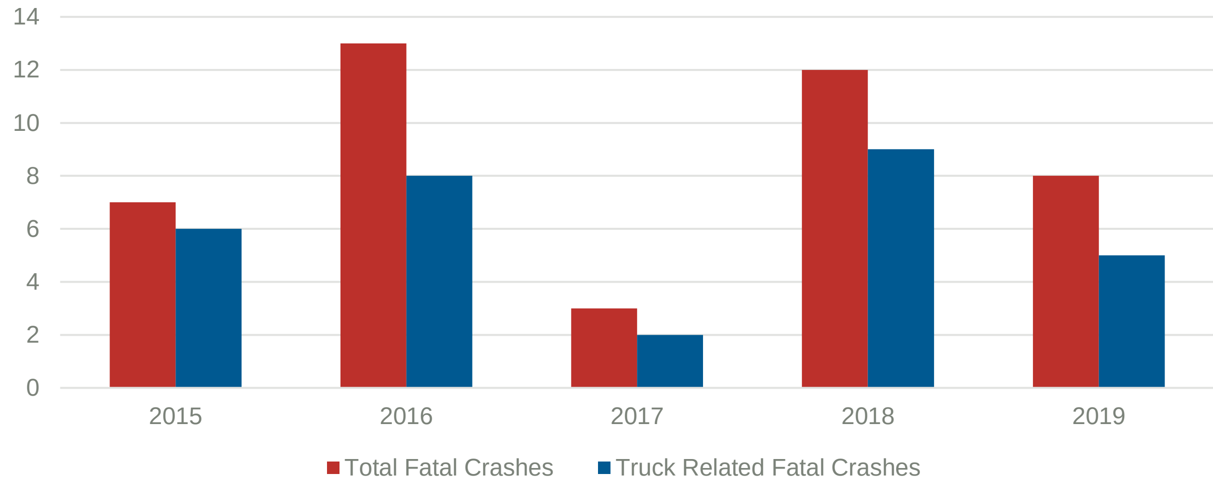
1.1. Importance of Traffic Incident Management

Traffic incidents may block travel lanes, but even when on the shoulder these incidents can cause driver distractions and congestion. Traffic incidents have a significant impact on Missouri's transportation system, leading to secondary crashes, safety risks for first responders, costly travel delays, and economic impacts.

Traveler Safety

According to the Federal Highway Administration (FHWA), approximately 20 percent of all traffic incidents are secondary crashes[1]. Traffic incidents may include crashes, stalled vehicles, overheating, or running out of fuel. Secondary crashes are collisions resulting from the initial incident, either occurring at the incident scene or within the traffic queue. Secondary crashes can be particularly severe on high-speed highways, particularly rural interstates, often times as a result of a rear-end collision. Although secondary crashes are not directly tracked in Missouri, there are surrogate measures that can approximate this statistic. For instance, rear-end collisions on rural Missouri interstates not attributed to work zones have resulted in 43 fatal crashes between 2015-2019[2], based on data from the National Highway Traffic Safety Administration (NHTSA). Most of these fatal crashes—30 of the 43—involved at least one large truck in the collision. See **Figure 1**.

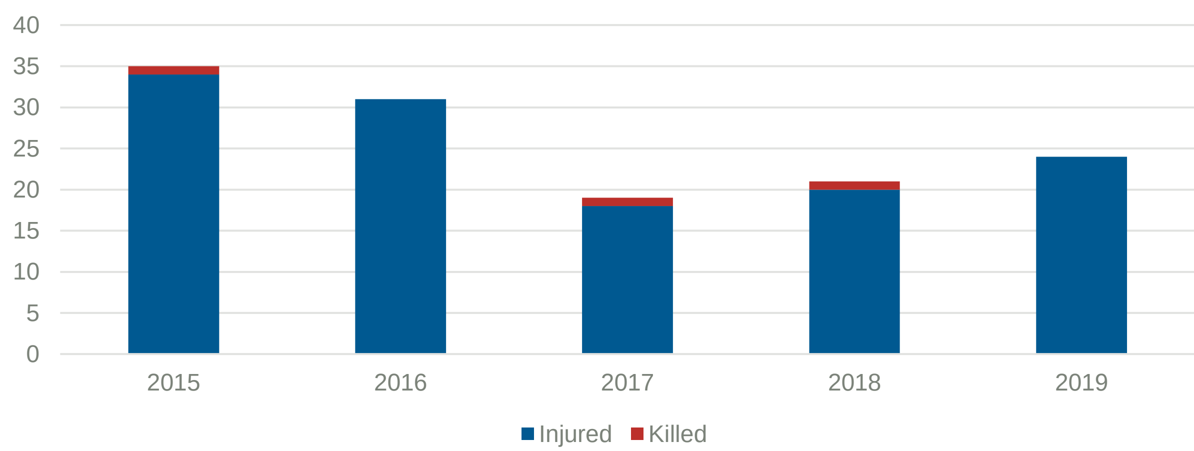
Figure 1. Fatal Crashes on Rural Interstates due to Rear-End Collisions, Not in Work Zone, in Missouri 2015-2019



Responder Safety

Responders at a traffic incident scene such as law enforcement, fire and rescue, tow operators, or MoDOT personnel are vulnerable when traffic is moving. Incident responders risk their lives when tending to injured victims, assisting stranded motorists, or clearing debris from the roadway, particularly on high-speed facilities such as interstates. Although crashes involving responders at traffic incidents are not directly tracked in Missouri, there are proxy measures that can approximate this statistic. For instance, the number of responder pedestrians (i.e., outside of their vehicle) injured by a motor vehicle between 2015 and 2019 in Missouri was 130[3]. Of these collisions, three resulted in a responder fatality. See **Figure 2**.

Figure 2. Responder Pedestrians Injured or Killed by Motor Vehicles in Missouri, 2015-2019

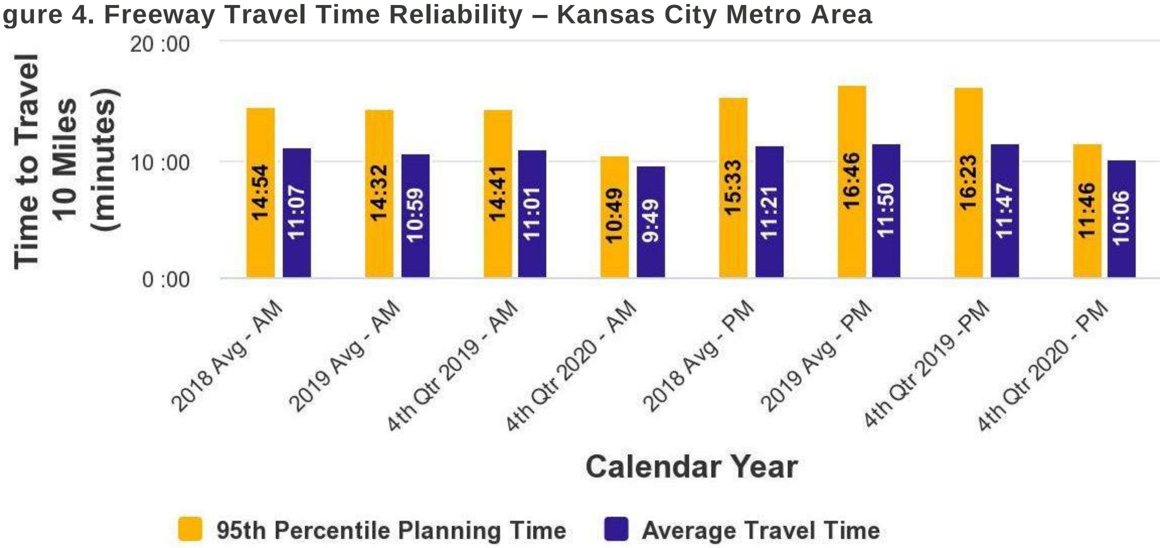


Travel Delays

According to FHWA, approximately 25 percent of all traffic congestion in the US is due to traffic incidents[4]. Traffic incidents can cause drivers to be delayed, resulting in lost time and being late to work, school, or appointments. Although travel delays due to traffic incidents are not directly tracked in Missouri, there are other measures that serve as substitutes. MoDOT tracks reliability of travel times on freeways in the St. Louis and Kansas City metro areas for instance. As shown in **Figure 3** and **Figure 4**, the 95th percentile planning time in 2019 for PM rush hour in the St. Louis and Kansas City metro areas are 56 percent and 42 percent greater than the average travel time, respectively[5]. This means that for travelers to plan to reach their destination 95 percent of the time during the PM rush hour, they should add that much more time to account for unexpected travel delays. The below measures are updated through 4th quarter 2020.

Figure 3. Freeway Travel Time Reliability – St. Louis Metro Area

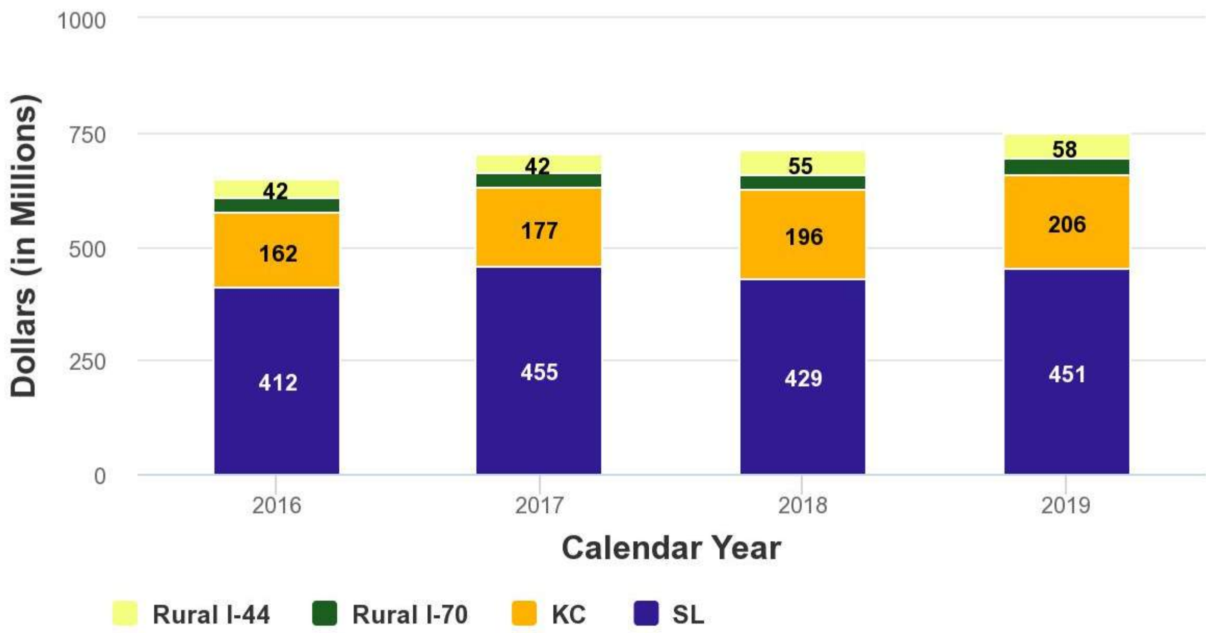
Figure 4. Freeway Travel Time Reliability – Kansas City Metro Area



Economic Impacts

Travel delays, particularly due to traffic incidents, result in a broad impact to the economy, affecting travelers, employers, businesses, and industries. Travelers stuck in unexpected traffic waste fuel and may, for instance, be late for work, impacting employers. Businesses and industries that rely on timely deliveries can lose business. And in the modern world of increased reliance on connected supply chains and on-time delivery to consumers, unexpected travel delays can have a deep and hidden economic impact. Although economic impacts due to traffic incidents are not directly measured in Missouri, as shown in **Figure 5** the cost of congestion on select state roads is significant, resulting in an economic impact of $750 million in 2019[5].

Figure 5. Cost of Congestion on Select State Roads in Missouri



1.2. Vision, Goals, and Objectives

TSMO and TIM are integral to support MoDOT's overall mission and strategic initiatives. MoDOT's TIM vision ***is to enhance the safety and efficiency of Missouri's transportation system for travelers and incident responders***. Broken down further, there are five goals to achieve this vision in Missouri, each with specific objectives:

Goal #1	**Enhance safety of traveling public** • ***Objective 1.1:*** Reduce number and severity of secondary crashes • ***Objective 1.2:*** Record and track secondary crashes
Goal #2	**Enhance safety of incident responders** • ***Objective 2.1:*** Reduce number and severity of responders struck • ***Objective 2.2:*** Record and track crashes involving incident responders
Goal #3	**Enhance reliability and efficiency of Missouri's transportation system** • ***Objective 3.1:*** Respond to incidents quickly • ***Objective 3.2:*** Clear incidents quickly
Goal #4	**Strengthen coordination, communication, and collaboration between MoDOT and TIM partners** • ***Objective 4.1:*** Formalize and implement coordination agreements with TIM partners • ***Objective 4.2:*** Regularly meet with TIM partners at state, regional, and local levels
Goal #5	**Establish TIM as a core TSMO program at MoDOT** • ***Objective 5.1:*** Establish TIM policies, procedures, and protocols within MoDOT • ***Objective 5.2:*** Fill MoDOT TIM coordinator positions

1.3. Performance Measures and Targets

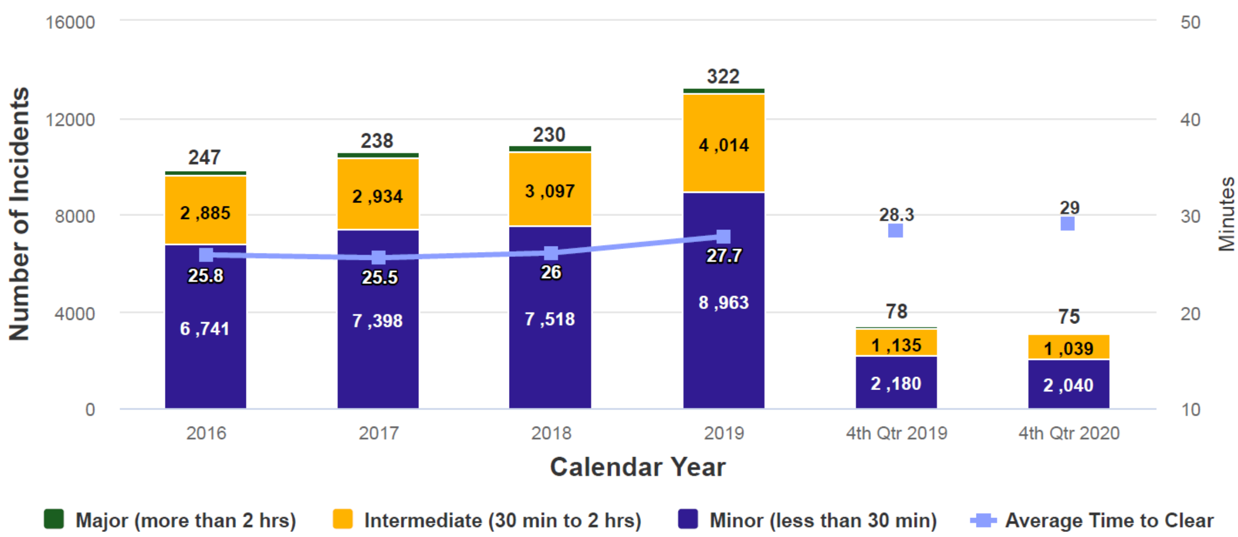
As noted in **Section 1.1**, there are a number of existing performance measures in Missouri related to TIM. Performance measures are essential to ensure successful implementation of TIM. Quantifying and documenting relevant performance measures are an objective of the MoDOT TSMO Program Plan.

There are three performance measures currently tracked by MoDOT related to TIM:

1. **Reliability on Major Routes**
2. **Cost & Impact of Traffic Congestion**
3. **Average Time to Clear Traffic Incidents**

Each of these measures have multiple sub-measures, as well as associated targets. Some of the first two measures are shown in **Section 1.1**. The third measure, Average Time to Clear Traffic Incidents, is shown in **Figures 6-10**. All measures are updated through 4th quarter 2020.

Figure 6. Average Time to Clear Traffic Incidents – St. Louis

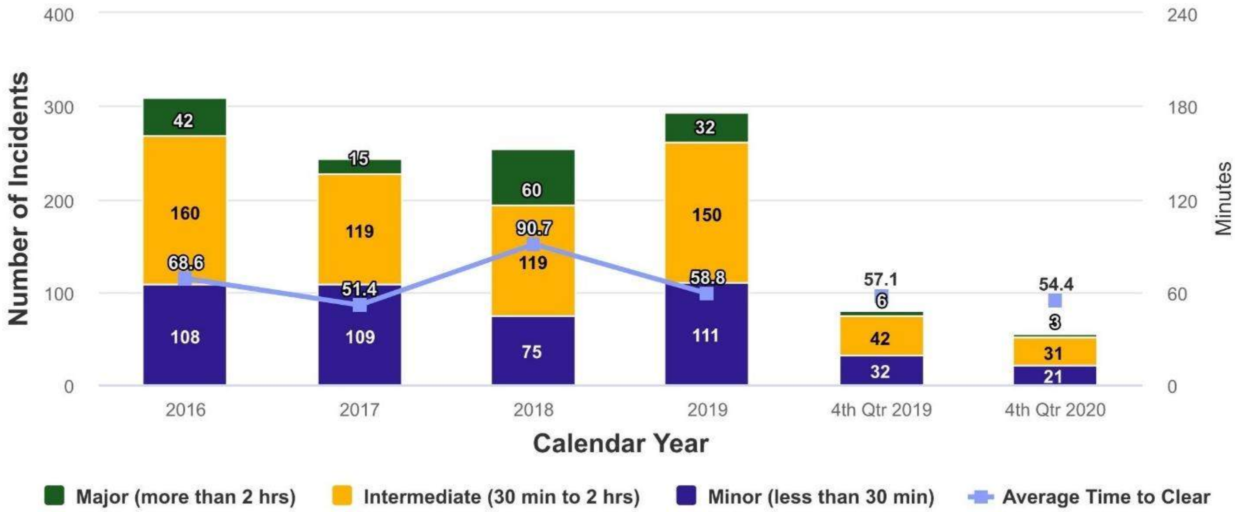


2020 Target: Below 23.9 Minutes to clear

Figure 7. Average Time to Clear Traffic Incidents – Kansas City

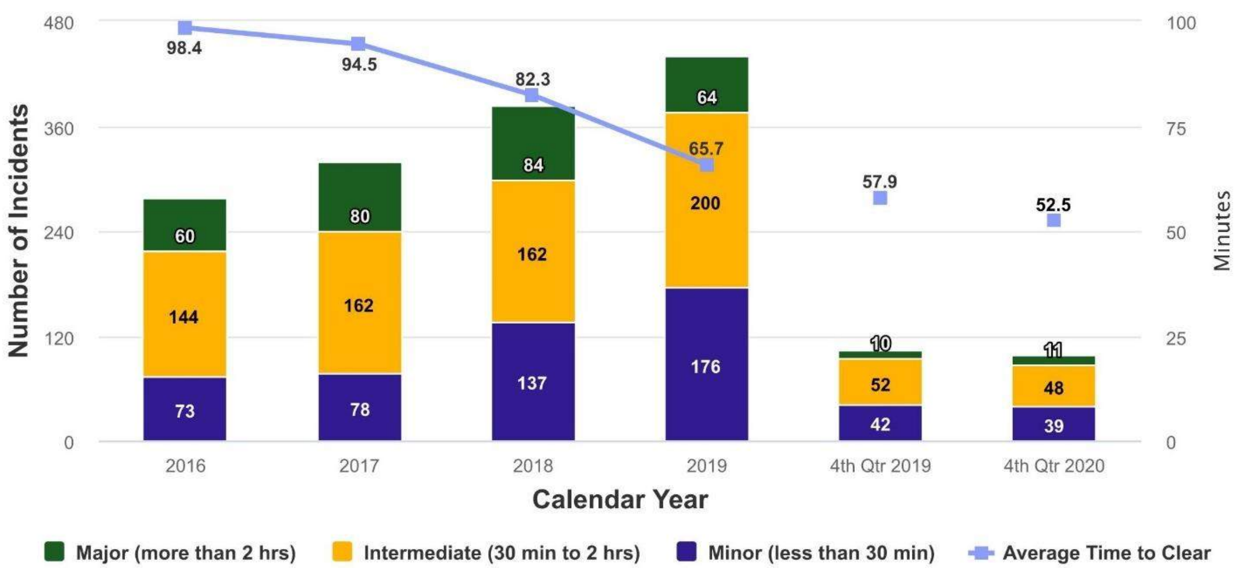
Figure 8. Average Time to Clear Traffic Incidents – Springfield

Figure 9. Average Time to Clear Traffic Incidents – I-70 Rural



2020 Target: Below 60.6 Minutes to clear

Figure 10. Average Time to Clear Traffic Incidents – I-44 Rural



2020 Target: Below 76.7 Minutes to clear

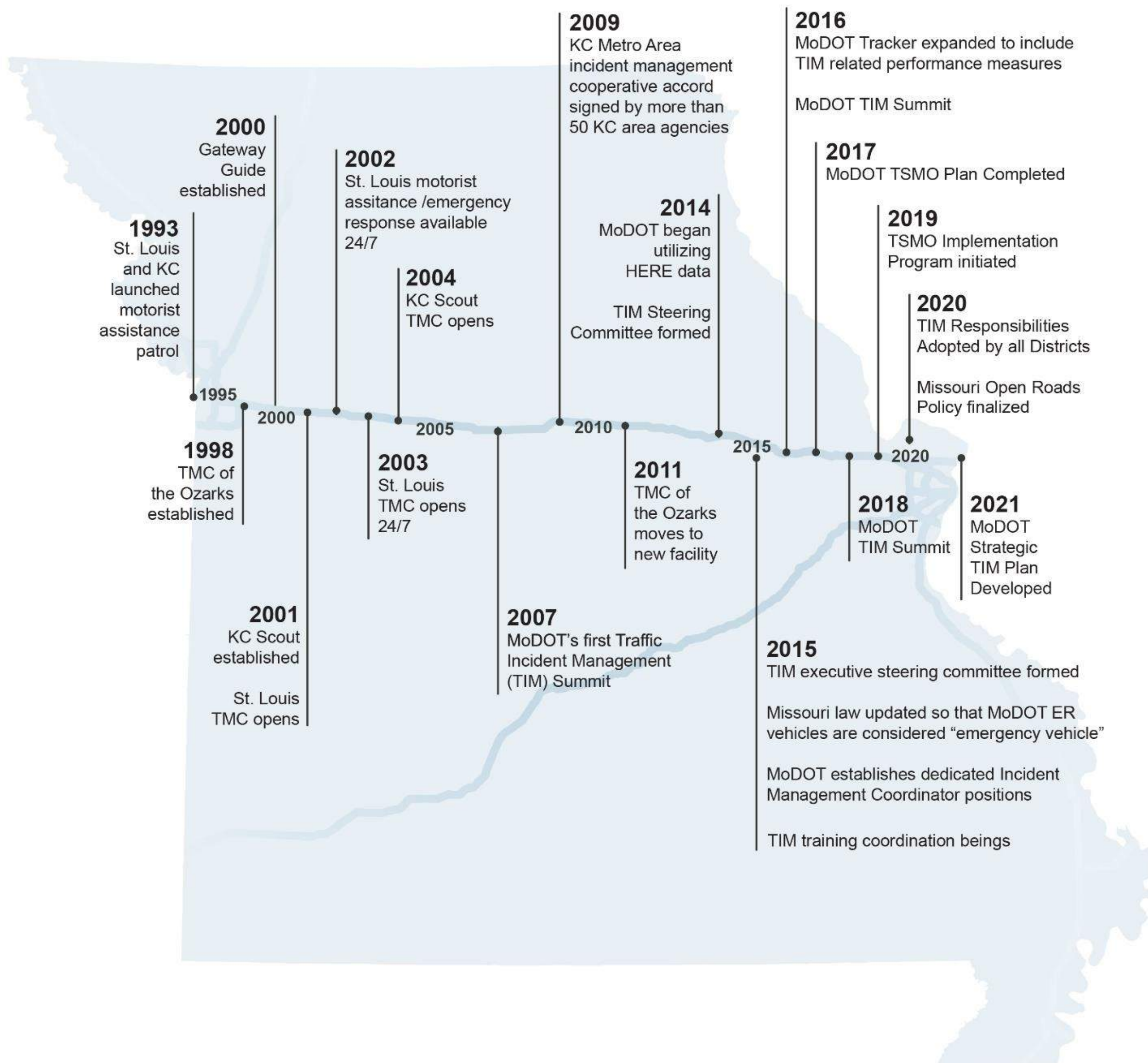
These performance measures can be directly accessed through the Tracker website https://www.modot.org/tracker-measures-departmental-performance.

2. EXISTING TIM PRACTICES IN MISSOURI

2.1. History of TIM in Missouri

MoDOT has made significant progress in recent years implementing TIM strategies in Missouri with its partners. While TIM strategies were first implemented in major metro areas in Missouri in the 1990s with the establishment of motor assistance patrols and traffic management centers, additional accomplishments to advance TIM have been made within the last 10 to 15 years. A timeline of the major TIM accomplishments to date in Missouri is provided in **Figure 11**.

Figure 11. Timeline of Missouri TIM Efforts



2.2. Status of Missouri TIM Practices

The status of TIM in Missouri may be best conveyed through the most recent TIM Capability Maturity Self-Assessment (SA). Based on FHWA's capability maturity model, this approach allows stakeholders to assess how advanced their capabilities are within various TIM components. A component may be performed inconsistently based on individual champions outside mainstream activities (least advanced) or performed as part of a core program integrated with leadership and other stakeholders on a continual basis (most advanced).

The FHWA works with TIM partners in regions covering each urban area to conduct a self-assessment annually. The assessments consist of questions that generally fall into three categories:

- **Strategic** – Questions covering formal policies and understandings among agencies and TIM partners including performance measure and program evaluation.
- **Tactical** – Questions covering on-scene response and clearance practices, traffic control, and responder and motorist safety.
- **Support** – Questions on interagency communications, data sharing, ITS for TIM and traveler information.

In Missouri, TIM self-assessments are conducted for the St. Louis, Kansas City, and Southwest Missouri regions. Each of these regions is covered with an emergency response program. A summary of the emergency response programs in each region is provided in **Table** .

Table 1. Regional Emergency Response Programs

Region	Safety Service Patrol Availability	Emergency Response Availability	Traffic Management Center
St. Louis Gateway Guide	24/7/365 (limited holiday coverage)	24/7/365	St. Louis Region
Kansas City KC Scout	24/7/365 (limited holiday coverage)	24/7/365	Kansas City Region
Southwest	7 days per week: 7am – 6pm	24/7/365	Springfield

Self-assessment scores are given for each question on a scale from 1 to 4, with 4 being the highest capability level. See **Figure 12** for descriptions of each maturity level. These scores are in turn converted into a percentage. The national average scores, as well as the Missouri regional scores, are provided in **Table** .

Figure 12. Capability Maturity Model Levels[6]

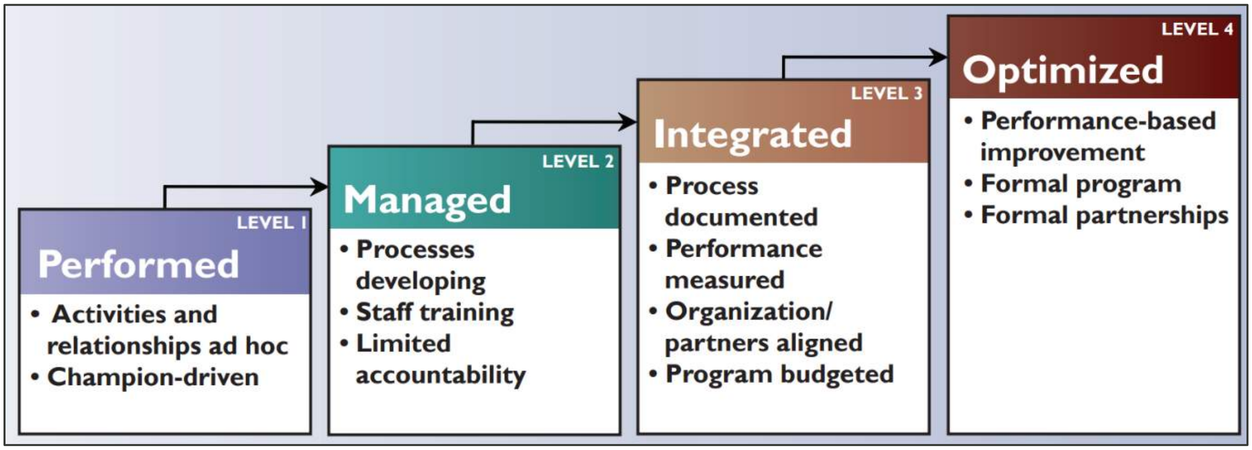


Table 2. TIM Capability Maturity Self-Assessment 2020

Category	2019 National Average*	2020 Missouri Average**	St. Louis	Kansas City	Southwest
Strategic	**68.5%**	**68%**	50%	71%	81%
Tactical	**77.5%**	**71%**	69%	69%	75%
Support	**74.0%**	**67%**	58%	58%	83%
Overall	**73.3%**	**69%**	59%	70%	79%

*Most recent national scores available: https://ops.fhwa.dot.gov/eto_tim_pse/preparedness/tim/self.htm.
**There have been major changes to the FHWA self-assessment since 2019.

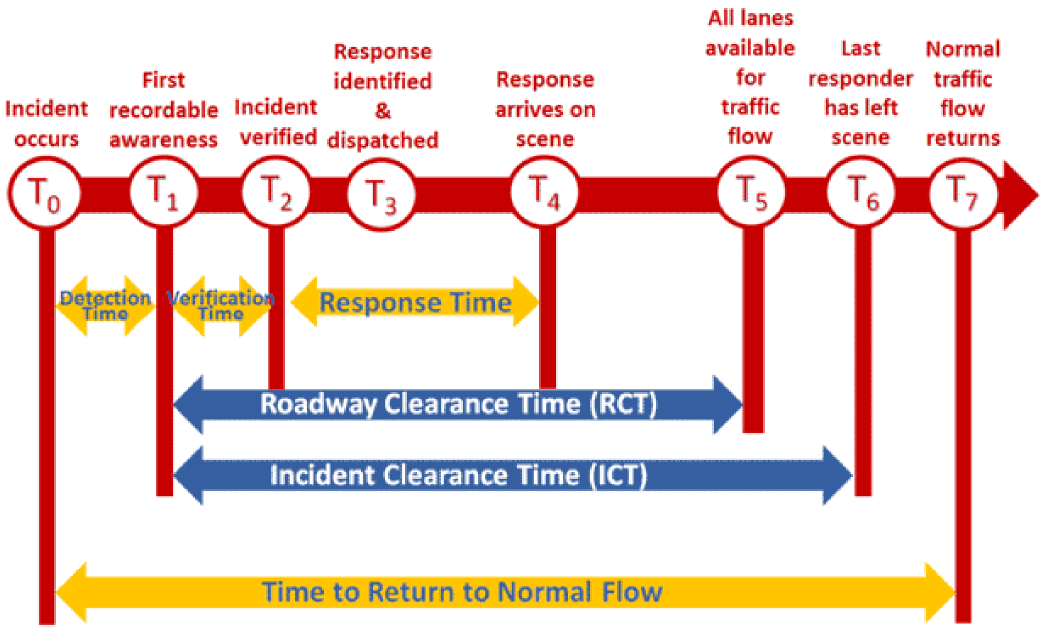
Examples of TIM components that were rated as highly mature in the 2020 TIM Capability Maturity SA include:

STRATEGIC
Performance measures such as roadway clearance time (RCT) and incident clearance time (ICT) are measured and used. See **Figure 13** for illustration of RCT and ICT.

TACTICAL
Safety service patrol programs are in place for all three regions with substantial coverage.

SUPPORT
Policies and procedures are in place for signal timing changes to support traffic management during incident response.

Figure 13. Timeline of Traffic Incident Elements



Examples of TIM components that were rated as having opportunities for maturity in the 2020 TIM Capability Maturity SA include:

STRATEGIC

- Having all disciplines and agencies participate in TIM enhancement activities.
- Establishing and using performance targets for secondary crashes.
- Conducting TIM training in a multidiscipline setting.
- Conducting multidiscipline, multi-agency after action reviews.

TACTICAL

- Having tow operator/rotation list policies include penalties for non-compliance of response criteria.
- Procedures for incidents involving a fatality prior to medical examiner arrival.

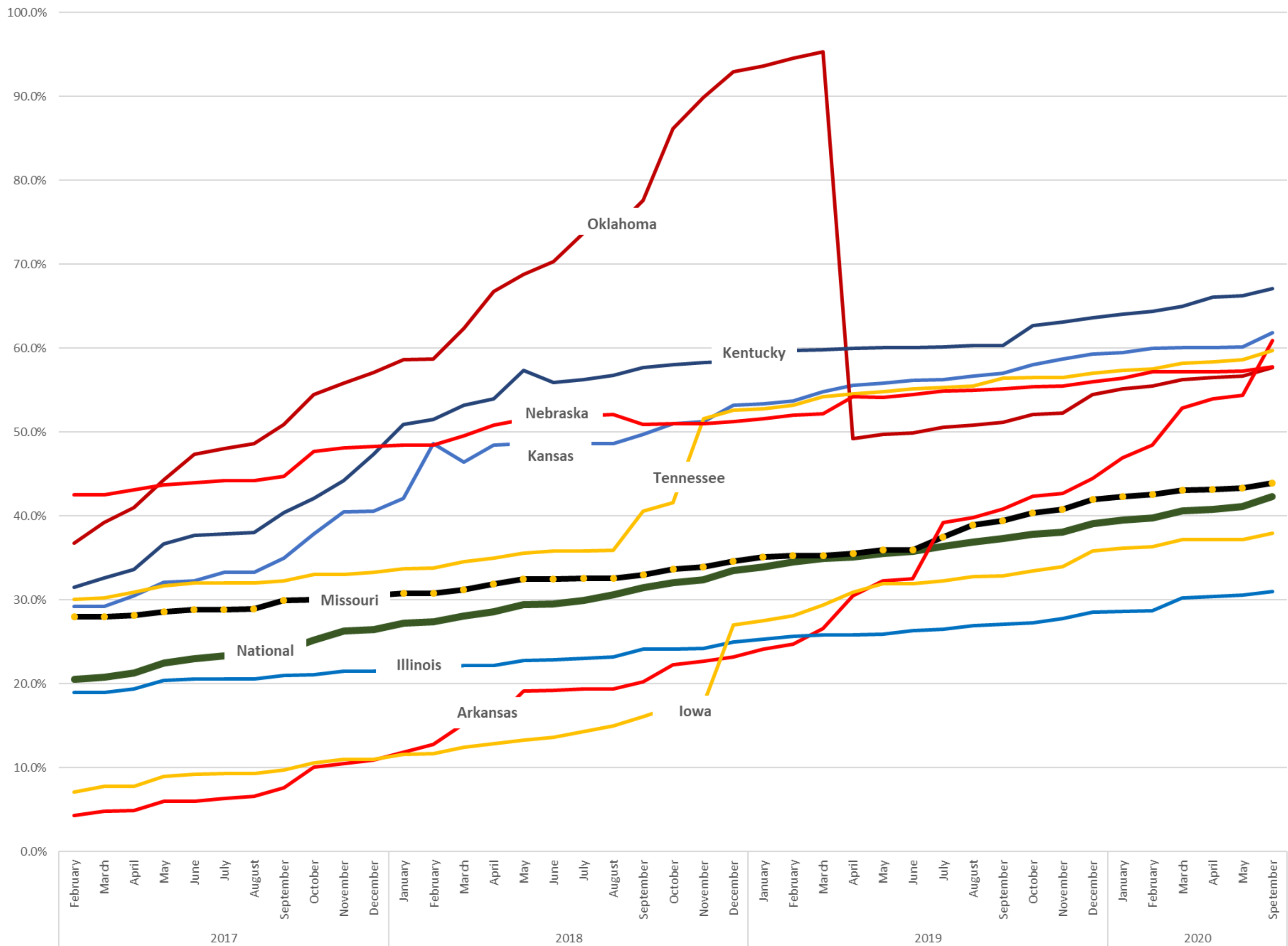
SUPPORT

- Sharing of TIM video for real-time operational purposes.
- Pre-planned detour routes identified and shared with TIM stakeholders.

Detailed self-assessment scores for each region in Missouri is found in **Appendix B**.

Since TIM training is not only a major focus at the national level but in Missouri as well, the common TIM training performance measure—percent of responders trained—was reviewed. As shown in **Figure 14**, the percent of Missouri responders trained in TIM is approximately 44 percent, slightly above the national average of 42 percent. Many of Missouri's adjacent states have percentages exceeding the national average.

Figure 14. TIM Training by Percent of Responders – Missouri, Adjacent States, and National



3. TIM PROGRAM ASSESSMENT

Although Missouri has made significant progress advancing TIM in recent years, as noted in **Section 2.2** there are still opportunities for growing capabilities in certain areas. In order to determine next steps for implementation, an assessment was conducted to identify targeted opportunity areas that align with the vision/goals/objectives identified in **Section 1.2**.
The assessment utilized the following resources:

- **TIM Gap Analysis** – Previous MoDOT TIM Gap Analysis and the FHWA TIM Gap Analysis Primer[7].

- **Self-Assessment –** 2020 Missouri TIM Capability Maturity Self-Assessments (SA) and the 2019 FHWA Capability Maturity Self-Assessment National Analysis Report.

- **National Unified Goal (NUG)** – The National Traffic Incident Management Coalition NUG for TIM[8].

As noted in the FHWA TIM Gap Analysis Primer, the criteria found in the FHWA TIM SA and the NUG are the two recognized authorities on TIM program assessments. However, as noted in this Primer, the two approaches are similar but have some differences. For instance, the SA asks if a state has an "authority removal" and "driver removal" laws, while the NUG only refers to "move over/slow down" laws. The Primer includes an assessment checklist that is similar to the SA to the NUG, but with some differences. To account for these differences, a comprehensive approach shown in **Table** was developed and used in the assessment.

Each TIM program component was evaluated to determine if it could be a focus area for improvement. The evaluation included previous MoDOT TIM Gap Analysis results, feedback from MoDOT, the 2020 Missouri TIM Capability Maturity SA, and input from the TIM Coordinating Team. As noted in **Table** , the strategic components have the most area for high priority improvement. This is consistent with the FHWA national TIM Capability Maturity SA scores, since historically this area typically has the lowest scores across all regions and states.

The detailed assessment matrix can be found in **Appendix C**.

Table 3. Missouri TIM Program Assessment

No.	TIM Program Component	Criteria Included In:			Focus Area for Improvement
		Gap Analysis Primer	2020 SA	NUG	
STRATEGIC					
1	Have a TIM multiagency team or task force that meets regularly to discuss and plan for TIM activities	Yes	Yes	Yes	HIGH PRIORITY
2	Conduct multiagency TIM training	Yes	Yes	Yes	HIGH PRIORITY
3	Conduct multiagency post-incident debriefings (after action reviews)	Yes	Yes	No	HIGH PRIORITY
4	Conduct special event planning	Yes	No	No	LOW PRIORITY
5	Conduct workzone planning	Yes	No	No	LOW PRIORITY
6	Have multiagency agreements for quick clearance with clearly defined roles and responsibilities	Yes	No	Yes	HIGH PRIORITY
7	Conduct planning to support TIM activities across participating agencies, including MPO	Yes	Yes	No	NO
8	Have a position that has TIM as primary job function	Yes	Yes	No	NO*
9	Have multiagency agreements for RCT and ICT	Yes	Yes	No	NO
10	Have methods to collect and analyze RCT and ICT	Yes	Yes	No	NO
11	Have RCT and ICT targets	Yes	Yes	Yes	NO
12	Routinely review progress in achieving RCT and ICT targets	Yes	Yes	Yes	NO
13	Track performance in reducing secondary incidents	Yes	Yes	No	HIGH PRIORITY
14	Have secondary incident targets	Yes	Yes	No	HIGH PRIORITY
15	Deploy technology to support TIM activities (e.g. incident detection & responder notification)	Yes	No	Yes	NO
16	24/7 availability of responders and equipment	Yes	No	Yes	NO
17	Multiagency resource management	Yes	No	No	NO
18	Funding for TIM	Yes	Yes	No	NO
19	Education and awareness partnerships for TIM	Yes	Yes	Yes	NO
TACTICAL					
20	Have "authority removal" law	Yes	Yes	No	NO
21	Have "driver removal"/STEER IT CLEAR IT law	Yes	Yes	No	NO
22	Have MOVE OVER law	Yes	No	Yes	NO
23	Driver training and awareness related to TIM laws	No	No	Yes	NO
24	Have Safety Service Patrol (SSP) Program	Yes	Yes	No	NO
25	Utilize Incident Command System (ICS) on scene	Yes	Yes	No	LOW PRIORITY
26	Have pre-staged response equipment for timely response	Yes	Yes	No	NO
27	Tow operator/rotation list policies deploy resources based on type/severity of incident	No	Yes	No	HIGH PRIORITY
28	Tow operator/rotation list policies include penalties for non-compliance of response criteria	No	Yes	No	LOW PRIORITY
29	Identify and document tow operator capabilities	Yes	Yes	No	HIGH PRIORITY
30	Identify and document hazmat operator capabilities	Yes	No	No	NO
31	Authority to override hazmat contractor to call in other resources	Yes	No	No	NO
32	Medical examiner response clearly defined for incidents involving fatalities	Yes	Yes	No	NO
33	Have procedure for removing deceased prior to medical examiner arrival	No	Yes	No	LOW PRIORITY
34	Electric utility companies' role clearly defined for incidents involving downed electrical wires	Yes	No	No	LOW PRIORITY
35	Have procedures for expedited accident reconstruction/investigation	Yes	Yes	No	NO
36	Have policy for removal of abandoned vehicles	Yes	No	No	LOW PRIORITY
37	Train responders in MUTCD traffic control	Yes	Yes	No	NO
38	Utilize resources to conduct traffic control procedures for various levels of incidents	Yes	Yes	No	NO
39	Utilize traffic control procedures for back of queue	Yes	Yes	No	NO
40	Have procedures/guidelines for safe vehicle positioning	No	Yes	No	NO
41	Have procedures for equipment staging and emergency lighting	Yes	Yes	No	NO
42	Have multidisciplinary communication practices and procedures	No	No	Yes	LOW PRIORITY
43	Have procedures for prompt responder notification	Yes	No	Yes	LOW PRIORITY
SUPPORT					
44	Use TMC for incident detection, notification, response	Yes	No	No	NO
45	Share data/video between agencies	Yes	Yes	No	HIGH PRIORITY
46	Have policies/procedures for traffic management during incident response, such as signal timing changes and pre-planned detours	Yes	Yes	No	HIGH PRIORITY
47	Provide interoperable, interagency communications onsite between incident responders	Yes	No	Yes	LOW PRIORITY
48	Have real-time motorist information system	Yes	No	Yes	LOW PRIORITY
49	Provide motorists with travel time estimates	Yes	No	Yes	NO
50	Develop and implement cost recovery and management systems	Yes	No	No	LOW PRIORITY
51	Have partnerships with news media and information providers	No	No	Yes	LOW PRIORITY

**Recently accomplished*

4. RECOMMENDATIONS

Missouri has optimized and integrated many mature TIM practices. The region(s) need to continue and expand upon these best TIM practices. However, based on the 2020 multi-agency TIM program assessment, with concurrence from district Incident Management and TIM Coordinators, a focus on these categories: ***Strategic, Tactical*** and ***Support*** should be prioritized in these TIM components:

STRATEGIC:

1. Within each district form a district or regional TIM multiagency team(s), task force(s), or committee(s) and conduct consistent and regular meetings involving the TIM stakeholders and meet regularly to discuss TIM plan activities and training.
2. Continue and expand multiagency and multidisciplinary TIM training.
    - Classroom
    - Virtual
    - Web-based
3. Establish a process to conduct post-incident after action reviews.
    - Regional TIM committees establish guidelines that identify under what conditions such reviews will be taken in their region, as well as which agency and position will be responsible to lead such efforts.
4. Have a multiagency agreement for quick clearance within the regional TIM committees.
    - Use the Statewide Open Roads Agreement as a framework for the regional agreement
5. Expand tracking of secondary crashes as a performance measure within the regions, as well as establishing targets.

TACTICAL

1. Towing and Recovery within regional TIM collations work with and inform responders and dispatch agencies of their recovery capabilities.
    - Agencies with authority to request and dispatch tow consider type and severity of incidents in addition to recovery procedures to expedite quick clearance and recovery.
    - Agencies with authority to request and dispatch tow to incident scenes ensure they are dispatching/requesting tow and recovery responders that have the capabilities and special equipment to perform the work for the type and severity of the incident they are being requested for.

2. Regional TIM collations discuss and plan for fatal incident procedures including but not limited to discussion and plans for:
   - Expedited accident reconstruction/investigation
     a. New ‘available’ technologies or processes for reconstruction/investigation
     b. Optional concurrent activities for expedited restoration of traffic flow
   - Delayed response by medical examiner or designee procedures
     a. To prevent secondary incidents and restore traffic flow in incidents involving fatalities. Possible available options for relocating or removing deceased prior to medical examiners arrival to incident scene.

SUPPORT

1. Expand and improve video sharing technologies as camera systems become obsolete and are updated.
2. Have pre-planned detour routes identified and shared between TIM stakeholders for critical corridors.
3. Expand TMCs use of new technologies and remote connectivity for corridor signal timing coordination during incidents and for incident bypass routes
4. As technology and accessibility becomes available to do so.
   - Access and expand CAD feed information at MoDOT TMCs
   - Expand interoperable, interagency communications onsite between responders/agencies

REFERENCES

[1] FHWA TIM "one pager": https://ops.fhwa.dot.gov/aboutus/one_pagers/tim.htm

[2] NHTSA Fatality Analysis Reporting System (FARS): https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars

[3] MSHP Statistical Analysis Center: https://www.machs.mshp.dps.mo.gov/MSHPWeb/SAC/Compendium/TrafficCompendium.html

[4] FHWA Traffic Congestion and Reliability Report: https://ops.fhwa.dot.gov/congestion_report/executive_summary.htm

[5] MoDOT Tracker: https://www.modot.org/tracker-measures-departmental-performance

[6] FHWA Creating an Effective Program to Advance TSMO: https://ops.fhwa.dot.gov/publications/fhwahop12003/fhwahop12003.pdf

[7] FHWA TIM Gap Analysis Primer: https://ops.fhwa.dot.gov/publications/fhwahop15007/fhwahop15007.pdf

[8] National Traffic Incident Management Coalition National Unified Goal for TIM: http://ntimc.transportation.org/Documents/NUGUnifiedGoal-Nov07.pdf

MODOT STRATEGIC TRAFFIC INCIDENT MANAGEMENT PLAN

Missouri Department of Transportation

March 2021

171.11 Roadside Appurtenances

From Engineering_Policy_Guide
Jump to navigationJump to search

Contents

~~RAP(A1) Crashworthy End Treatments~~

~~On high speed (50 mph) and high volume (6000 vpd) National Highway System roads, guardrail approach ends that are damaged beyond repair shall be replaced with crashworthy end sections meeting current standards.~~

~~Blunt ends, BCTs and turned downs may still be used on the trailing ends of guardrail, on one-way highways in locations where they cannot be impacted from the reverse direction, if they provide the anchorage needed for redirection of an impacting vehicle.~~

~~Guardrail end treatments shall be periodically adjusted for tension.~~

~~Reason for policy:~~

- ~~To ensure guardrail is placed in appropriate locations and installed as per current specifications~~

~~Effective Date: 6/1/99~~

~~Revision Dates:~~

RAP(A3) Signpost Breakaway Features

All sign posts are to be installed and maintained with breakaway features on all MoDOT maintained highways.

Reason for policy:

- To meet FHWA standards
- To reduce potential damages from errant vehicles striking roadside signs

Effective Date: 6/1/99

Revision Dates:

RAP(A4) Culvert Ends

See S&A(C2) Culvert Ends.

171.11.1 Protective Barrier

~~RAP(B1) Guardrail~~

~~Guardrail is placed at hazardous locations as a protective barrier that both restrains and redirects traffic. Requests for the placement of additional guardrail by the public should be considered on the basis of traffic safety and design criteria. All installations of guardrail must meet standard design and construction specifications.~~

~~Guardrail should not be used indiscriminately to avoid posing a greater hazard than the hazard itself. Guardrail should not be used to protect non-MoDOT property off the right of way.~~

~~Reason for policy:~~

- ~~To ensure guardrail is placed in appropriate locations and installed as per current specifications~~

~~Effective Date: 6/1/99~~

~~Revision Dates:~~

~~RAP(B2) Guard Cable~~

~~Cable and wire fabric guardrail shall be periodically adjusted for tension to assure effectiveness and to improve appearance.~~

~~Reason for policy:~~

- ~~To ensure guard cable will perform as designed~~

~~Effective Date: 6/1/99~~

~~Revision Dates:~~

~~RAP(B3) Fixed Impact Attenuators~~

~~The maintenance and repair of fixed impact attenuators requires the replacement units to be spotted in the same locations as the original modules. A detailed drawing of each installation should be available for maintenance crews performing needed repairs.~~

~~Reason for policy:~~

- ~~To assure proper operation of fixed impact attenuators~~

~~Effective Date: 6/1/99~~

~~Revision Dates:~~

RAP(B4) Concrete Median Barriers

Concrete median barriers shall be replaced or repaired where the damage resulted in loss of a significant piece of concrete. The type of section and extent of damage will dictate whether the section should be replaced or repaired in place.

Reason for policy:

- To assure proper operation of barriers

Effective Date: 6/1/99

Revision Dates:

606.2 Guard Cable

Videos

Successful guard cable test

Guard Cable in Action

MoDOT's You Tube Guard Cable video

606.2.1 Guard Cable Types

~~Cable median barriers, commonly referred to as guard cable, remain one of the most efficient roadside safety treatment available today.~~ Guard cable consists of twisted wire ropes mounted on weak posts. ~~It is relatively inexpensive to install, compared to more rigid systems, and has been proven effective at capturing errant vehicles.~~ There are two types of guard cable systems in use on Missouri roadways: low-tension and high-tension.

606.2.1.1 Low-Tension. Since no single producer exclusively manufactures low-tension guard cable, this system has been commonly called the "U.S. generic" system or non-proprietary. Low-tension guard cables typically consist~~s~~ of three cables placed at different heights and are tensioned ~~only enough~~ to eliminate sag between posts. Large springs at either end of the cable run are compressed, according to temperature, to achieve the system's ~~low~~ tension. The cable itself is strung on posts that are directly driven into the ground.

Low-tension Guard Cable

Typically, ~~W~~when a vehicle impacts the low-tension system ~~under normal conditions~~, the cable stretches laterally "catching" the vehicle~~moves as much as 12 ft~~. This movement is known as the dynamic deflection.

Median Guard Cable

Summary, 2006

Report, 2010

See also: Innovation Library

Given the low~~lack of~~ tension of~~in~~ the system, individual installations, or "runs", of cable are limited to 2000 ft. with an anchor assembly at each end. When a vehicle strikes low-tension cable, the system can become~~s~~ disabled and shall be repaired as soon as practical. ~~will not function properly if subsequently struck by another vehicle. As such, it is critical to repair the guard cable promptly.~~

Low-tension systems ~~have been in service for some time and~~ have proven their value by reducing cross-median incidents~~accidents~~. However, the installation of new ~~issues related to down time and the necessity to utilize on-call contracting cause a perpetual drain on MoDOT resources. For these reasons, the use of~~ low-tension cable systems should be limited to small-scale installations~~ with special circumstances~~.

606.2.1.2 High-Tension. High-tension cable barrier looks very similar to low-tension cable but the two systems are very different in most other aspects. High-tension guard cable consists of three or four pre-stressed cables supported by weak posts.

High-tension Guard Cable

During installation, the cables are placed on the posts and then tightened to the manufacturer's recommended~~a specific~~ tension~~, ranging from approximately 2,000 to 9,000 pounds according to temperature~~. Due to this tightening, the cable installations can be of indefinite length. ~~In fact, t~~The runs are typically only limited by the presence of ~~obstacles such as~~ median openings~~ or bridge columns~~.

~~Under normal conditions,~~ Typically, when a vehicle impacts the high-tension system the cable, like low-tension guard cable, it will laterally deflect~~s as much as 8 ft~~. The inherent tension within the system also allows the cable to remain at the proper height, even after an impact removes several posts. ~~While t~~The high-tension system is not designed to continue to function in that condition, therefore repairs shall be made as soon as practical. ~~is a great deal of anecdotal evidence that it does just that.~~

As of 2007, all high-tension guard cable systems are proprietary, that is, marketed under exclusive rights of a specific manufacturer. Five systems are currently marketed in the United States.

See End Terminals, Crash Cushions and Barrier Systems (link) for the list of approved high-tension guard cable manufacturers.

~~Currently Approved High-Tension Systems and Manufacturers~~	
~~High-Tension System~~	~~Manufacturer~~
~~Brifen~~	~~Brifen USA~~
~~CASS~~	~~Trinity Industries, Inc.~~
~~Gibraltar~~	~~Gibraltar~~
~~Safence~~	~~Safence, Inc.~~
~~U.S. High Tension~~	~~Marion Steel Company~~

A common installation of high-tension guard cable employs concrete footings into which metal tubes are cast, forming sockets. The socket allows a post to be replaced with relative ease during a repair operation. The damaged post can be ~~is simply~~ removed from the socket and replaced with a new~~virgin~~ post. Socketed systems eliminate the requirement for specialized post driving equipment and subsurface utility location for each repair.

~~A socketed, high-tension system should be chosen for large-scale guard cable installations. While such a system generally has a higher initial cost, the low cost and high efficiency with which it can be maintained make it a better value over its life cycle. A high-tension system incorporating socketed posts is easily repaired and maintained with the resources currently available to the district maintenance personnel. Additionally, h~~High-tension systems can be used on a variety of median inslopes, often eliminating the need for costly slope corrections and drainage modifications.

~~As of 2007, all high-tension systems are proprietary, that is, marketed under exclusive rights of a specific manufacturer. Five systems are currently marketed in the United States.~~

606.2.2 Systematic Application of Median Guard Cable

Median guard cable is most effective when installed as a system-wide solution to address cross-median crash types. The benefits are severely limited if the cable is only used in spot locations in response to crashes at those locations.

Additionally, when determining the most appropriate locations for guard cable application, the designation of a route (interstate, US highway, state route) should not be a primary consideration.

A corridor should have similar geometry and traffic volume and the placement of guard cable on the corridor should have logical termini. Spot location installation of new median guard cable should be used sparingly only in unique situations.

606.2.23 Warrants

Analyses of cross-median incidentcrash history and traffic volume provide valuable information in determining the likelihood of future incidentssevere crashes on these routes. In order to prevent future incidentsfatalities and disabling injuries, it is important to focus safety efforts on locations that will benefit the most from safety countermeasures.

The risk of cross-median crashes can be influenced by median width and the traffic volume on both roadways (two-way AADT). Figure 606.2.2... shows various levels for implementation based on the anticipated benefits of reducing severe crashes compared to costs for installation, maintenance, and overall crash impact.The Highway Safety and Traffic Division may be contacted for additional details on how the anticipated benefits of guard cable installation were determined.

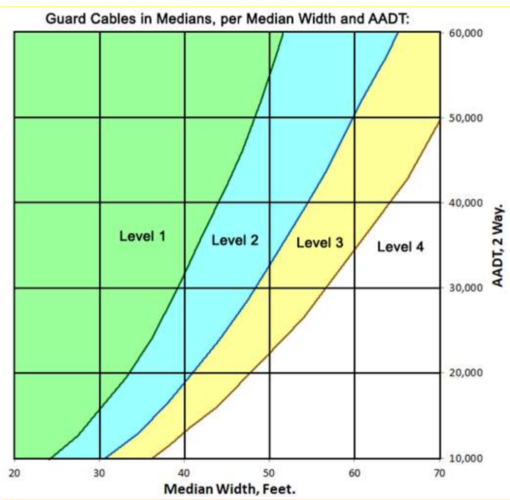


Figure 606.2.2, Median Guard Cable Levels as Related to Median Width and Two-Way AADT

Median Guard Cable should be installed in Level 1 locations.

Median Guard Cable may be installed in Level 2 or 3 locations based on engineering judgment. Level 2 should be a higher priority than level 3. Guard Cable may be installed on level 4, but is not typical and should had additional justification based on the context of the location.

606.2.2~~3~~.1 ~~Crash~~ Data. Analysis of incidents~~crashes~~ on a candidate corridor should focus on cross-median incidents~~crashes~~ on that route~~ and, even more so, on those crashes resulting in fatalities and disabling injuries~~.

It is important this data analysis is accurate and complete for all roadways~~robust, particularly on expressways~~. Due to at-grade intersection incidents~~crashes~~ on these routes, a simple query of cross-median incidents~~crashes~~ may include unwanted events and exclude necessary ones. Accuracy of this~~these~~ data is vital in decision-making.

The data should be reviewed ~~often~~regularly~~each year~~ to validate priorities and identify any emerging cross-median safety concerns. A regular review of divided highway traffic volume and incidents~~crashes~~ will provide information to ~~proactively~~ address severe cross-median incidents~~crashes~~.

606.2.2~~3~~.2 Traffic Volume. Recent research has connected traffic volume growth directly to cross-median incidents~~crash events~~. As volume increases, the probability of a motorist crossing the median and hitting an oncoming vehicle also increases. Instead of relying solely on ~~crash~~incident history, there is an opportunity to proactively address this ~~crash~~incident type before the ~~crashincidentes~~incidents occur by studying traffic volume patterns and installing a system of median guard cable on routes with sharply increasing volumes. See Figure 606.2.2~~...~~ for the anticipated impact traffic volume has on severe crash risk and anticipated value for guard cable installation.

606.2.2~~3~~.3 Median Width. Recent national experience has shown that cross-median ~~crashincidentes~~incidents can occur on highways with median widths above MoDOT's initial 60 ft. threshold. Although this width has largely proven to be effective in ~~detering~~deterring such ~~crashincidentes~~incidents, no route will be excluded from analysis solely on the basis of median width. Divided highways with very wide medians are expected to have ~~little or no~~ a low risk of cross-median ~~crash~~incidents ~~history, effectively removing them from consideration for barrier installation.~~ See Figure 606.2.2~~...~~ for the anticipated impact median width has on severe crash risk and anticipated value for guard cable installation.

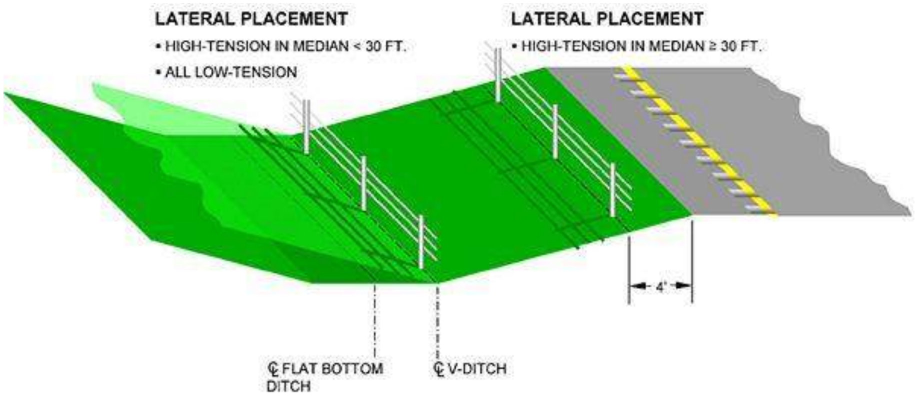
606.2.3~~4~~ Design and Installation Guidelines

606.2.3~~4~~.1 Lateral Placement in the Median

Dynamics of Cross-Median ~~Crash~~Incidentes. When a vehicle leaves the roadway and enters the median, certain predictable dynamics occur. Vehicles may enter the median at a variety of speeds and angles but for the purposes of roadside safety research and testing, a 62~~0~~ mph departure at a ~~20° or~~ 25° angle is generally used.

Upon departure, a vehicle will initially continue along its vertical trajectory. As the inslope falls away along the 25° vehicle path, the vehicle effectively becomes briefly airborne. When the vehicle's inertia can no longer overcome gravity, it lands and its suspension is deeply compressed. As the vehicle continues to travel through the median, the suspension rebounds and the bumper of the vehicle stays at a relatively constant height throughout the remainder of the errant journey.

Every guard cable ~~crash~~incident is slightly different because of a host of site-specific factors. In general, however, the front of the vehicle must engage at least two of the three or four cables present in order to be contained by the system. Given the dynamics described above, lateral placement of the cable can be grouped into two main categories: medians wider than 30 ft. and those narrower than 30 ft.



Medians 30 ft. or wider. The guard cable should be installed no more than 4 ft. downslope of the edge of the shoulder. With wider shoulders, the downslope location could be less than 4 ft., but in any case, there shall~~must~~ be 8 ft. between the barrier and the edge of traveled way. There are several advantages to this location but chief among them is the performance of the system in a ~~crash~~incident. At the 4 ft. downslope location, the errant vehicle adjacent to the barrier, while airborne, is not at a great enough altitude to override the cable during a front side encounter. From the opposing direction, or backside, the suspension of the errant vehicle will have recovered enough to allow an impact to occur under relatively normal impact conditions.

If the 8 ft. separation cannot be obtained, the designer must work with the Central Office Design Division to assess the potential safety impacts of a decreased deflection distance. ~~If the arrangement cannot be proven reasonably safe, a~~ A different barrier system should~~must~~ be considered~~used~~.

Medians narrower than 30 ft. In medians narrower than 30 ft., the guard cable should be installed within 1 ft. of the vertex of either a V or flat-bottomed ditch. As previously discussed, this location performs the most advantageously. The 4 ft. downslope location starts to fail in narrower medians as the suspension of the vehicle impacting from the back side (i.e. the opposite direction) is the most tightly compressed around that location. Again, a fully compressed suspension has proven to be the principal reason for vehicles underriding the system.

Alternating Sides. The designer may choose to alternate the sides of the median where the barrier is placed for the purpose of reducing any shy line issues or discomfort for motorists. The change should occur at natural breaks in the barrier such as emergency crossovers or median bridge columns.

~~**Lateral Placement of Low-tension Guard Cable.** New installations of low-tension guard cable should be installed within 1 ft. of the vertex of either a V or flat-bottomed ditch. Retrofits should be located at the existing offset, provided the system is functioning well.~~

606.2.34.2 Parallel Installations

In-service experience with parallel installations has shown less than desirable results. The close proximity of each installation to traffic has caused an inordinately high incidence of nuisance hits resulting in higher than acceptable long-term maintenance costs. Vegetative maintenance is also a concern.

Parallel installations of guard cable should not be used. Instead, designers should rely upon guard cable designed for the situation as a single run or consider a barrier system other than guard cable.

606.2.34.3 Post Spacing

While guard cable has been tested and approved with post spacing ranging from 6.5 to 32.5 ft., it is widely believed that the wider post spacing leads to greater deflections and an increased likelihood of vehicle penetration due to underride or traveling between the cables. For this reason, post spacing should not exceed the conventional limit of 20 ft. or manufacturer's recommendation. Additionally, increasing post spacing through horizontal curves increases the opportunity for the cable to assume a chord length if the posts are damaged. If enough posts are damaged, the cable could project into the travelway on the inside of the curve.

606.2.34.4 Slopes

1V:6H (6:1) or Flatter Slopes. Guard cable, like most roadside hardware, is intended for use on slopes that are 1V:6H (6:1) or flatter. This requirement is based on both computer modeling and full-scale crash testing and represents sound theory. In practice, however, slopes as flat at 1V:6H are often the exception.

Steeper Slopes. All of the proprietary high-tension systems are now approved for use on slopes with gradients between 1V:6H (6:1) ~~and~~ to 1V:4H (4:1). Their use, while generally more expensive, represents the most cost-effective solution for shielding steeper slopes. Further, since more than three equivalent sources exist, there is no need to obtain a material certification for their use.

606.2.34.5 Vegetative Barrier

Vegetation control in the area between the cable and the passing lane mustshould be addressed. Failure to provide some positive form of vegetation control will hinder the future maintenance of the system. Positive vegetation control measures may include herbicides, a geotextile-aggregate strip or asphalt apron. The core team shallmust consult with the local maintenance personnel to arrive at a vegetative control measure that is mutually agreeable. Vegetation control may not be omitted from a project as a practical design or value engineering measure. See EPG 606.2.5 below for vegetation maintenance.

A district's decision to mow around the barrier must be approved by Central Office Maintenance. Such mowing operations must be accomplished without impeding through traffic in any manner.

Anchor Assembly

Vegetation control may not be omitted from a project as a practical design or value engineering measure.

606.2.34.6 Termination at Crossovers and Emergency Crossovers

The design for guard cable termination as well as the grading for the crossover shallshould be in accordance with Standard Plan 606.41, Sheet 7 of 7. Refer to EPG 240.4 Guard Cable Termination at Emergency Crossovers for additional information.

606.2.45 Maintenance and Repair

Irrespective of routes treated, proper placement or system used, cable median barrier Guard cable is only as functional as its ongoing maintenance and repair. Proper maintenance and incident repair will ensure that the system is always in a state of functionality to provide motorists a greater level of safety on Missouri roadwayshighways.

Vegetation Maintenance. District maintenance shall provide vegetative control around guard cable systems. Positive vVegetation maintenancecontrol measures mayshould include mowing, herbicides, a geotextile-aggregate strip or an asphalt apron may have been constructed during initial installation.

Routine MaintenanceCable Tension. Outside of vegetation control, there is little routine maintenance required for a guard cable system. If pre-stressed cables are used for high-tension systems and compensators are properly compressed for low-tension systems, the tension in the cable should properly acclimate to any weather condition. The tension monitoring stage occurs during and shortly after construction.To ensure the proper cable tension is being maintained on guard cable systems not repaired due to incidents, cable monitoring shall be performed on a yearly basis. Cable tension monitoring shall be performed as a function of Job Order Contracting (JOC). Tension logs shall be stored in the contract specific eProjects folder. The tension log form is available at EPG 101 Standard Forms (add link here).

Cable Height. The importance of cable height to properly capture and redirect errant vehicles has been demonstrated. Although cable height is relatively static in all systems, erosion and tire rutting under the barrier can sometimes cause a localized increase in height, resulting in possible underride. When ditch erosion or rutting causes the cable heights to be outside the manufacturer's recommended maximum, corrective measures shall be performed either by the on-call contractor or by in-house Maintenance forces.

Maintenance personnel should be educated on the necessity of properaware of minimum and maximum cable heights and encouraged to identify and repair locations where erosion or the accumulation of silt have altered the relative cable height.

Median Condition. A secondary issue, closely related to incident repair, is the post-entry condition of the median. In addition to the repair of the roadside hardware, tThe median condition with respect to rutting, loss of vegetation and incidentaccident debris should be remedied by Maintenance forces following each incidentaccident. These incidental concerns

~~could cause instability in the trajectory of future errant vehicles and could, at worst, result in a failure of the system.~~

Guard Cable Repair. Incident repairs shall be performed by the on-call contractor. See EPG 147.3.10 (link) for additional Job Order Contracting requirements for guard cable repairs.

~~**Low-Tension Cable Barrier Repair: On-Call Contract.** Maintenance of low-tension cable barrier is vastly more complicated than that of a high-tension system. In fact, the complexity of the system coupled with the frequency of crash incidents, have traditionally resulted in the system's maintenance being outsourced through on-call contracts.~~

~~**High-Tension Cable Barrier Repair: In-House.** Equipment and hardware needs for the repair of high-tension, socketed guard cable are minimal and repairs can generally be accomplished in under an hour with two workers, some hand tools and a pickup truck.~~

~~**Response Time.** Due to the importance of the median guard cable performing when needed, it is vital to quickly respond to repair needs. This will often necessitate an effort to identify cable hits as soon as possible after the incident and then respond with repair as quickly as possible.~~

606.2.5~~6~~ Maintenance Planning Guidelines for Guard Cable

See Maintenance Planning Guideline for Guard Cable.

Index of all Maintenance Planning Guidelines.

606.2.6~~7~~ Construction Inspection Guidelines for Guard Cable

For Sec 606.50.2. The embankment slope between the shoulder and the guard cable should be 1V:6H (6:1) or flatter, unless the system is approved for use on slopes as steep as 1V:4H (4:1). If only one run of three-strand guard cable is installed in the median, the slope on both sides of the guard cable should be 1V:6H (6:1) or flatter, unless the system is approved for use on slopes as steep as 1V:4H (4:1). No exceptions should be allowed unless approved by the Central Office. This is essential for the guard cable to perform as designed.

The embankment slope behind the guard cable is not critical (may be as steep as 1V:2H (2:1)) if another run of three-strand guard cable is installed on the other side of the median to prevent~~otect~~ crossovers from that direction of traffic or if adequate clear zone is provided in the other direction of traffic. Such "double runs" are discouraged, however, since both the initial and lifetime costs are doubled.

Sieve Size	Percent Passing by Weight (mass)
3 in. (75mm)	100
1 in. (25mm)	80
No. 4 (4.75mm)	0-35

Aggregate Bedding (for Sec. 606.50.2.4). ~~Having a p~~Predominantly one-sized stone as a bedding material for guard cable, as currently specified in Sec 606.50.4, will act as marbles when a vehicle impacts the bedding material and will likely result in an impacting vehicle to dive under the cable system and continue across the median into the opposing traffic, thereby defeating the purpose of the guard cable system. This is elevated to even a larger safety issue where contractors have provided sand or gravel as the bedding material, which have a greater tendency to roll like marbles when impacted and increases the probability for a vehicle to dive beneath the barrier system. In the interim of getting a specification revision, existing jobs should be change ordered to a bedding material consisting of a uniform, angular graded material of a gradation similar to that shown below. Verification of the gradation should be accomplished by visual inspection, and when in suspect, a sieve analysis should be conducted.

Delineators (for Sec. 606.50.2.5). All three-strand guard cable, regardless of the location of the guard cable, should be delineated, with delineator spacing, reflective sheeting and reflector colors in accordance with Sec 606.10.2.3.

Guard Cable Tension Log

Date	Entered By	Contractor	Route	Begin MM	End MM	Total Length	County	System Type	Strand Tension (lbs)			Temp.	Remarks
									Top	Middle	Bottom		
7/29/2019	*John Doe*	*John Doe, LLC*	*Ex. I-70*	*100.0*	*104.4*	*4.4*	*Boone*	*Gibraltar HTCB*	*5180*	*5140*	*5280*	*88*	*Gibraltar; driven posts*

NOTE: Internal document links have been disabled. Since this EPG article has not been implemented yet, the internal links do not work as intended. The internal document links will be fully functioning once uploaded/implemented into the EPG (i.e. EPG 905.3.2 references EPG 905.3.2.5 which will be a link in the final EPG version).

EPG 905.1 Traffic Data Collection

To perform a traffic study, certain data should be collected. A good source of data can be obtained throughfrom MoDOT's tools, that include:

• Transportation Management System (TMS) - . TMS has inventories for roadway information as well as crash information.

• Interactive AADT Map – shows traffic volumes at some locations that are associated with actual count data and some data that are estimated volumes (not based on count data). This map breaks down traffic by both generalized vehicle classifications and directional, hourly volume breakdowns.

For some traffic studies, data from TMS or interactive AADT map may be enough. For other studies, field data will be required. The Traffic Data Collection article will show how to "right-size data collection" data available from TMS and data required from the fieldbased on purpose and need of study. Refer to EPG 905.3.3 Data Collection for how to collect data in a Transportation Impact Analysis.

EPG 905.3 Transportation Impact Analysis

905.3.1 Introduction

A Transportation Impact Analysis (TIA) evaluates the potential adverse effects of proposed projects on surrounding and supporting transportation infrastructure and services. A TIA determines if the adverse effects constitute significant impacts, and, if so, how the significant impacts can be mitigated. The guidance in this article was developed to provide a technical approach to TIAs that is consistent, instills confidence in its findings, and sets MoDOT up for success in managing Missouri's transportation system safely and reliably.

905.3.1.1 Background

Transportation Impact Analysis (TIA) is one of the critical activities for a project and can influence the project schedule, scope, and budget, as well as NEPA and AJR approvals. TIAs can impact the effort associated with all planning efforts including traffic data collection, forecasting, and analysis. Each transportation project is unique and the approach for individual projects should be modified to fit each unique project. As such, when developing the TIA, there must always be a balance between the project's goals and objectives, available schedule and budget, and the complexity of the analysis to be performed, particularly analysis involving microsimulation or the *Highway Safety Manual* (HSM).

905.3.1.2 Purpose

MoDOT recognizes the critical role that TIAs have on their ability to program and implement projects that provide great value to their customers. The purpose of EPG 905.3 Transportation Impact Analysis is to ensure that TIAs developed for MoDOT are consistent with the traffic engineering and transportation planning standards of practice and include the latest research and industry best practices. EPG 905.3 Transportation Impact Analysis provides direction to project managers, project engineers and planners, consultants, and all TIA users on how TIAs should best be incorporated into a transportation project's development.

905.3.2 Methodology and Scoping

Additional Information

Technical References

Accompaniment to Volume Development

Accompaniment to HCS

Accompaniment to Synchro/SimTraffic

Accompaniment to VISSIM

During the development of a TIA, it is important to assess current and future safety and traffic operation conditions and the effectiveness of potential solutions using traffic and safety analysis methodologies and tools. There are several analysis methodologies and tools available for use that all vary in their scope, capabilities, methodology, input requirements, and output. The goals of EPG 905.3.2 Methodology and Scoping are to assist traffic engineers, planners, and project managers in the selection of the appropriate analysis tools and to enable effective communication of the analysis methodology and workplan through appropriate scoping documentation. The MoDOT TIA Methods and Assumptions Report is the deliverable by which MoDOT stakeholders can accomplish the goals of EPG 905.3.2 Methodology and Scoping. More information about this report template is in EPG 905.3.2.5 Scope the Project.

The steps for selecting appropriate traffic and safety analysis methodologies, tools, and scoping workplans include the following:

1. Understand available traffic and safety analysis tools

2. Identify the project's analytical phase

3. Determine the project's analytical context

4. Select appropriate Analysis Tool(s)

5. Scope the analysis methodology and workplan through the completion of the MoDOT TIA Methods and Assumptions Report template.

905.3.2.1 Overview of Traffic and Safety Analysis Tools

905.3.2.1.1 Traffic Analysis Tools

Traffic analysis tools are some of the most efficient methods to evaluate transportation improvement projects. EPG 905.3.2.1 addresses quantifiable traffic operations analysis tool categories, but does not include real-time or predictive models. Traffic analysis tools include software packages, methodologies, and procedures, and are defined as tools typically used for the following tasks:

• Evaluating, simulating, or optimizing the operations of transportation facilities and systems.
• Modeling existing operations and predicting probable outcomes for proposed design alternatives.
• Evaluating various analytical contexts, including planning, design, and operations/construction projects.

Traffic analysis tools can be categorized into the general categories of sketch planning, travel demand models, analytical/deterministic models, and microscopic simulation models. Table 1 provides a description of these categories, in addition to pros and cons of each model type and examples of the analysis tool types. Note that travel demand models are used primarily in long-range planning completed before capacity analysis and are not covered in detail in EPG 905.3 Transportation Impact Analysis. However, the utilization of travel demand models in traffic forecasts is covered in EPG 905.3.4.6 Traffic Forecast Types and Tools and EPG 905.3.4.7 Forecast Application.

Table 905.3.2.1.1, Traffic Analysis Tool Categories

Analysis Tool Category	Description	Pros	Cons	Examples of Tools
Sketch Planning	Produces general order-of-magnitude estimates of travel demand and traffic operations in response to transportation improvements.	• Simple & low cost • Data needs low (just highly aggregated data)	• Limited in scope • Restricted presentation capabilities • Limited analytical robustness	• HCS • CAPX[1]
Travel Demand Models[2]	Mathematical models that forecast	• Good for use in forecasting	• Poor representation of	• TransCAD

	future travel demand based on current conditions and future projections of household and employment characteristics.	regional population, employment, and traffic growth • Consideration of destination choice, mode choice, time-of-day travel choice, and route choice	operational characteristics of traffic • Large models have lengthy model run durations and large storage needs.	• VISUM • Cube • Emme
Analytical/Deterministic	Uses static formulas to determine the relationships of flow, speed, and density of the traffic stream.	• Quickly predict capacity, density, speed, delay, and queuing • Good for analyzing isolated or small-scale transportation facilities	• Limited in their abilities to analyze network or system effects on traffic flow • Does not model the variability in driver/vehicle characteristics.	• HCS • Synchro • SIDRA
Microscopic Simulation Model	Simulates the movement of individual vehicles based on vehicle and driver behavior theories.	• Good for analyzing large-scale transportation facilities • Interactions with other vehicles and adjacent intersections help determine MOEs	• Requires a great amount of time and effort to build and calibrate • Can require large computer processing time and storage requirements	• SimTraffic • VISSIM

[1] More information about CAPX is available.
[2] Travel Demand Models are used primarily in long-range planning completed before capacity analysis and are not covered in detail in EPG 905.3. EPG 905.3.4.6 Traffic Forecast Types and Tools includes travel demand models and other common forecasting traffic forecasting tools. Additional information on travel demand models is available.

The common analysis software tools are summarized below:

- **Highway Capacity Software (HCS):** HCS is a deterministic software that is based off the equation-based methodologies of the *Highway Capacity Manual* (HCM). HCS can be used quickly and easily with simplistic parameters and inputs. Since HCS is strictly equation-based, it does not have the ability to analyze oversaturated conditions where queues dynamically interact between closely spaced network elements, such as ramps and intersections.

• **SIDRA Intersection Software:** The *Signalized & Unsignalized Intersection Design and Research Aid* (SIDRA) software is a deterministic tool that can be used to analyze roundabout operations, signalized and unsignalized intersections, single-point urban interchanges, and signalized midblock crossings for pedestrians. In the United States, SIDRA is primarily used to analyze roundabout operations because of its ability to model the effects of gap-acceptance (including roundabout geometry) on roundabout Level of Service (LOS).

• **Synchro Software:** Trafficware's Synchro is a macroscopic analysis and optimization software application that supports HCM methodologies and the Intersection Capacity Utilization method for determining intersection capacity. Synchro is ideally used to analyze arterials and networks of multiple signalized and/or stop/yield-controlled intersections. The Synchro software application allows users to code roadway networks in a map-based interface (with aerial imagery overlays if desired) in addition to specifying key parameters in roadway link and intersection node tables. Then the user can specify the types of measures of effectiveness (MOEs) to quantify in auto generated summary reports. Note that Synchro is a companion model to SimTraffic (SimTraffic analysis for a project is first accessed in the Synchro interface).

• **SimTraffic Software:** SimTraffic is a microsimulation tool that simulates the movement of individual vehicles based on vehicle and driver behavior theories. SimTraffic is a companion model to Synchro that simulates the coded transportation network (network is coded in Synchro) and measures the performance of each individual vehicle as they move through the system. Since each individual vehicle will react differently to the influences of other vehicles, pedestrians, bicyclists, roadway geometry, and grades, models with the same geometric and volume inputs will generate slightly different results, similar to how an intersection in the field will perform differently day-to day under otherwise identical conditions. Note that SimTraffic models generally have greater data requirements than Synchro models.

• **VISSIM Software:** VISSIM (translated to "Verkehr In Staedten SIMulation" in German) software is a microsimulation tool that is used to analyze multimodal traffic flows. VISSIM is capable of analyzing signal prioritization and optimization, dynamic traffic assignments, freeway operations, traffic management strategies, pedestrian flows, and the interaction of different transportation modes. Traffic flows are simulated by moving the driver-vehicle units and by using a car-following and lane-changing logic that allows drivers from multiple lanes to react to each other.

vVISSIM's extensive analysis, microsimulation, and animation capabilities make it one of the most labor-intensive analysis tools available. The tool is especially effective at analyzing complex and unique geometrics and traffic patterns. It can be used to evaluate arterials and freeways, but it should not be used to analyze two-way-left-turn (TWLTL) lanes.

905.3.2.1.2 Safety Analysis Tools

Highway Safety Manual (HSM) provides comprehensive countermeasure selection guidance for the various crash pattern types for particular locations, including along roadway segments, at signalized and unsignalized intersections, and for bicyclist and pedestrian related issues. Within the HSM, crash modification factors (CMFs) are introduced as values used to determine the predicted reduction in crashes from implementing a chosen countermeasure(s). Quantitative safety evaluations can be performed using the following tools that utilize HSM methodology:

- **MoDOT Crash Prediction Tool:** The MoDOT Crash Prediction Tool is internal to MoDOT staff and utilizes Transportation Management Systems (TMS) data to analyze rural two-lane highways. The tool is used for network screening and project safety analysis; it automates crash data and provides the Level of Service for Safety (LOSS) and predicted and expected crashes.
- HSM Spreadsheets: The HSM spreadsheets provide high-level overviews of the predicted number of crashes within a study corridor.
- ISATe: The ISATe is an analytical tool to examine safety performance and to predict crashes on freeways and interchanges. This tool is a version of the HSM spreadsheet and allows for the analysis of speed change lanes, as well as ramps and ramp terminals.
- IHSDM: The IHSDM is a suite of software analysis tools that support HSM procedures and methodologies and are used to evaluate the safety and operational effects of geometric design decisions on highway projects.

Additional resources that can be used to supplement the tools above and assist in conducting safety analyses include, but are not limited to:

- **MoDOT Crash Statistics Map:** The MoDOT Crash Statistics Map is internal to MoDOT, but can be accessed externally with permission. It allows users to get a visual representation of crashes and their locations across the state. It also allows users to pull historical crash data and filter that information based on various crash and roadway attributes, such as crash type or curve radius. Data can also be filtered by more specific criteria, such as crashes involving older drivers or pedestrians. Results can be exported to either Excel or PDF for use.
- **Crash Modification Factors (CMFs):** CMFs are values used to determine the predicted reduction in crashes from implementing a chosen countermeasure(s). Refer to EPG 905.3.6.2.8 Crash Modification Factors (CMF) for more information.
- **Missouri's Strategic Highway Safety Plan (SHSP):** Missouri's SHSP is the State's plan (collaboratively developed with stakeholders throughout the State) to reduce fatal and serious injury crashes through an assessment of current and desired performance and a comprehensive collection of data-driven strategies. Additionally, there are regional Highway Safety Plans that are tailored to individual regions in Missouri and are used to inform the SHSP.

For more detailed information about available safety analysis tools and the appropriate applications of safety analyses, refer to EPG 905.3.6 Safety Analysis.

905.3.2.2 Identify the Project's Analytical Phase and Appropriateness of TIA

After the user understands the general background of analysis and safety tools available, the first project-specific step is to identify the analytical phase of the TIA project. The analytical phase is the stage of planning/engineering and the level of analysis at which traffic capacity analysis and/or safety analysis will be completed. Listed below is an explanation of the general analytical phases:

- **Generalized Planning:** High level analysis of transportation system elements to obtain general order-of-magnitude estimates of performance-based capacity constraints and operational control.
- **Conceptual Planning:** Broad criteria and system performance-based analysis on geometric and physical capacity constraints and operational systems such as traffic control and land use.
- **Preliminary Engineering; Design; Operational:** Detailed system performance-based analysis on individual user interactions, geometry, and operational elements.

The determination of whether a TIA should be completed should be determined by factors such as if there is a new development that will generate 100 or more peak hour driveway trips or if the existing traffic on an adjacent facility will increase by at least 20%. For more details on potential triggers to determine when a TIA should be completed for a development, refer to Figure 905.3.4.8.1. Refer to EPG 941 Permits and Access Requests for additional information on permits and access requests.

905.3.2.3 Determine the Project's Analytical Context

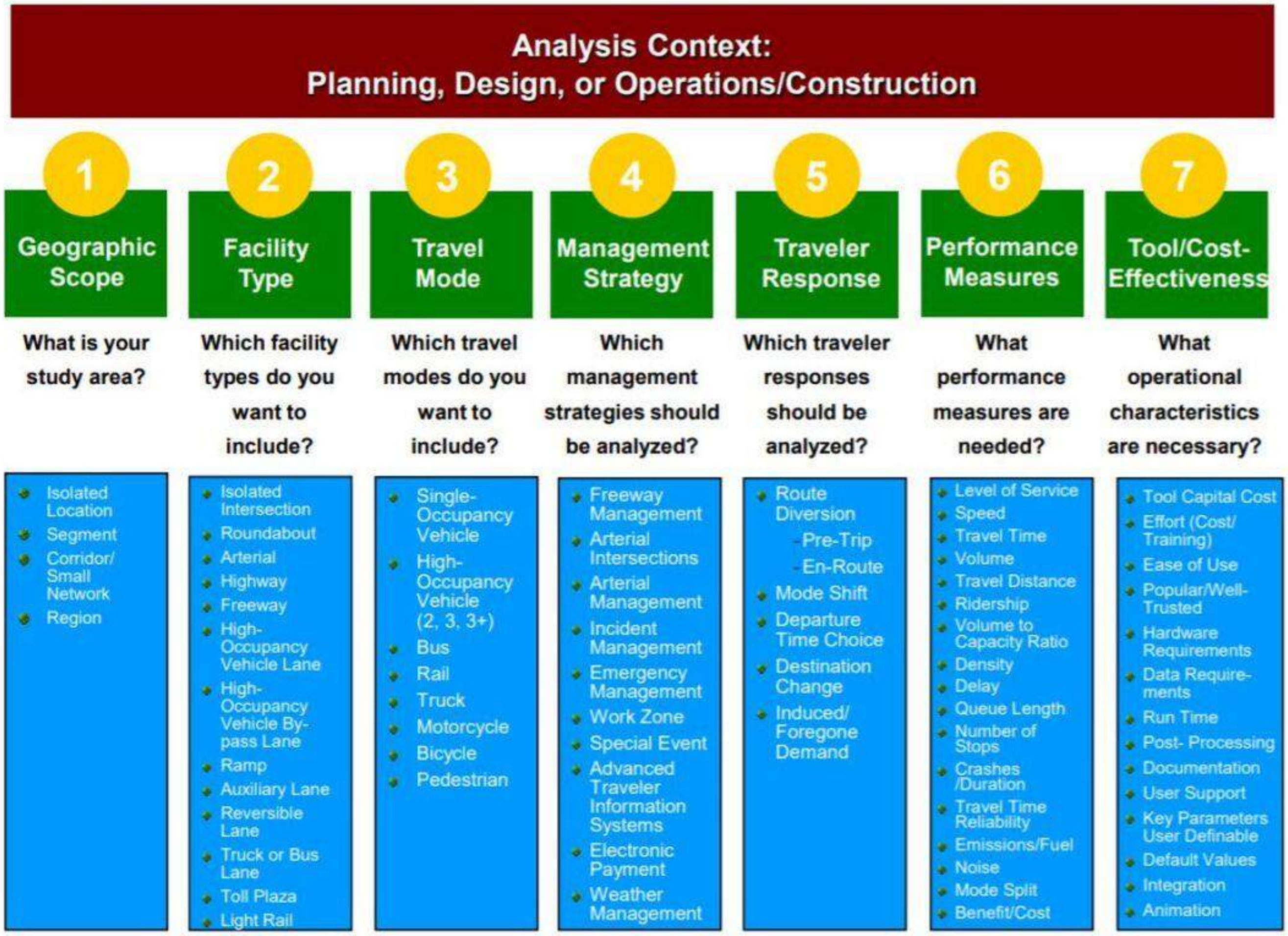


Fig. 905.3.2.3.1, Analytical Context of Project
Source: FHWA Report Number HOP-16-072, *Scoping and Conducting Data-Driven 21st Century Transportation System Analyses*, published January 2017

A project's analytical context should be determined by assessing the following attributes of a project. These attributes are summarized in Fig. 905.3.2.3.1 and listed below:

1. **Geographic Scope:** The study area size of the project. General categories include an isolated intersection or interchange, a roadway segment, a corridor or small network, and an entire citywide or countywide region.
2. **Facility Type:** The transportation facility type(s) that will be analyzed during the project. Examples of facility types include arterials, highways, ramps, and isolated intersections, among other facility types.
3. **Travel Mode:** The travel mode is the means by which transportation facility users will be traveling on the facility. This includes data collection and accurate estimates to determine the proportional breakdown of all vehicle, transit, bicycle, and pedestrian usage.
4. **Management Strategy:** The transportation management strategies that should be analyzed.

5. **Traveler Response:** This attribute indicates how travelers can change their route of travel, change their travel time, use a different mode of transportation, change their destination, or cancel/create a new trip. These traveler responses would be measured due to responses to different operational improvements.
6. **Performance Measures:** The ability of the analysis tool to produce various performance measures in the areas of safety, efficiency, mobility, productivity, and the environment. Common performance measures/MOEs include but are not limited to the list below:

- Level of Service (LOS)
- Speed
- Travel Time
- Volume Desired (Demand)
- Actual Volumes (throughput)
- Ridership
- Volume-to-Capacity (v/c)
- Density
- Delay
- Queue Length
- Vehicle Miles Traveled (VMT)
- Vehicle Hours Traveled (VHT)
- Travel Time Reliability
- Crash Reductions
- Benefit/Cost
- Lives Saved
- Serious Injuries Reduced

Two items that are important to understand for assessing performance measures include:
Typical MOEs by Study Type: Contextualize how MOEs considered will be used for varying study types. Table 905.3.2.3.2 summarizes typical volume-based, time-based, and accessibility MOEs to be aware of based on study type.

Table 905.3.2.3.2, Typical MOEs by Study Type

Study Type	Traffic Volume-Based MOEs	Typical Time-Based MOEs	Accessibility MOEs

Air quality conformity analysis	Area-wide Vehicle Miles of Travel	Speeds	
Asset management, including bridge and pavement needs	Link-specific volumes		
Capital Improvement Program, prioritization	Benefit/cost,Level of Service		
Congestion management process	Corridor volumes	Speeds	
Corridor mobility studies	Intersection Level of Service, intersection turning movements, traffic volumes	Segment travel times	Conflict point comparisons to weight access restrictions[1]
Demand management plans	Number of peak-hour trips, Level of Service	Vehicle Hours of Delay	
Environmental impact statements	Vehicle Miles of Travel, emissions, traffic crashes	Vehicle Hours of Travel	
Evacuation plans	Hourly traffic volumes, throughput	Travel times	
Facility design and operations	Design hour traffic volumes		
Highway feasibility studies	Benefit/cost, screenline volumes, Level of Service	Vehicle Hours of Travel	Access to labor market and jobs[2]
Interchange justification requests	Traffic volumes,Level of Service		
Roadway (general and freight) long-range planning	Vehicle Miles of Travel,Level of Service	Vehicle Hours of Travel	Access to labor market and jobs[2]
Traffic impact studies	Intersection turning movements, Level of Service, delay per vehicle		

Note: Table is based on NCHRP 765 Table 2-1
[1] Applicable to both capacity and safety analyses
[2] Access to the labor market and jobs (as studied at the long-range planning and feasibility study planning levels) can be studied through an assessment of delay and travel time and the constraining factors of capacity and congestion to accessing employment destinations. Regional travel demand models can be used to assess these MOEs for an entire region and to do a select link analysis that identifies a proportional breakdown of how facilities are being used to access key employers. Additionally, stakeholder surveys or travel-time contours can be used to review access to labor markets.

Travel-time contours have been used to illustrate the effects of congestion on access to destinations (including the labor market and jobs). Travel-time contour maps are similar to topographical maps, with lines encircling a destination that radiate outward and do not touch. The spacing between the lines corresponds to the travel times needed to traverse them for a given distance (closely spaced lines would correspond to slower speeds than widely spaced lines).

Typical MOEs by Analysis Tool: Table 905.3.2.3.3 provides common MOEs reported for common analysis software tools. Note that the focus of Table 905.3.2.3.3 is on comparing and contrasting the traffic operations MOEs between multiple analysis tools. It is not an exhaustive list of MOEs and does not include safety MOEs. Most safety focused tools report similar MOEs. The key differences for the safety tools include the level of detail that the particular tool can drill down to.

Table 905.3.2.3.3, Typical MOEs analyzed by Analysis Tool

Traffic Operations MOE	HCS	SIDRA	Synchro	SimTraffic	VISSIM[1]
Average (Mean) Queue Length (feet)				✔	✔
50th Percentile (Median) Queue Length (feet)	✔		✔		✔
95th Percentile Queue Length (feet)[2]	✔	✔	✔	✔	✔
Maximum Queue Length (feet)				✔	✔
Volume-to-Capacity (v/c) Ratio	✔	✔	✔		
Density (passenger car/lane/mile)	✔				
Density (vehicles/lane/mile)	✔				✔
Control Delay (seconds/vehicle)	✔	✔	✔		
Microsimulation Delay (seconds/vehicle)				✔	✔
Travel Time (seconds)	✔			✔	✔
Reliability (Percentile Travel Time Indices)	✔				
Percent of Time Spent Following	✔				
Space Mean Speed (mph)	✔	✔	✔	✔	✔
Time Mean Speed (mph)					✔

[1] VISSIM can be used to specify any percentile queue results from 0% to 100%.
[2] The 95th percentile queue parameter in both SimTraffic and VISSIM are computed values (not based on “observed”/simulated trips). Therefore, the maximum queue is recommended for

both SimTraffic and VISSIM instead. Refer to Table 905.3.5.2.3.5 Queue Lengths in Synchro and Sim Traffic for more discussion.

For general background information, definitions, and the typical usage of MOEs, refer to the FHWA Traffic Analysis Toolbox Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools MOEs.

7. **Tool/Cost Effectiveness:** Evaluate the management and operational considerations for selecting the most appropriate tool based on financial, personnel, or skill-related resource requirements.

905.3.2.4 Analysis Tool Selection

Table 905.3.2.4 displays a general list of traffic analysis and safety tools to select, which are determined by a project's level of analysis and facility type. For a more detailed method to determine an appropriate traffic analysis tool, refer to MoDOT Analysis Tool Selection. Both the generalized and detailed tool analysis methods to select a tool are only guidance to help the user. Additional, project specific concerns, such as the analysis objective and project constraints should always be considered when selecting an analysis tool.

Table 905.3.2.4, Typical Traffic and Safety Analysis Tools by Level of Analysis

Level of Analysis		**Facility Type**					
Category	**Description**	**Isolated Intersections/Interchanges**	**Interconnected Intersections/Interchanges**	**Roundabouts**	**Freeways**	**Urban/Suburban Arterials**	**Rural Two-Lane Highways and Multi-Lane Highways**
Generalized Planning	• High level analysis • General order-of-magnitude estimates • Perform	HCS CAPX HSM[1] ISATe[2]	HCS HSM[1] ISATe[2]	HCS CAPX SIDRA HSM	HCS ISATe	HCS Synchro HSM	HCS HSM MoDOT Prediction Tool[3]

	ance-based capacity constraints and operational control						
Conceptual Planning	• Broad criteria and system performance based analysis • Geometric and physical capacity constraints • Operational systems such as traffic control and land use	HCS Synchro SimTraffic HSM[1] ISATe[2] IHSDM	Synchro SimTraffic VISSIM HSM[1] ISATe[2] IHSDM	SIDRA VISSIM IHSDM	HCS VISSIM ISATe IHSDM	HCS Synchro SimTraffic VISSIM HSM IHSDM	HCS HSM IHSDM MoDOT Prediction Tool[3]
Preliminary Engineering; Design; Operational	• Detailed system performance-based analysis • Individual user interactions •	HCS Synchro SimTraffic VISSIM HSM[1] ISATe[2] IHSDM	Synchro SimTraffic VISSIM HSM[1] ISATe[2] IHSDM	SIDRA VISSIM IHSDM	HCS VISSIM ISATe IHSDM	Synchro SimTraffic VISSIM HSM IHSDM	HCS HSM IHSDM MoDOT Prediction Tool[3]

	Geometry • Operational elements						
Note: Red Text is for safety tools. Also, HSM is short for "HSM Spreadsheets." [1] HSM Spreadsheets are appropriate for intersections and ramp terminal intersections, but not interchanges. [2] ISATe is appropriate for interchanges, but not intersections. [3] The MoDOT Prediction Tool is appropriate for rural two-lane highways only.							

905.3.2.4.1 Use of Complementary Traffic Analysis Tools

There are certain situations where it is beneficial to use multiple analysis tools to blend together the complementary capabilities and strengths of certain tools. A few common situations of blending tools together are provided below. Note that this list is not intended to be prescriptive nor comprehensive.

Synchro and SimTraffic

MoDOT recommends that SimTraffic runs be completed for transportation projects where traffic volumes are at or near capacity or where operations in one part of the study area are expected to have a noticeable impact on other study area locations. This will allow decisionmakers to form a more complete understanding of the traffic flow patterns for a particular project. To help inform this decision, Table 905.3.2.4.1 displays a comparison of key attributes that Synchro and SimTraffic have:

Table 905.3.2.4.1, Synchro and SimTraffic Comparison

Attribute Descriptions	Synchro	SimTraffic
High-level planning study	✔	✔
Geometry and volume attributes are key inputs	✔	✔
Software can optimize signal timings	✔	
Interactions with other vehicles and adjacent intersections help determine MOEs		✔
Realistic traffic simulations can be displayed		✔
Does not require large computer processing time and storage requirements	✔	
A single error at one intersection will NOT impact all intersections	✔	
Better suited to anticipate delay when upstream bottlenecks exist	✔	

Better suited to show delay when queuing and blocking problems exist		✔

Synchro and HCS

This could occur when a project encompasses an arterial, an interchange, and multiple freeway segments when microsimulation is NOT required. In this scenario:

- Traffic conditions would be undersaturated. Otherwise, a microsimulation tool should be used.
- HCS would be used to analyze freeway merging, diverging, and weaving segments
- Synchro would be used to analyze the signalized intersections along the arterial as well as the operations on the arterial facility.

Synchro or HCS and VISSIM

This could occur when a project encompasses an arterial, an interchange, and multiple freeway segments when microsimulation is required. In this scenario:

- Traffic conditions would be undersaturated, but microsimulation would still be needed.
- HCS would be used to analyze the operations of the freeway.
- Synchro would be used to analyze the signalized intersections of the arterial.
- Synchro could be used to develop optimized traffic signal timings for VISSIM.
- VISSIM would be used to analyze the intersections, arterials, interchanges, and freeway operations to simulate interactions in one model.

Synchro and SIDRA

This could occur when a project encompasses an arterial that includes a roundabout and one or more signalized or unsignalized (non-roundabout) intersections. In this scenario:

- Microsimulation would NOT be needed.
- Synchro would be used to analyze the signalized and unsignalized (non-roundabout) intersections of the arterial.
- SIDRA would be used to analyze the operations of the roundabout.

SIDRA and VISSIM This could occur for the analysis of a roundabout with oversaturated traffic conditions or with impacts to adjacent intersections. In this scenario:

- Microsimulation would be needed.
- SIDRA would be used, initially, to analyze the operations of the roundabout.
- VISSIM would be used to analyze the roundabout (and adjacent intersections). This could include microsimulation results and animation.

905.3.2.5 Scope the Project

It is important for the project manager, modeler, reviewer, and other involved personnel to develop an effective plan for conducting the necessary analysis. All parties also must agree on assumptions to be made to complete the analysis. The TIA Methods and Assumptions Report will ensure that expectations are set before any analysis is performed and it sets the stage for effective communication throughout the process. The intent is for this report to be updated as methodologies and assumptions change during the project. This report can then be referenced and appended to later project reports.

The intent of EPG 905.3.2.5 Scope the Project is to inform the TIA Methods and Assumptions Report template, which includes section numbers that correspond to the step numbers below.

1. **Stakeholder Acceptance:** Identify and coordinate with the appropriate stakeholders. The *TIA Methods & Assumptions Report* provides a section to enter key stakeholders that include "MoDOT Representative," "FHWA Representative," and "County/Municipal Representative." Additional stakeholders can be documented as needed.
2. **Understand Project Background Information.** ("Introduction" section in *TIA Methods & Assumptions Report*): Identify the project's need for study, previous studies completed, the study's schedule, and key project stakeholders.
3. **Definition of the Study Area:** Determine the study area based on the logical geographic termini, the project purpose and need, and the expected limits of potential impacts. It is especially important to ensure that the analysis study area is extensive enough in its geographic reach to reasonably estimate transportation and land development impacts. This may differ for the traffic analysis and the safety analysis.
4. **Analysis Years/Periods:** Information is provided below on time of day analysis and on typical analysis years. Sometimes this step is best completed iteratively with Step 6 (traffic forecasting) to determine appropriate horizon years based on forecasting assumptions and constraints (refer to Step 6). This may differ for the traffic analysis and the safety analysis.

    a. **Time of Day Analysis:** Typically, only AADT forecasts are needed for planning level studies. Project-level operational analysis will typically include AM and PM peak period forecasts. Safety studies may perform time of day analysis at specific locations, such as schools, which see disproportionate volumes during peak hours. Determine if a peak period of one hour is sufficient, or if a longer period is needed to capture the buildup and dissipation of congestion.

    b. **Specify Analysis Years:** The appropriate years to analyze for a project vary based on how the project will be used. A 20-year horizon after the opening year of the project, at minimum, is typically used to forecast future travel demand on the network. The planning horizon could be shorter for design projects.

    Table 905.3.2.5 provides basic information about typical analysis years studied. All of the analysis years listed should be included in the project analysis, unless otherwise justified and discussed with the appropriate MoDOT representatives. For all projects, it is important that the "Existing Base Year" be included due to its importance for model calibration to existing year traffic conditions.

Table 905.3.2.5, Analysis Years

Year	Description
Existing Base Year	A base year that is typically as close as possible to the current year.
Assumed Interim/Opening Year	Expected future year that the project will open; in the case of phased projects this might be a sequence of intermediate analysis years.
Horizon/ Design Year	A future analysis year that is at least 20 years into the future after the opening year of the project.
Horizon Years for Safety Projects	Use the life cycle length of the longest countermeasure for the horizon year. Consider setting a maximum safety horizon year of 20 years after the opening year of the project and documenting special circumstances if setting a horizon year longer than 20 years out is necessary.

5. **Design Alternatives:** Determine all appropriate design alternatives that the study will consider. This step will require collaboration with stakeholders. Sometimes this step is best completed iteratively with Step 6 (traffic forecasting) to determine appropriate alternatives based on future travel demand. The design alternatives may not be known during the initial scoping of the project but will be determined during the study.

6. **Traffic Forecast:** A traffic forecast should be completed to understand current and future travel demand on study area facilities. This involves determining the appropriate forecast scenarios and assessing the characteristics that are influencing travel demand.

a. **Determine Appropriate Forecast Scenarios:**

i. Determine if additional transportation projects (other than the subject project) should be included in the forecast. A common situation includes projects that are assumed to be completed in a forecast Future Year as the result of a Metropolitan Planning Organization's (MPO's) Metropolitan Transportation Plan (usually fiscally constrained or committed, but not illustrative projects).

ii. Verify if multiple changes to land use characteristics and/or socioeconomic data (e.g., households, population, employment) should be forecasted.

iii. Determine the different transportation project geometric alternatives that should be forecasted (e.g., multiple bypass scenarios that could potentially bypass a town going to either the east or west).

b. **Assess Travel Demand Characteristics:** Complete an early assessment of the current and anticipated travel demand in the study area. Examples of items to document include:

i. The nature of demand in the corridor in terms of trucks versus passenger cars, through versus local trips, or non-discretionary trips (such as commute to work) versus discretionary trips (such as shopping trips).

ii. Unique major generators in the corridor.

iii. What magnitude of growth in travel demand is anticipated?

iv. The extent of need for the project based on today's travel conditions versus anticipation of growth.

7. **Traffic Operations Analysis:** Determine and document the appropriate traffic operations analysis software program(s) and software version for use in the study. This decision should be made in coordination with stakeholders. Refer to EPG 905.3.2.1 Overview of Traffic and Safety Analysis Tools through EPG 905.3.2.4 Analysis Tool Selection for detailed information to help inform the decision-making process for selecting a tool.
8. **Safety Analysis**: Determine and document the appropriate safety analysis software program(s) and software version for use in the study. This decision should be made in coordination with stakeholders. Refer to EPG 905.3.2.1 Overview of Traffic and Safety Analysis Tools through EPG 905.3.2.4 Analysis Tool Selection and EPG 905.3.6 Safety Analysis for detailed information to help inform the decision-making process for selecting a tool.
9. **Conclusion:** Document a brief summary of the study's intent and methodology.
10. **Record of Revision:** If applicable, document the revision number, date of revision, and content that has been revised.

905.3.3 Data Collection

905.3.3.1 Overview

Federal Highway Administration's (FHWA) *Traffic Monitoring Guide* (2016) describes federal guidelines for establishing and maintaining traffic monitoring programs and guidance for traffic monitoring methodologies. The guide especially focuses on maintaining a continuous data program, a short duration data program, calculations and computations to apply to raw data, and quality assurance processes.

In addition to federal guidelines, state-level departments of transportation (DOTs) usually have monitoring systems responsible for programming, collecting, analyzing and reporting traffic volume and vehicle classification data on Interstates and highways in their jurisdiction. MoDOT maintains an online interactive AADT map that is updated annually. This map breaks down traffic by both generalized vehicle classifications and directional, hourly volume breakdowns. **Disclaimer:** MoDOT's interactive AADT map shows volumes at some locations that are associated with actual count data and some data that are estimated volumes (not based on count data). If the analyst has any data concerns, then please contact the MoDOT TMS unit.

For transportation projects, it is important to work with MoDOT to determine how to best analyze existing traffic count data provided by MoDOT or other local sources and if additional project-specific short duration counts will be needed to meet project needs. EPG 905.3.3 Data Collection will answer these guiding questions about traffic data collection:

1. Why Collect Count Data – Understand the needs of the project

2. When Gather Count Data – Determine if or when to collect data

3. What Count Data to Collect – Assess what type of data is needed.

905.3.3.2 Understand the Needs of the Project (The "Why")

To determine what traffic count data is needed, it is important to think about the background of a transportation project's goals. The NCHRP 765 states that "analysts should be cognizant of the context in which the information they produce will be used and come to an understanding about the MOEs to be published and presented at the outset of a study."

Developing an understanding of the data collection needs for a project takes place during project scoping. The MOEs to be used during the study should help inform the data collection needs. See EPG 905.3.2.3 Determine the Project's Analytical Context for guidance about the determination of MOEs.

General questions to consider when determining data needs are:

- Do we need intersection turning movement count data?
- Will only particular peak hour data be required, or will a 24-hour estimation of a typical weekday's travel be needed?
- What additional data will be necessary to address project-specific MOEs (such as queue lengths, vehicle speeds, travel time, etc.)?

905.3.3.3 Determine If or When to Best Collect Data (The "When")

Is New Traffic Data Needed?

Age limits for the relevancy of traffic counts are context sensitive to the regional characteristics (urban, rural, or suburban) and recent growth patterns of an area (i.e., has there been recent developments that would influence traffic volumes?). MoDOT recommends that new traffic count data should be collected if the most recent, available data is more than three years old.

As noted in EPG 905.3.3.1 Overview, MoDOT maintains an online interactive AADT map that is updated annually and includes both generalized vehicle classifications and directional, hourly volume breakdowns. MoDOT's official AADT data should be the first data source to refer to when determining data needs. However, always be cognizant if turning movement counts or other data breakdowns (e.g., 15-minute volume bins, vehicle speeds, etc.) will be needed in addition to existing AADT data. (EPG 905.3.3.4 Assess What Type of Data is Needed (The "What") elaborates on this.)

Regardless of the precise age of the pre-existing count data, it is important to determine what the unique data needs are for a transportation project. General questions to help determine if new count data is needed are:

- Is there pre-existing count data that has been collected within the past three years that is reflective of present-day traffic patterns for the area?

- Have there been recent changes to the general area’s transportation network?

- Have there been recent land use changes or new developments completed in the area?

Please refer to EPG 905.3.3.5 Data Collection Plan and Checklist for guidance about documenting assumptions.

When to Collect Data

For most traffic studies, it is important for traffic counts to reflect normal weekday and/or peak hour traffic conditions (unless performing special studies). Certain conditions may not yield the best or most accurate data. FHWA's *Traffic Monitoring Guide* advises that traffic counts should not be collected on Fridays, for example, since they tend to have lower morning volumes and slightly higher afternoon volumes than other weekdays. The guide also states that traffic volumes on Mondays can be fairly similar to typical weekdays, but if you are to complete traffic counts on a Monday, be sensitive to the location (i.e., Monday counts in areas influenced by rural, recreational areas can experience patterns similar to a Friday). As a result, it is recommended to avoid collecting traffic count data on Mondays and Fridays altogether and only collect data from Tuesday to Thursday. Exceptions would include unique studies where special event and/or recreational trips are a concern, though even then, it is advised to provide the special event/recreational data as a supplement to typical (Tuesday – Thursday) weekday traffic data.

Determining when not to collect data can provide more accurate information. MoDOT recommends the following traffic count rules for when NOT to collect data:

- Sundays, Mondays, Fridays and Saturdays
- When public schools are not in session (generally, late May through early August, depending on the study area; the exact timeframe should be confirmed prior to collecting traffic data)
- During holiday periods when travel patterns are not routine (from a week before Thanksgiving to a week after New Year)
- Days when special events at major traffic generators may disrupt routine traffic patterns
- During special events that generate traffic that is not typical of everyday operations
- During or immediately following significant inclement weather events (e.g., blizzards, heavy rain, etc.)
- During federal and/or state issued advisories or restrictions (an example would be travel advisories issued for the COV-19 pandemic)
- During the week following a time change due to the start or end of Daylight-Savings Time
- During construction in or near the project area
- During traffic incidents (e.g., crashes) that disrupt normal traffic patterns
- During off-peak season when traffic is typically influenced to be lower than during a seasonal peak. For example, it may not be desirable to count roadways around the Lake of the Ozarks during winter, when demand is significantly less than during the summer.

905.3.3.4 Assess What Type of Data is Needed (The “What”)

The following guidelines are recommended for intersection turning movement counts, roadway segment counts, data needed for various software tools, and the determination of vehicle classifications that will be used for traffic and safety analysis. Other data may be needed for traffic and safety analysis, but the below count data has specific MoDOT requirements. Other data collected should follow standard industry practices.

Intersection Turning Movement Count Recommendations

• For a transportation project that includes multiple intersections, collaborate with all appropriate parties to determine what intersections need turning movement counts. Turning movement counts are typically needed if:

o The intersecting road carries at least 400 vehicles per day.

o The intersection has turning movement count data older than three years. Also, ensure that the recently collected count includes all appropriate data needed for the project.

• Provide generalized personal vehicle and heavy truck classifications (collecting heavy trucks in MoDOT standardized categories is preferred – refer to Vehicle Classifications)

• Collect the data in 15-minute intervals

• If trying to estimate peak hour traffic volumes only, then collect at least two-hours in each peak period. Existing segment hourly counts can be used to inform the timing for the two-hour counts, but typically 7:00 AM to 9:00 AM and 4:00 PM to 6:00 PM will include the peak hours.

• Strongly consider a minimum 12-hour turning movement count from 6 AM to 6 PM if trying to estimate 24-hour traffic volumes, if the traffic peak may occur during midday, and/or if a signal warrant analysis is anticipated

• Collect bi-directional data for all turning movements (covers both directions).

Roadway Segment Count Recommendations

• For a transportation project that includes roadway segments, review existing MoDOT AADT data to determine what recent data is available. Roadway segment counts are recommended if:

o It supplements the turning movement counts with project-specific roadway segment counts. These segment counts should be at strategically important locations to capture key traffic patterns and assess the influence of nearby traffic generators.

o There is a gap in recent, relevant historic AADT on the roadway. Typically, it is advised to use traffic data that is no older than three years old.

o The only available historic AADT on MoDOT's Interactive AADT map are volume estimates that are not based on actual count data (confirm with the MoDOT TMS unit if there are any concerns or questions about data source).

• Provide generalized personal vehicle and heavy truck classifications (collecting heavy trucks in MoDOT standardized categories is preferred – refer to Vehicle Classifications)

• Collect the data in one-hour intervals at a minimum (15 minutes preferred)

• Collect the data for a minimum contiguous 24- to 48-hour period, or one to two weeks if daily variation throughout the week is desired

• Collect bi-directional data (covers both directions).

Origin-Destination Data Collection Recommendations

Origin-destination (O-D) data is appropriate for some projects to be used for loading traffic demand data into a microsimulation model. O-D data is summarized in a matrix table that displays the number of trips (traffic demand) traveling from each origin (table row) to each destination (table column) in the study area.

Due to the additional cost constraints of collecting the data through typical O-D collection methods (e.g., Bluetooth wireless readers, aerial observation, and third-party probe data providers), it is recommended that the analyst discuss the appropriateness of O-D data collection with MoDOT before proceeding. O-D data is especially useful for complex corridors where traffic patterns affect operations such as closely spaced intersections and certain freeway weaving segments.

Typical Data Needs for Software Tools

For transportation projects that utilize software tool analysis, it is important to understand analysis-specific data needs and input parameters that can often vary based on different analysis tools. Table 905.3.3.4 provides information about the typical traffic and roadway input parameters needed to utilize each analysis tool.

Table 905.3.3.4, Typical Input Data for Different Analysis Types

Input Data Category		Traffic Analysis Tool				
		HCS	SIDRA	Synchro/SimTraffic	VISSIM	HSM
Traffic Operations and Control Characteristics	Speed	✔	✔	✔	✔	
	Speed Limit	✔	✔	✔	✔	✔
	Driver Behavior				✔	
	Parking	✔	✔	✔	✔	✔
	Signs		✔		✔	
	Signals (Timing and Phasing)	✔	✔	✔	✔	✔
	Detectors	✔		✔	✔	
	Intersection Control Type	✔	✔	✔	✔	✔
	Right/Left Turn Treatment	✔	✔	✔	✔	✔
	Railroad Crossing			✔	✔	✔
	Lane Restrictions				✔	
	Toll Facility				✔	

	Ramp Metering				✔	
Traffic Characteristics	Demand	✔	✔	✔	✔	✔
	Queue		✔	✔	✔	
	Capacity/Saturation Flow			✔	✔	
	Pedestrian Counts	✔	✔	✔	✔	✔
	Bicycle Counts	✔	✔		✔	✔
	Bus & Transit	✔		✔	✔	
	Fleet Characteristics	✔	✔	✔	✔	
	Occupancy				✔	
	Major Traffic Generators				✔	
Roadway Characteristics	Road Classification	✔	✔	✔	✔	✔
	Cross Section	✔	✔	✔	✔	✔
	Geometry	✔	✔	✔	✔	✔
	Roadside	✔			✔	✔
	Access Control	✔			✔	✔
	Access Density	✔			✔	✔
	Aerial Images	✔		✔	✔	

Note: “HSM” is used to represent all HSM-based tools because all the HSM-based tools use similar data inputs. Additionally, red check marks are used to distinguish safety tools (i.e., “HSM”) from operations analysis tools.

Vehicle Classifications

FHWA's *Traffic Monitoring Guide* classifies all vehicles into 13 distinctly different categories. Figure 905.3.3.4.1 is a FHWA graphic of these 13 different categories.

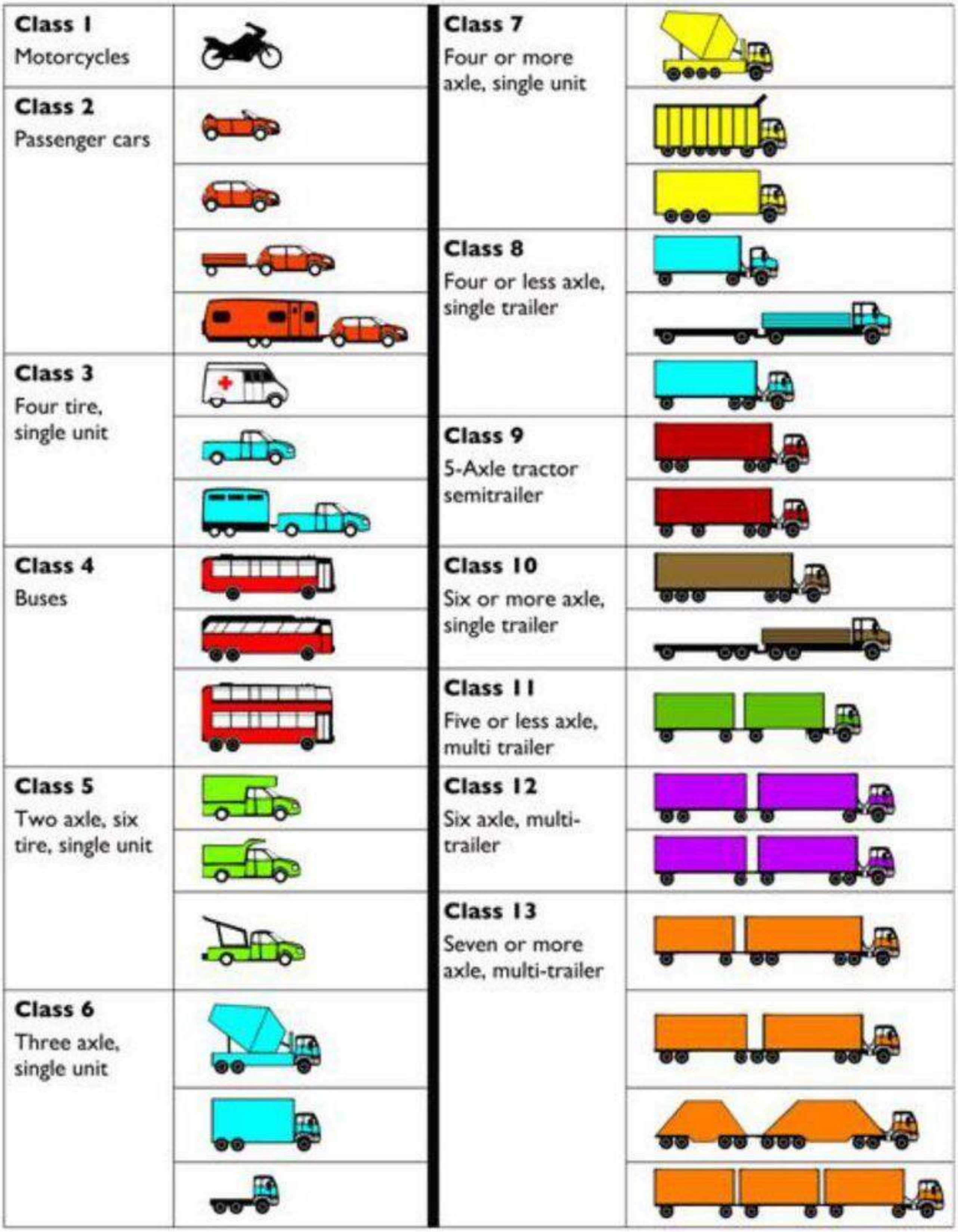


Figure 905.3.3.4.1, FHWA Vehicle Classifications

For the purposes of a traffic study, a heavy truck percentage provides the ratio of heavy trucks to overall vehicles on a roadway segment. MoDOT typically classifies vehicle proportions into the following six classifications for data collection purposes:

- Motorcycles (FHWA Class 1)
- Passenger Cars (FHWA Class 2)
- Panel Trucks (i.e., Two-Axle, Four-Tire Single Unit Vehicles) (FHWA Class 3)
- Buses (FHWA Class 4)
- Single Unit Trucks (FHWA Classes 5, 6, 7)
- Combination Semi-Trailers (FHWA Classes 8 – 13).

905.3.3.5 Data Collection Plan and Checklist

The data collection plan documents what, when, and how data will be collected. The checklist will ensure that project deliverables, check-in points, and other considerations (including traffic data needs) are effectively communicated and documented throughout the project development process.

905.3.4 Traffic Forecasting and Volume Development

905.3.4.1 Purpose

EPG 905.3.4 details methodology options and best practices for developing traffic volume estimates and forecasts to be used in the planning for, and development of, transportation projects. Accurate and timely traffic volume estimates are crucial for ensuring the success of transportation projects through each stage, including transportation impact analyses (TIAs).

The following guidance provides information on best practices as identified through a review of both federal and state level guideline documents. It is important to note that this traffic volume development and forecasting information are predominantly the product of recommended guidelines rather than strict policy requirements. The National Cooperative Highway Research Program (NCHRP) 765 Report, *Analytical Travel Forecasting Approaches for Project-Level Planning and Design* (2014), summarizes this distinction:

> *"Project-level traffic forecasting has an underlying codification at the federal, state/MPO, and industry guideline level. In most cases, traffic forecasting procedures are the product of recommended guidelines rather than strict policy requirements. Thus, there is tremendous variation in practitioner procedures.*
> *"At the federal level, traffic forecasting is required for air quality analysis, major investment projects and highway design projects undertaken by the federal government (Special Report 288, FHWA [22]). Traffic forecasting is also an integral part of several*

standard transportation processes, such as highway design—see the AASHTO Policy on Geometric Design (121), and the Highway Capacity Manual (21).

Underlying federal codification for traffic forecasts includes 23 USC 109, 23 CFR 625 which states that plans and specifications for National Highway System (NHS) projects shall provide for a facility that will "adequately serve the existing and planned future traffic of the highway in a manner that is conducive to safety, durability and economy of maintenance."

905.3.4.2 Background

Traffic volumes describe the number of vehicles at a point on a roadway and are the most basic, readily understood output of the traffic forecasting and analysis processes. Traffic volume-based measures deal with the quantity of use of transportation facilities. The quantity can either be calculated at a specific point on a transportation network or between origins and destinations. Demand is associated with a specific time frame anywhere from 15 minutes to a 365-day annual period.

The NCHRP 765 Report provides the following summary for traffic volumes:

Volumes can describe how the distribution and magnitude of demand change across different supply/demand scenarios. Volumes can describe throughput—a measure of the quantity of transportation activity that can be accommodated at a single point or multiple points on a transportation network. Volumes are also a critical input to assessments of congestion and economic and environmental impact."

Traffic forecasts are produced to assess transportation performance under different assumptions about transportation supply and demand. A traffic forecast uses existing traffic volume counts, historic traffic volume trends, travel demand model projections (if available), land use plans and socioeconomic data to predict traffic volumes and traffic flow patterns for a given year in the future. A traffic forecast is typically developed for a specific transportation project and is used for subsequent capacity analysis, geometric design and pavement design.

905.3.4.3 Daily Traffic Volume Refinement

After raw short-term traffic count data is collected, it should be processed by factoring it into Average Annual Daily Traffic (AADT) using factors that can be requested from MoDOT Planning. This process is accomplished using the following steps:

1. Axle Correction Factor (ACF): If the count method includes vehicle axle data (i.e., tube counts), then an ACF should be used to adjust the axle counts into vehicle counts. An ACF is developed from classification counts by dividing the total number of vehicles by the total number of axles.
2. Partial Weekday Traffic Count Adjustment: If partial weekday data was collected, then an adjustment factor is used to convert partial weekday traffic count data to 24-hour weekday daily traffic volume estimates, also known as Average Daily Traffic (ADT).

The adjustment factor is representative of the percentage of 24-hour traffic volumes that typically occur on a weekday during the time range specified (e.g., 6 AM – 6 PM for a 12-hour traffic count). The adjustment factor usually varies by the type of roadway facility (e.g., interstate, US route, state highway, etc.).

3. Average annual daily traffic (AADT): The ADT value is converted to AADT, which represents the average traffic volume throughout the year considering typical traffic conditions. A true AADT is developed by utilizing a full year of traffic count data, such as data generated from a permanent traffic counter. However, AADT can also be estimated with short-term traffic counts (usually a 24- to 48-hour period) using the following formula:

$$AADT = ADT \times \text{Seasonal Adjustment Factor}$$

905.3.4.4 Design Hour Traffic Volume Refinement

For most traffic analyses, AM and PM peak period (one or more hours) traffic volumes will be needed. Often design hour volumes are also needed, especially for design studies. The key phrases below are important to estimate the design hour characteristics of a location:

- **Design Hour:** An hour with a traffic volume used for designing the geometric and control elements of a facility. The design hour selected will allow the designed facility to accommodate peak hour traffic during most days. The Highway Performance Monitoring System considers the hour corresponding to the 30th highest hourly volume of the year as the design hour. In the absence of continuous counters to determine the 30th highest hourly volume of the year, local jurisdictions and/or Metropolitan Planning Organizations (MPOs) can adjust their design hour based on local facility-specific traffic conditions (refer to Page 22 of the *FHWA Traffic Data Computation Method Pocket Guide*).
- **Design hourly volume (DHV):** The volume of vehicles that travel through a segment of roadway during the design hour. The DHV is used for making roadway structural and capacity design decisions in the design year because traffic volume varies by hour and from day to day throughout the year. The formula for calculating the DHV using a design hour factor (K) is:

$$DHV = K \times AADT$$

- **Design Hour Factor/K Factor:** The proportion of the AADT that occurs during the design hour. K-factors are typically estimated to be between 8% and 12%, with lower K-factors generally occurring on primary routes and higher K-values occurring on secondary routes. In the absence of available traffic data, a planning level estimate of K=10% is sometimes assumed (for high level, sketch planning ONLY). For further information about the typical weekday and weekend hourly distribution of traffic volumes, refer to Figures 1.1 through 1.5 of FHWA's *Measures for Congestion, Reliability, and Freight Step-by-Step Metric Calculation Procedures* (Published June 2018).

$$K = DHV/AADT$$

- **Peak Hour Directional Split (D Factor):** The percentage of the total two-way peak hour traffic that occurs in the dominantly traveled direction.

905.3.4.5 Traffic Volume Balancing

Raw traffic volumes along a corridor will have inconsistencies when initially tabulated. These differences in Base Year traffic volumes are frequently the result of the presence of other intersecting roadways along a corridor or traffic data collection method variations (e.g., data collected on different days, counter error, unexpected traffic incidents, etc.). Future Year traffic volumes will frequently have inconsistencies due to varying growth rates applied along the corridor.

It is generally beneficial for a traffic forecast to "balance" the traffic volumes, which refers to the process of eliminating the traffic volume difference between multiple points completely. The NCHRP 765 states that "balancing helps to 'clean' traffic volume data by tempering the effects of outliers and counting errors."

For certain forecasts or project locations, balancing might not affect the overall quality of the traffic forecast. However, balancing is needed for microsimulation models or for any analysis type where the difference between the traffic volumes of two given points does not match their predicted traffic volumes for intersection roadways or driveways. Also, it is important to balance traffic volumes when an Origin-Destination (O-D) trip table matrix will be used for subsequent capacity analysis. Balanced traffic volumes will result in a faster convergence when the O-D matrix estimation is applied because the matrix estimation algorithms tend to fluctuate when attempting to match conflicting goals.

The following methods are available to balance traffic forecast volumes are summarized in Table 905.3.4.5. Engineering judgement is recommended to determine which method is appropriate based on traffic volume data available.

Table 905.3.4.5, Typical Traffic Volume Balancing

Method	Description	Pros	Cons
Split the Difference	Add half of the total link imbalance to the lower volume intersection and subtract the remainder of the total link imbalance to the higher volume intersection.	Realistic results	Time consuming, especially if multiple intersections are completed
Higher Volume Distributed	Use the higher volume from one intersection to override the lower volume of the adjacent intersection and then distribute the volume difference based on the existing turning movement count distributions.	Realistic results	Time consuming
Higher Volume Through	Use the highest volume and carry it through the other locations adding the	Ease of calculations	Conservatively high through volumes relative to turning

	excess traffic only to the through movements.		movement volumes at lower volume intersections.
Spreadsheet Link Volume Forcing	Use the link volume forcing option of the NCHRP 255 spreadsheet to automatically balance/smooth volumes. This method should be used with caution and does not always produce the desired outcome if convergence cannot be reached.	Automated calculations	May not produce all desired results
Combination	A combination of all or some of the other methods. For example, the NCHRP Override process may be used first to get the volumes closer to being balanced, and then a combination of the Higher Volume Distributed method at the internal intersections and the Higher Volume Through at the network termini could be used.	Realistic results	Time consuming

General Balancing Rules of Thumb:

General "rules of thumb" to help the analyst make sound decisions for balancing traffic volume data include:

- **Understand data deficiencies:** Understand the locations of where data collected is more likely accurate, defensible, and verifiable by multiple sources. Rely on those data sources to carry forward traffic volumes during balancing.
- **Balance the project's needs between realistic results and efficient calculations:** If a high-level analysis is being completed and it is acceptable to maintain conservatively high volumes in certain locations, then perhaps the analyst could consider using the "higher volume through" method. That method in high-level planning would not be time consuming relative to the analysis needs at that stage. If the analysis level is preliminary engineering and greater detail is needed, then perhaps a combination of various methods is needed where the analyst can start with one method and iteratively adjust when comparing to other methods.
- **Determine level of error and if new data is needed:** If the volumes being balanced are 10% or more off, then the analyst should revisit the data and determine if errors have been made in the data processing or the traffic forecast. If the data is inaccurate, then consider collecting additional data.

905.3.4.6 Traffic Forecast Types and Tools

There are two general types of traffic forecasts: planning-level forecasts and project-level forecasts.

1. **Planning-level forecasts** typically do not require current traffic data to be collected. If traffic data is collected, it is usually limited to just roadway segment data with no turning movement counts required. Planning-level forecasts are either completed (1) during long range transportation planning for any given project or regional analysis (at least 20-year horizon required by FHWA for MPO planning), or (2) during the project planning and programming for a "preservation" project. A "preservation" project includes roadway resurfacing, reconditioning, pavement replacement, roadway maintenance or bridge rehabilitation/replacement. Regional travel demand models and historic AADT growth rates are typically used for planning-level forecasts.
2. **Project-level forecasts** require both turning movement count and roadway segment traffic data to be collected. Project-level forecasts are completed during the project planning and programming for widening, new location, bridge replacement (if capacity changes are made) and new roadway capacity or new development-based projects. Regional travel demand models, historic AADT growth rates, turning movement analyses and new development trip generation analyses (as needed) are typically used for project-level forecasts.

Traffic Forecasting Tool(s): In coordination with understanding the applicable forecast type, it is important to understand the most appropriate tool to use for a traffic forecast, given factors such as the transportation project needs, size and complexity of the project, and resources available. The NCHRP 765 lists the most common forecasting tools as summarized in Table 905.3.4.6.

Table 905.3.4.6, Common Traffic Forecasting Tools

<table>
<tr><th>Tool</th><th>Description</th><th>When to Apply</th><th>Potential Shortcomings</th></tr>
<tr><td>Growth Rate</td><td>Focuses on extending the observed traffic growth patterns at a given location to a future year.</td><td rowspan="3">• No travel demand model is available
• Historic growth in the study area is stable and expected to remain that way in the future
• Project is small in size and complexity
• Resources and/or time in schedule is unavailable to more in-depth analyses</td><td rowspan="3">These methods do not naturally focus the constraining factor of a roadway's capacity.</td></tr>
<tr><td>Trend Line Analysis</td><td>Review and analyze existing, historic AADT data to calculate trend line growth rates for medium-term and long-term timeframes (often 10 to 20 years in the past). Outlier data points will be eliminated from the analysis as appropriate.</td></tr>
<tr><td>Time-Series Analysis</td><td>Estimates traffic volumes as a function of time and, perhaps, a small set of explanatory variables.</td></tr>
<tr><td>Turning Movement Analysis</td><td>The process of analyzing, refining, and balancing turning movement</td><td>• Daily intersection turning movement counts</td><td>Does not focus on estimating base year to future year growth.</td></tr>
</table>

	count data for intersections studied as part of a traffic forecast.	• Design hour intersection turning movements volumes and factors	Is typically done in conjunction with other tools.
Travel Demand Model	A series of mathematical equations that represent how choices are made when people travel. A travel demand model combines a network (supply) with population and employment by location (demand for travel). A travel demand model can encompass roadway networks and population/employment for an entire metropolitan region.	• Travel demand model is available for the region studied • Growth in the study area is anticipated to change at varying rates relative to historic growth • Resources and project schedule is available for model utilization	Is not always appropriate for projects of small size and complexity (e.g., small road bridge replacement or site development with no roadway network forecast needed)
Traffic Simulation Model	Traffic simulation models are designed to emulate the behavior of traffic in a transportation network over time and space to predict system performance	When the quantification of peak hour volumes, capacity, Level of Service, travel times, or other measures of effectiveness (MOEs) are needed in addition to daily forecasted volumes.	Is not a standalone forecasting tool – is typically applied for an in-depth capacity analysis after forecasted traffic volumes have been determined.

Utilizing a travel demand model is the preferred tool for developing a traffic forecast if a travel demand model is available for a study area. It is important to confirm with the MPO or appropriate local entity that the regional travel demand model has been approved by the region before utilization of the model. Regions such as St. Louis and Kansas City are usually robust in consistently approving model updates, but always verify from the appropriate sources before using.

Growth rates, trend line analyses, and time-series analyses are all similar and have some overlap. The differences are that the emphasis points for each tool are “constant growth rate over time” (growth rate tool), historic traffic volume data regression lines (trend line analysis), and extrapolating trends over a period of time that can be either constant or variable in growth (time-series analysis).

Turning movement analyses are typically completed in conjunction with other tools and traffic simulation models are often completed for traffic capacity analyses, which are developed subsequently after traffic forecasts.

905.3.4.7 Forecast Application

The development of a traffic forecast includes the following steps:

1. Collect and Review Data
    a. Collect data from the existing available data sources, including but not limited to:
        i. AADT for the past 10 to 20 years
        ii. Other pre-existing traffic count data
        iii. Previous traffic forecasts for the project and other relevant forecasts in the general area
        iv. Information from available plans, including local land use plans, relevant demographic data and regional transportation plans
        v. Consultation with local planners, engineers and other appropriate parties regarding traffic patterns, pending development plans, land use plans and historic growth
        vi. On-site field investigation
    b. Develop historic AADT rates for long- and mid-term (approximately 20 and 10 years, respectively) historic growth. Look for natural breaks in the data as well as data anomalies.
    c. Collect project-specific traffic count data as needed
    d. Convert raw project-specific daily count data to AADT estimates using seasonality and other factors
2. Develop Base Year No-Build (i.e., existing no build) volumes. The scenario may include intersection quadrant turning movements, design data (K & D factors, heavy truck percentages), and be balanced unless otherwise specified
3. Utilize Travel Demand Model (when available)
    a. Review the Model Validation – Compare the existing model traffic volumes to actual project AADT estimates
    b. Review the Transportation Network – Ensure accuracy of the model base year network relative to the actual transportation network. Also, check that all fiscally constrained MTP projects as identified by an MPO are included in the model's future year network
    c. Calculate model growth. Per NCHRP 765, there are two methods, which are displayed in Table 905.3.4.7. It is advised that a preferred method be selected by reviewing the results from both methods and evaluating them within the context of existing traffic volumes and turning movements.

Table 905.3.4.7, Model Growth Calculation Methods

Method	Description	Pros	Cons
Difference Method	Applies the difference between the base year turning movement count and the base year model assignment to the future year model	Results are not easily inflated by nearby land use changes.	Two items must both be accurate: 1. Model assignment (must be calibrated very closely to traffic count data)

	turning movement assignment. **Formula:** $FF_{di} = FA_i + (BC_i - BA_i)$ FF_{di} = future year forecast volume for turning movement i, FA_i = future year model assignment, BC_i = base year count, BA_i = base year model assignment		2. The relationship between the base year and future year model assignments must be reasonable
Ratio Method	Utilizes a traffic growth factor by dividing the future year model volume by the base year model volume. **Formula:** $FF_{ri} = BC_i * (FA_i/BA_i)$ FF_{ri} = future year forecast volume for turning movement i, BC_i = base year count, FA_i = future year model assignment, BA_i = base year model assignment	Unlike the difference method, the ratio method can work if model volumes assigned do not calibrate accurately with count data (within reason). The ratio method is primarily focused on the relationship between the base year and future year model assignments. (The NCHRP 765 states that the ratio method is better than the difference method because it is less susceptible to inaccurate model assignment, especially over a long time horizon.)	Drastic changes in model assignment from base year to future year (from land use changes, for instance) or low model volumes could produce unreasonable growth.
Note: NCHRP 255 discussed averaging the results from the ratio and difference methods as a means to reduce the extremes that may be reached by either the ratio or difference method. However, NCHRP 765 supplants NCHRP 255 and advises that the average method not be used because averaging will reduce the accuracy of one method or the other.			

4. Develop Future Year No-Build Forecast – Apply both model and historic AADT growth to Base Year No-Build traffic volumes to estimate Future Year No-Build traffic volumes. Review and adjust traffic volumes based on knowledge of future land use, professional judgement and to maintain reasonable corridor traffic volume balancing.
5. Develop Base Year and Future Year Build Forecasts – Utilize the travel demand model (when available) to determine diversion and/or growth on the transportation network in the study area. Apply the diversion to the No-Build scenarios or the growth to the base scenarios to estimate Build scenario volumes. Review and adjust traffic volumes based on knowledge of network changes, professional judgement and to maintain reasonable corridor traffic volume balancing.

6. Coordinate and provide a review period with all appropriate parties during forecast development to ensure that reasonable forecast assumptions are made. Refer to the MoDOT TIA Guidance Methods and Assumptions template.
7. Document the forecast using a combination of figure diagrams and a report to explain all assumptions made. Refer to the MoDOT Methods and Assumptions Report Checklist and the Data Collection Plan and Checklist.

905.3.4.8 Forecast for a TIA

TIAs are engineering studies that compare before and after traffic conditions on road networks due to proposed land use changes. EPG 905.3.4.8 Forecast for a TIA focuses on project-level forecasts that are primarily developed to support the creation of TIAs. The forecasting scoping and application steps of a TIA forecast will be similar to the steps listed above. However, additional focus should be provided to identify potential development traffic to add to the forecast. Figure 905.3.4.8.1 guides the user if a development should be added to the forecast.

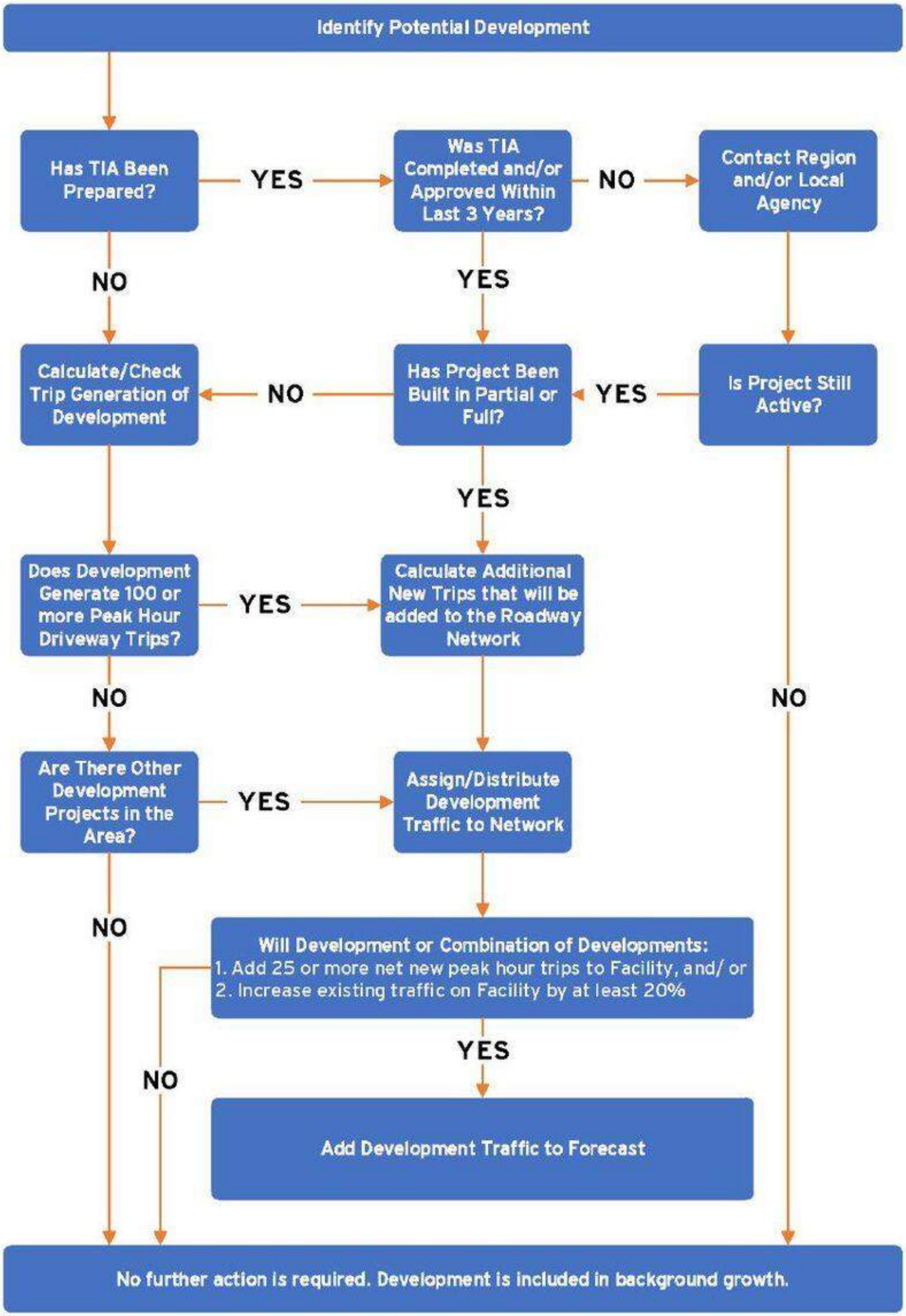


Figure 905.3.4.8.1, Identifying Potential Developments for Forecast

To determine the impact that proposed development(s) will have on future traffic conditions, it is important to identify how development trips will be generated, distributed, and assigned on the roadway network. The following five steps are used to make this determination:

1. **Assess Trip Generation Potential:** The most commonly accepted source for trip generation data on land use development is the Institute of Transportation Engineers (ITE) *Trip Generation Manual*. The ITE *Trip Generation Manual* includes trip generation characteristics of a wide variety of land use types. Land use types include port and terminal, industrial, residential, lodging, recreational, institutional, medical, office, retail, and services. Trip generation characteristics for these land use types were determined based on studies completed between the years 1980 and 2017.
Once the land use category is selected in the ITE *Trip Generation Manual*, an "independent variable" that the study is based off is selected. Independent variables usually include items such as square feet of development, number of employees, acres of land parcel(s), number of dwelling units, etc. The time period is then selected, which often includes the AM peak, the PM peak hour, weekday totals, and sometimes, weekend days. Also, some land use types can allow you to select a "setting/location" type, but often times it will be default to only one option, such as "General Urban/Suburban" for single-family detached housing.
The ITE *Trip Generation Manual* provides a web-based app (Figure 905.3.4.8.2 provides example of interface) to determine these study settings and to input the quantity of the project-specific independent variable to calculate an estimated, raw number of trips generated. The number of trips will be calculated using either a fitted curve equation or an average trip rate. In order to determine which method of trip generation calculation is relevant for the project, the reasonableness of the study's data sample attributes (e.g., R^2, standard deviation, and sample size) must be reviewed.

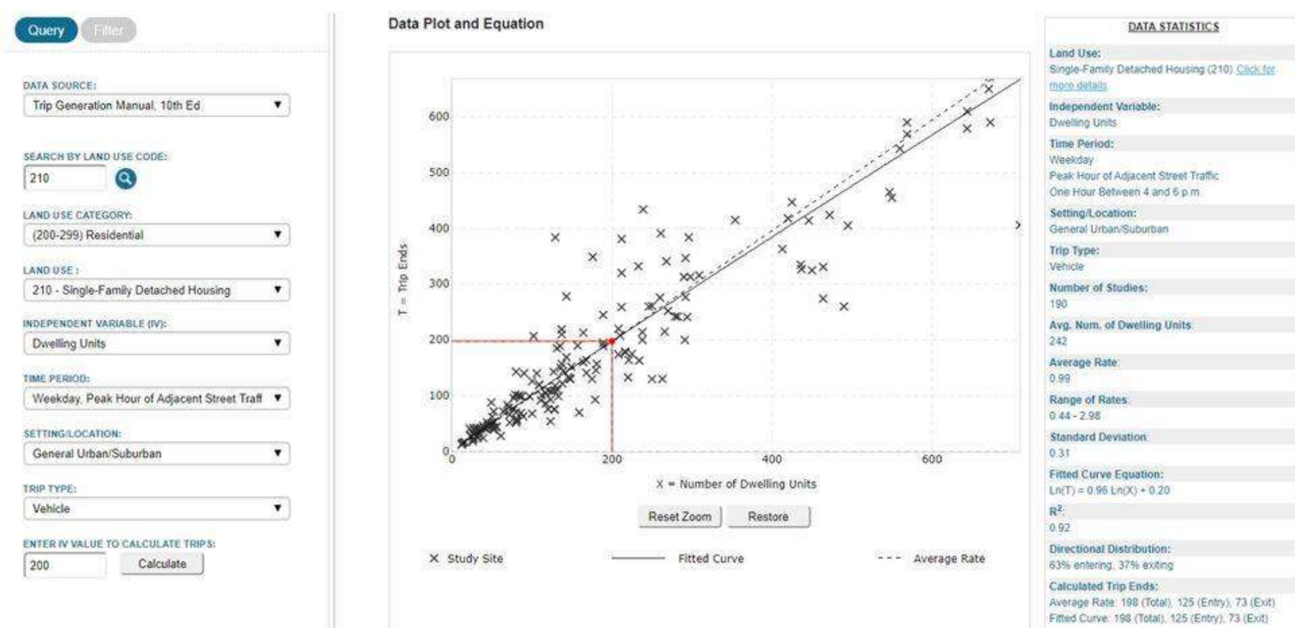


Figure 905.3.4.8.2, Layout of ITE *Trip Generation*, Web-Based App

Figure 905.3.4.8.3 displays a decision-making flow chart from the ITE *Trip Generation Handbook*, 3rd Edition, to help determine what trip generation method to use.

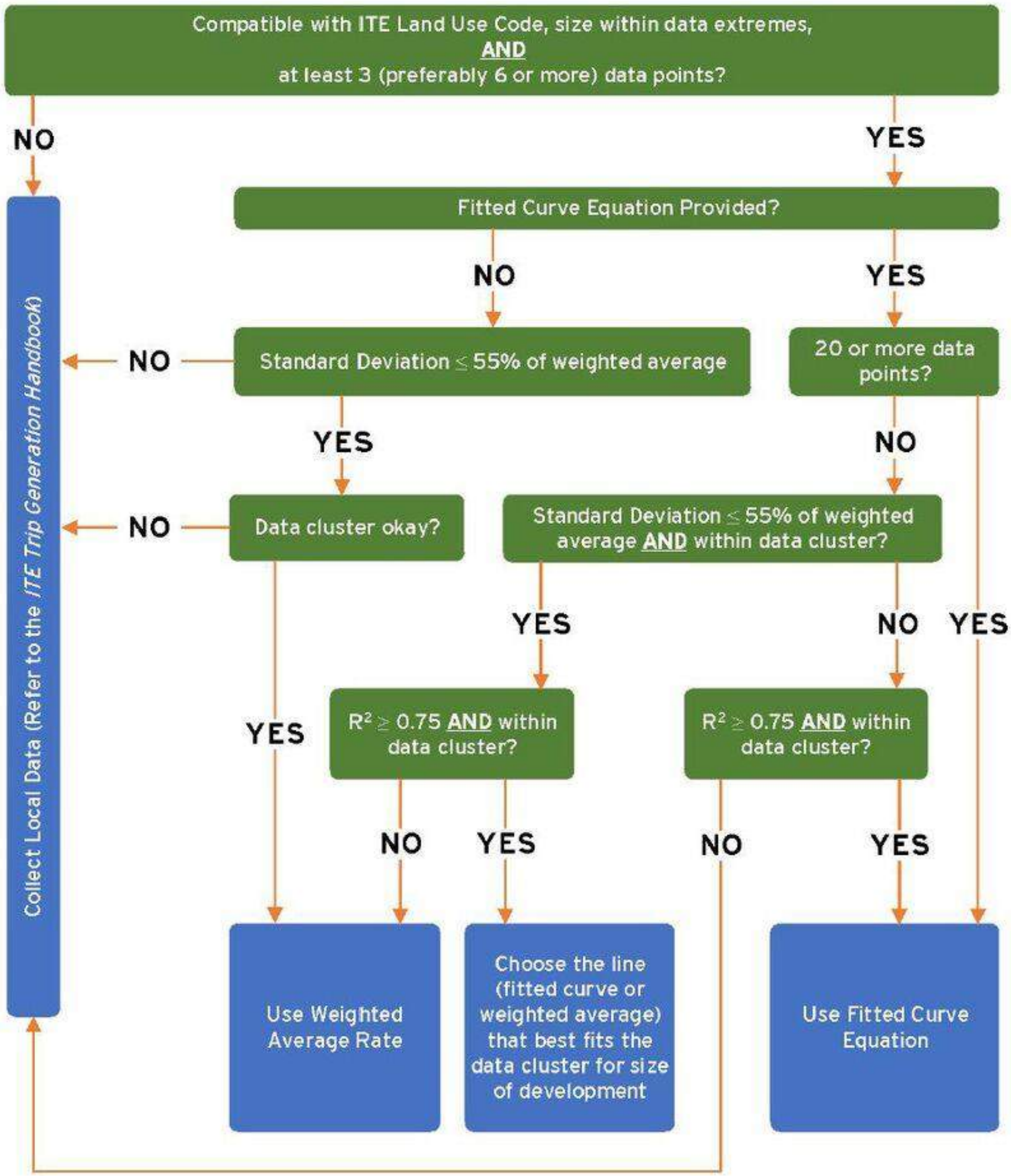


Figure 905.3.4.8.3, Selecting Appropriate Method to Estimate Trips Generated
Source: Figure 4.2 of ITE *Trip Generation Handbook*, 3rd Edition

2. **Mode Split:** The selection of trip mode choices should be informed by the availability of nearby transit and bicycle/pedestrian infrastructure, a review of available multi-modal count data, and coordination with local planning and engineering partners. Mode choice assumptions should be well documented in the final TIA.
3. **Estimate the Generated Trip Types:** The type of trips generated should be considered as part of the trip generation process. The total trips generated are determined and then the internal trips, pass-by trips and diverted link trips are subtracted to calculate new trips.

a. **New Trips:** New trips are "primary trips" that are made for the specific purpose of visiting the development. This trip type usually travels from an origin outside of the development to the development and then returns back to the origin.

b. **Internal Trips:** An internal trip is a trip that both originates and ends within the development. Internal trips rates will vary depending on the proposed land use type, size, and the context of the surrounding area. For instance, a mixed-use development in an urban area would likely have a higher internal trip rate than a typical commercial development in a rural area.

It is important to use internal capture calculations very cautiously. Internal Capture is often applicable to sites or subdivisions of sites that are accessible without using or crossing public streets. Internal Capture rates may be estimated using an automated worksheet tool in the NCHRP 684.

When using this spreadsheet, it is advised:

• That transit or non-motorized splits should not be used unless otherwise justified and approved.

• That vehicle occupancy should be "1.1" unless local data is available.

• The Walking Distances between land uses should be 1000 ft. or the calculated maximum distance between a given pair of land use categories in the proposed site.
The internal capture reduction should be applied before the pass-by trips are calculated.

c. **Pass-By Trips:** trips that are made as intermediate trips on the way from an origin to a primary trip destination and do not require a route diversion from another roadway. Pass-by trips are new at the site driveway but are not new on the adjacent roadway.

It is recommended that pass-by trip percentages should only be applied to land uses numbered in the 800s (retail) and 900s (services). For multi-use developments, pass-by percentages should be applied to the retail component only. Total pass-by trips (sum of entering and exiting) should not exceed 10% of the volume on the adjacent street.

d. **Diverted Link Trips:** Diverted link trips are the number of trips attracted from the existing traffic and require a route diversion from one roadway to another to reach the development. It is advised that:

• Diverted link trips should only be estimated in a TIA if reliable data reporting the percentage distribution of the three types of trips (primary, pass-by, and diverted link trips) are available for the land use being considered, and

• The travel routes for diverted trips can be clearly established.

If these conditions cannot be met, the analyst should treat all non-pass-by trips as primary trips.
4. **Trip Distribution:** Typically, site-related traffic is distributed onto the transportation network by using existing traffic flow patterns. Other distribution methods that revolve

around the gravity model or socioeconomic data may be considered, but typically those methods are completed to supplement the Existing Traffic Pattern method. The Gravity Model and Socioeconomic Data methods focus on travel patterns from a regional and sub-regional perspective and are too coarse to exclusively be used for site development trips without accompanying traffic patterns based on count data. These methods are summarized below, including a Table 905.3.4.8.4 comparison.

Table 905.3.4.8.4, Typical Trip Distribution Methods

<table>
<tr><th>Method</th><th>Description</th><th>Method Application</th><th>Required Data</th><th>When to Use</th></tr>
<tr><td>Existing Traffic Patterns</td><td>Derives trip distribution percentages based on existing data at sites that are comparable to the subject development.</td><td>The ITE Trip Generation Manual and the existing traffic counts, combined with local knowledge of traffic patterns and land use</td><td>• Traffic volume segment and turning movement count data that is representative of current traffic conditions.
• ITE Trip Generation Manual</td><td>Use for most TIA projects</td></tr>
<tr><td>Gravity Model</td><td>Estimates trip distribution based on characteristics of the land-use patterns within the vicinity of the subject development.</td><td>The gravity model formula (is usually applied through a travel demand model, though it can be applied manually)</td><td rowspan="2">• Land use socioeconomic data that is segmented into geographic zones of homogeneous land use types.
• Regional travel demand models are frequently the tool that is utilized for these analysis methods.
• US Census data to verify local socioeconomic data used.</td><td rowspan="2">Use when it is important to support the Existing Traffic Pattern method with estimates of traffic pattern movements from a regional perspective</td></tr>
<tr><td>Socioeconomic Data</td><td>Uses population and employment data to estimate trip distribution for the study area.</td><td>Various application methods (e.g., population data as a surrogate for retail trips, market area analysis, etc.)</td></tr>
</table>

a. **Existing Traffic Patterns:** Existing traffic count data is analyzed to determine current daily and peak hour traffic patterns on major study area roads near the traffic site. The ITE *Trip Generation Manual* provides the estimated directional distribution of trips for AM and PM peak hours and overall daily traffic. Figure 905.3.4.8.5 shows the circled directional distribution percentages.

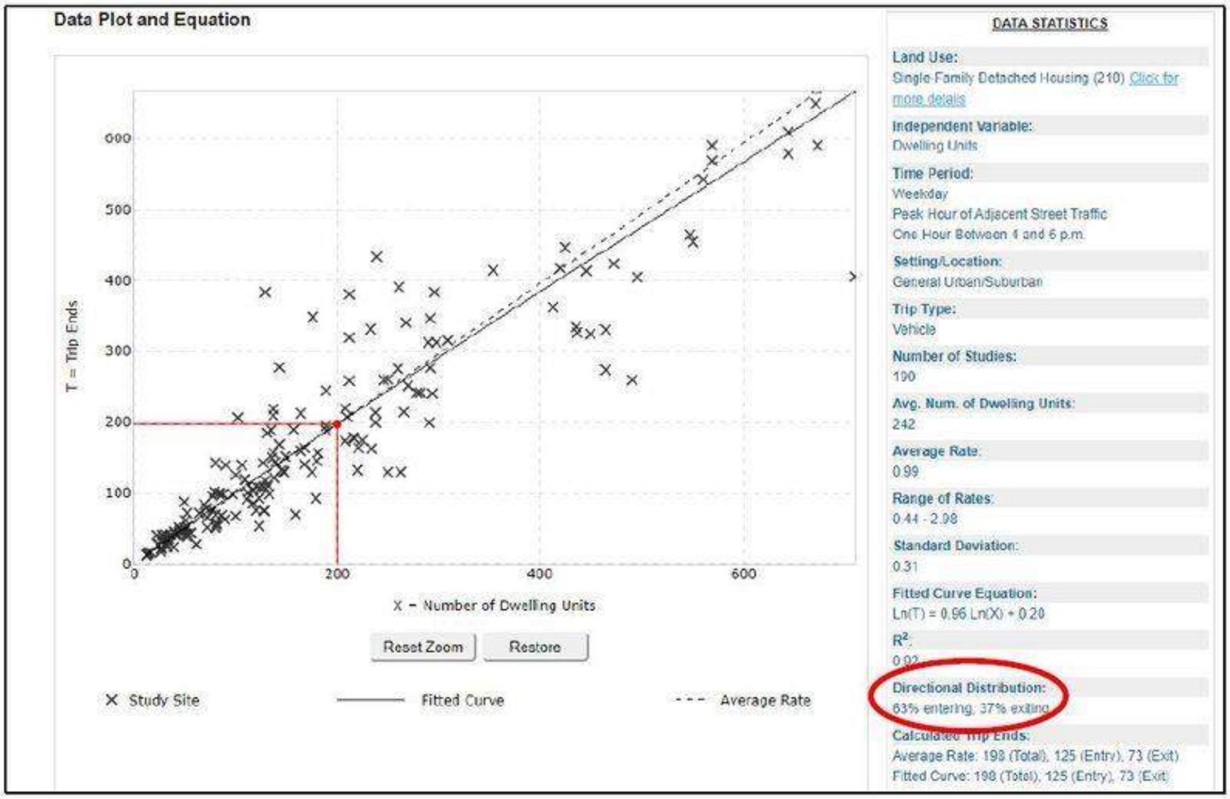


Figure 905.3.4.8.5, Directional Distribution in ITE Trip Generation, Web-Based App

The ITE *Trip Generation Manual* and the existing traffic counts, combined with local knowledge of traffic patterns and land use as well as professional judgement, are then used to determine the traffic distribution percentages to and from the site development. Figure 905.3.4.8.6 shows the transportation network distribution of site-related trips.

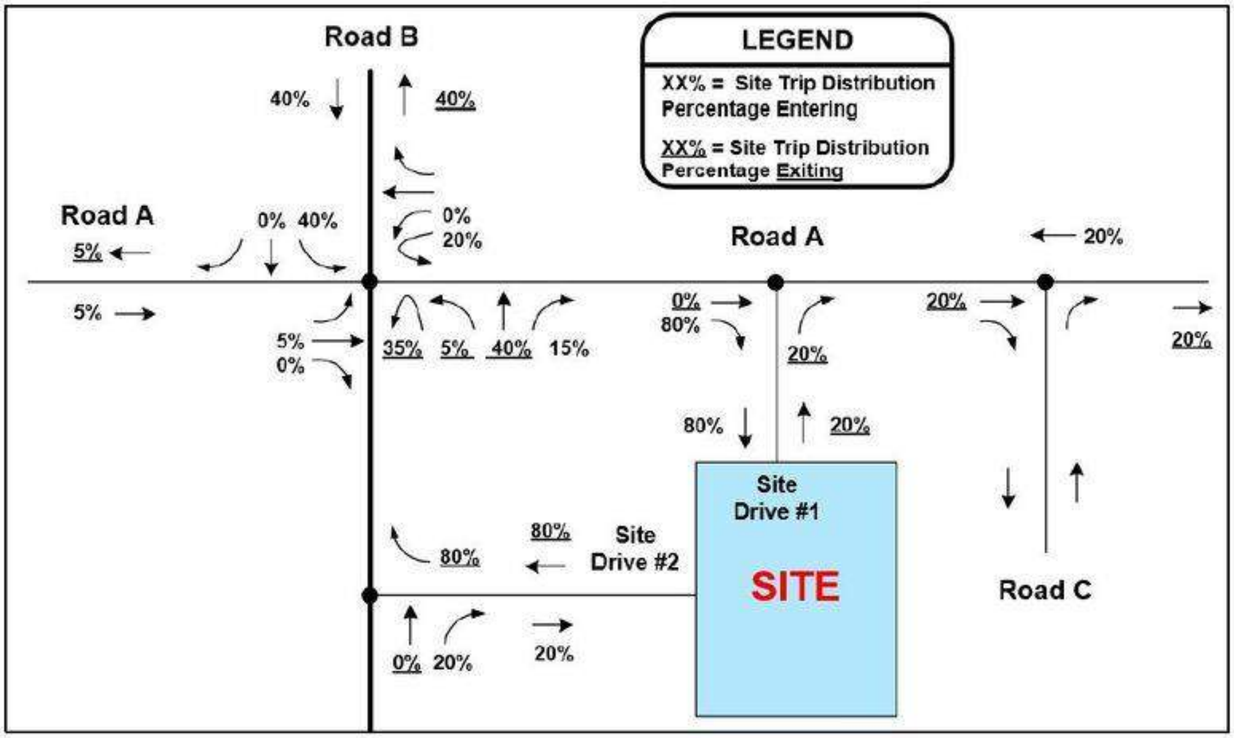


Figure 905.3.4.8.6, Site Trip Distribution onto Road Network

b. **Gravity Model Method:** The gravity model method partitions land use into zones of homogenous land use attributes (i.e., households and employment type) and determines the number of trips between each zone. Trips entering a zone are known as "attracted" trips while trips leaving a zone are "produced" trips. A zonal cumulative analysis based on a gravity model formula is used to determine the distribution of trip attractions and productions. Zones with larger trips generated will attract and produce more trips than smaller zones on a relative basis. Zones with less impedance (usually measured by distance or travel time) between them will have more trips distributed between them. The gravity model formula is:

$$T_{ij} = P_i \cdot \frac{A_j \cdot f(d_{ij})}{\sum_{\text{all zones } z} A_z \cdot f(d_{iz})}$$

where T_{ij} = the forecast flow produced by zone *i* and attracted to zone *j*
P_i = the forecast number of trips produced by zone *i*
A_j = the forecast number of trips attracted to zone *j*
d_{ij} = the impedance between zone *i* and zone *j*
$f(d_{ij})$ = the friction factor between zone *i* and zone *j*
The gravity model can be applied iteratively and can be constrained to productions or attractions. The gravity model trip distribution process can be applied manually or through the application of a regional travel demand model.

c. **Socioeconomic Data:** this method can be applied if an extensive database of socioeconomic data exists for the study area. This method would entail using population and employment data to estimate trip distribution for the study area. A regional travel demand model could provide socioeconomic data estimates developed by an MPO.

5. **Trip Assignment:** Traffic volumes to and from a future development are assigned to specific roadways either manually or using a travel demand model for larger studies. To create the trip assignment, the trip percentage distribution is applied to the trip generation for the assignment of new (primary), pass-by and diverted link site trips. Summing up the background, new (primary), pass-by and diverted link trips results in the final total trip assignment.

The assignment of each of the components of site trips (new (primary), pass-by, and diverted link) is recommended to be calculated and displayed on separate flow diagrams. Calculations are typically performed in a spreadsheet. A step-by-step example with exhibits is in Accompaniment to Volume Development.

a. **New (Primary) Trips:** 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.

b. **Pass-by Trips:** 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. Typically, pass-by trips should not exceed 5 to 10 percent of the traffic volumes on the adjacent roadways. Also, the egress and ingress pass-by volumes usually are equal.

c. **Diverted Link Trips:** The assignment of diverted link trips for each turning movement is calculated by multiplying the previously determined number of directional diverted link trips (trip generation) by the diverted link distribution percentage applicable to that movement. Typically, the egress and ingress diverted link volumes should be equal.

d. **Site Trip Summation:** 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 in Figure 905.3.4.8.7 (all example exhibits displayed in Accompaniment to Volume Development).

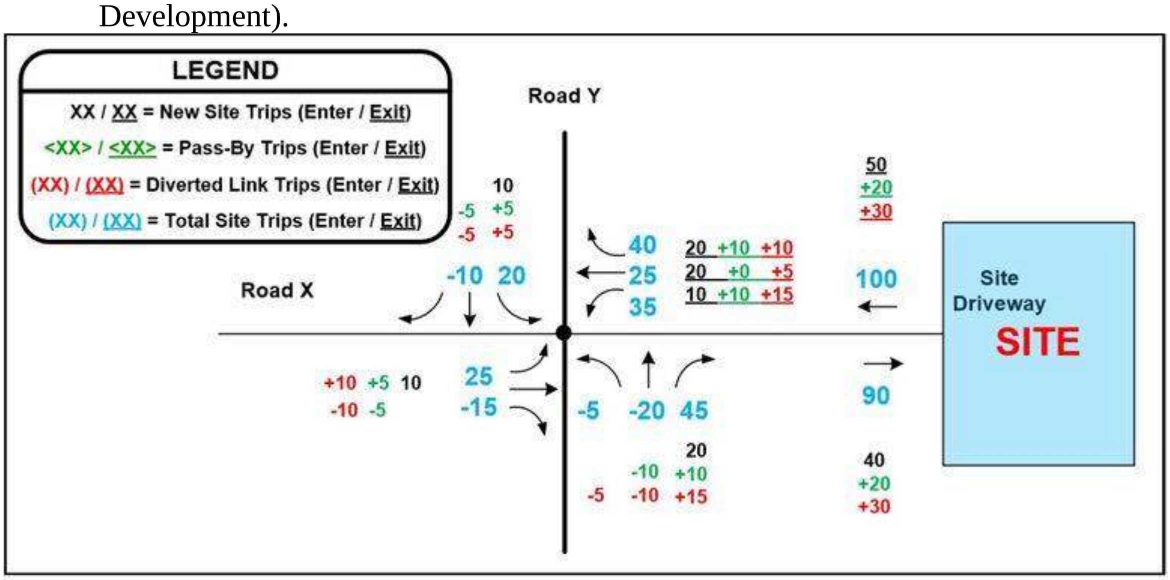


Figure 905.3.4.8.7, Total Site Trip Assignment

e. **Site Trips with Background Traffic:** The total site trips are then combined with Background Traffic to create Background plus Site trips as shown in Figure 905.3.4.8.8 (all example exhibits displayed in Accompaniment to Volume Development).

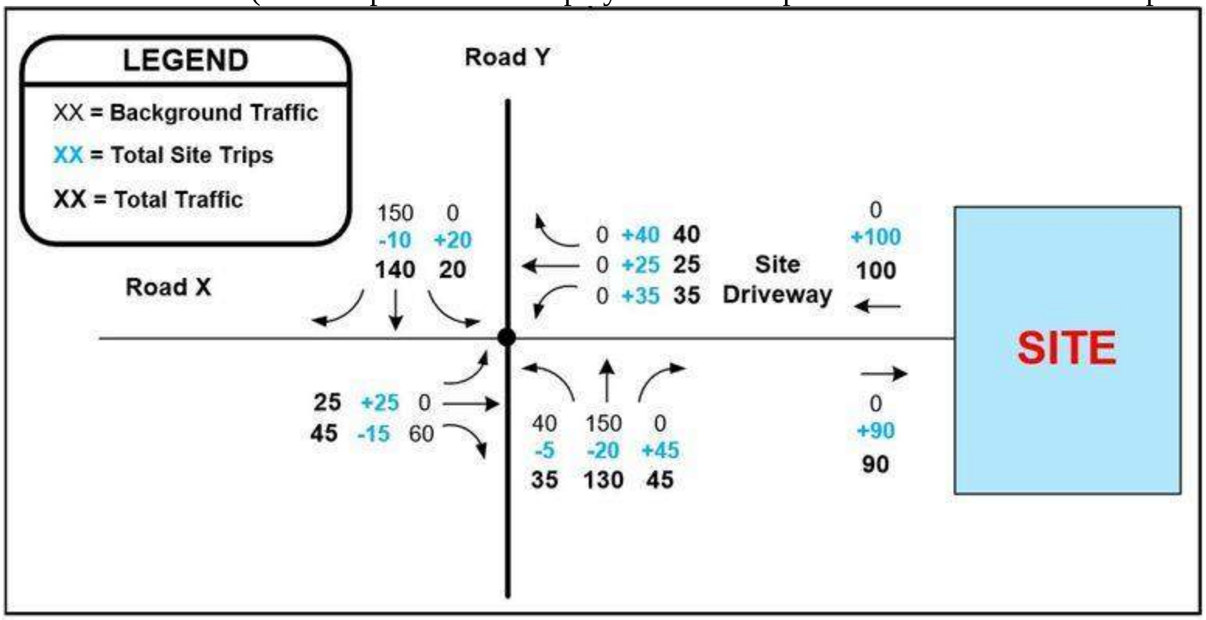


Figure 905.3.4.8.8, Site Trips with Total Traffic

In the diagram example above, Road Y would have a total of 140 southbound through trips after subtracting 10 trips lost from what was originally 150 background trips.

905.3.5 Traffic Analysis Tools

As discussed in EPG 905.3.2 Methodology and Scoping, each traffic analysis tool varies in analysis function and are useful and effective in understanding and assessing transportation needs for projects. EPG 905.3.5 Traffic Analysis Tools includes a review of existing traffic analysis tools and common modeling concerns, parameters, and best practices that are applicable for each tool. This article is subdivided into:

- EPG 905.3.5.1 Common Analysis Tool Input Parameters: common input parameters that are applicable to most analysis software tools.
- EPG 905.3.5.2. Static/Deterministic Models: HCS, SIDRA, and Synchro
- EPG 905.3.5.3 Microsimulation Models: SimTraffic and VISSIM
- EPG 905.3.5.4 Other Software
- EPG 905.3.5.5 Model Templates
- EPG 905.3.5.6 Review Checklists.

905.3.5.1 Common Analysis Tool Input Parameters

Table 905.3.5.1.1 displays common parameters that are generally applicable to most traffic analysis tools. All parameters in EPG 905.3 Transportation Impact Analysis are suggestions. It is important to use field data, if available, unless otherwise specified. The MoDOT suggested parameter values can be applied when no field data is available, to verify field data, and/or to replace field data if the data is unreasonable. The traffic analysis tools included in EPG 905.3 Transportation Impact Analysis have a standard set of input parameters.

The list of parameters in EPG 905.3 Transportation Impact Analysis are not exhaustive (for a full list of parameters, refer to each individual analysis tool's user guide), but focus on key traffic analysis parameters with specific MoDOT guidance for proper application.

Table 905.3.5.1.1, Common Parameters for Traffic Analysis Tools (When Field Data is Not Available)

Parameter	Parameter Description	Suggested/Typical Value(s)
Cycle Length (sec)	Total time required to service all competing traffic movements at a signalized intersection.	**Typical Maximum Value:** 140 seconds **Absolute Maximum Value:** 240 seconds **Coordinated Corridors:** Match corridor cycle length
Offset (sec)	Number of seconds that the reference (coordinated) phase lags after the master offset.	As long as a consistent reference phase is used, this should be equal to the travel time in the reference phase direction from the master intersection to the subject intersection.
Link Speed (mph)	The speed limit or safe, legal speed anticipated on an approach or segment.	**Typical Links:** Enter the speed limit or safe, legal speed anticipated at approach. **Typical Ramps:** 35 mph **Loop Ramps:** 25 mph **Driveways:** 25 mph
Storage Length (ft)	The storage bay length does not include the taper length. (In Synchro, this is a separate measurement that can be specified in the Simulation Settings table.)	Round user input up to the nearest 25' increment (e.g., round 160' up to 175'). This allows for a conservatively higher estimate to account for slight small inaccuracies in field data (319' vs. 324', for instance) and to account for the length of vehicles (assume the length of one vehicle per 25' of storage length).
Peak Hour Factor (PHF)	Peak hour traffic volumes are divided by the PHF to calculate the traffic flow rate during the busiest 15-minute period during the hour.	**Current Conditions:** Use traffic data, if available, to calculate PHF. **Current Conditions with no data and Future Conditions:** Use default value of 0.92
Conflicting Pedestrians (#/hr)	Enter the number of pedestrian calls per hour that conflict with permitted turn movements (do NOT enter all pedestrians activating this phase unless there is only one pedestrian per ped call).	
Conflicting Bicycles (#/hr)	Enter the number of bicycles that conflict with right turns. Enter 0 if bicycles cross the right-turn traffic ahead of the intersection.	

Bus Blockages (#/hr)	The number of local buses that will block traffic flow in as it enters or exits an intersection. The factor is applied by lane group and not the overall intersection as a whole.	**CBD Bus Stop:** 12 buses/hr **Non-CBD Bus Stop:** 2 buses/hr **Note:** Increasing bus blockage values will decrease the bus blockage factor and, consequently, decrease the saturated flow rate. However, this decrease can be gradual, as an increase of 2 to 12 buses stopped per hour (the typical difference in non-CBD vs. CBD stops) on a one-lane lane group would only lower the saturated flow rate by 4%.
Minimum Split (sec)	**Signal Plan:** User-defined value **Calculation:** Minimum Initial Green Time + Yellow Time + All-Red Time **OR** Walk Time + Flash Don't Walk + Yellow Time + All-Red Time (whichever is larger)	
Total Split (sec)	**Signal Plan:** User-defined value **Calculation:** Sum of maximum splits for movement, includes Yellow + All-Red	
Walk Time (sec)	**Actuated Signal:** 7 sec **Pre-Timed Signal:** Green interval minus "Flash Don't Walk"	
Flash Don't Walk (sec)	Based on 3.5 ft/s walking speed (from curb to curb)	
Yellow and All-Red Times	Refer to Table 905.3.5.1.2 and Table 905.3.5.1.3.	

Table 905.3.5.1.2, Duration of Minimum Yellow Change Interval

Approach Speed (mph)	Minimum Yellow Change[1] (sec)
25	3.0[2]
30	3.2
35	3.6
40	3.9
45	4.3
50	4.7
55	5.0
60	5.4
Note: Table based on Exhibit 6-2 from the NCHRP 812 [1] Based on negligible approach grades. A 0.1 second increase should be made for every 1% of downgrade and a 0.1 second decrease should be made for every 1% of	

upgrade. ² The NCHRP 812 recommends that a minimum of 3 seconds should be used.

Table 905.3.5.1.3, Duration of Red Clearance Interval

Approach Speed (mph)	Red Clearance (sec)				
	Width of Intersection (ft)				
	30	50	70	90	110
25	0.4	0.9	1.5	2.0	2.5
30	0.1	0.6	1.0	1.5	2.0
35	0.0	0.4	0.8	1.1	1.5
40	0.0	0.2	0.5	0.9	1.2
45	0.0	0.1	0.4	0.7	1.0
50	0.0	0.0	0.2	0.5	0.8
55	0.0	0.0	0.1	0.4	0.6
60	0.0	0.0	0.0	0.2	0.5
Note: Table based on Exhibit 6-3 from the NCHRP 812					

905.3.5.2. Static/Deterministic Models

Deterministic models use static formulas to determine the relationships of flow, speed, and density of the traffic stream. These models are ideal for analyzing isolated/small scale facilities and freeway/highway facility segments. Their strengths include their abilities to quickly predict capacity, density, speed, delay, and queuing. A key limitation includes their lack of ability to analyze network or system effects on travel flow. Common deterministic tools that will be summarized in EPG 905.3.5.2. Static/Deterministic Models include HCS, SIDRA, and Synchro.

905.3.5.2.1 HCS

Highway Capacity Software 7 (HCS7) is a traffic analysis software package which contains a series of modules that implement the procedures and methodologies outlined in the HCM, 6th Edition. HCS7 can be used to analyze the following modules and sub-modules:

- Streets
  - o Streets (includes signalized intersections)
  - o Reliability
- Stop
  - o All-Way Stop Controlled (AWSC)
  - o Two-Way Stop Controlled (TWSC)
- Roundabouts
- Highways

- o Two-Lane
- o Multilane
- • Freeways
- o Freeways
- ▪ Basic (Segment)
- ▪ Merge
- ▪ Diverge
- ▪ Weaving
- ▪ Facility
- o Reliability
- • Tools.

HCS7 is a widely accepted tool that can be used quickly and easily with simplistic parameters and inputs. Since HCS7 is limited to the deterministic methodologies of HCM6, it is strictly equation-based and does not have the ability to analyze oversaturated conditions where queues dynamically interact between closely spaced network elements such as ramps and intersections. The strengths and limitations of HCS7 should be considered when determining an appropriate analysis tool.

HCS7 utilizes standard HCM6 traffic data parameters and inputs. Refer to Table 905.3.5.2.1.1 and subsequent module summaries for guidance on standard HCS7 traffic and phasing parameters and inputs. It is important to note that the Freeway and Reliability modules are covered in greater detail than the other modules because of the benefit for using those modules for transportation projects relative to other modules (e.g., Synchro would often times be used for signalized intersections, but HCS would be chosen over Synchro to analyze freeways).

Note: The F1 key can be used to display a Description and Impact on Model Results for each data input field within HCS7.

Table 905.3.5.2.1.1, HCS: Typical User-Adjusted Parameters (When Field Data is Not Available)

Module	Input Section	Parameter(s)	Parameter Description	Suggested/Typical Value(s)
Streets (Signals)	Detailed Input Data	Queue Length Percentile	This entry specifies the probability that a computed queue length will not be exceeded during any one signal cycle.	Set the “Queue Length Percentile” to 95
	Traffic	Arrival Type	The quality of traffic progression as it approaches the intersection in question. Ranges from 1 to 6 with	**Select Moderate Progression:** 3 (HCS default)

			1 = poor progression and 6 = exceptional progression	
		Buses (#/hr)	Number of local buses/parking maneuvers that block traffic flow in a movement group within 250’ of the stop line (upstream or downstream). Non-zero bus stops/parking maneuvers per hour decreases the saturation flow rate.	**CBD Bus Stop:** 12 buses/hr **Non-CBD Bus Stop:** 2 buses/hr
		Parking (#/hr)		Select side (L,R,or L+R) there is on-street parking and number of parking maneuvers per hour that occur adjacent to a movement group and within 250ft upstream of the stop line.
		Heavy Vehicles (%)	The percentage of trucks and buses for each traffic movement.	Use field data or heavy vehicle estimates from the MoDOT AADT Map. Otherwise, use the HCM recommended default of 3%.
		Speed Limit	**Typical Approach:** Enter the speed limit or safe, legal speed anticipated at approach. **Driveways:** 25 mph	
Freeways	Geometric Data	Freeway Free Flow Speed (FFS)	The speed of traffic at very low-flow conditions (when drivers are not constrained by other vehicles, roadway geometry, or traffic control).	Use field data (85th percentile speed) if available. Otherwise, FFS can be estimated up to 5 mph above the speed limit.
	Geometric Data	Ramp FFS		**Typical Ramps:** 35 mph (HCS default for diverge/merge) **Loop Ramps:** 25 mph
Various Modules	Adjustment Factors	Driver Population	The level of driver familiarity with the facility and is used to adjust the Speed and Capacity Adjustment Factors. Values range from all familiar (heavy commuter traffic) to all unfamiliar (heavy tourist traffic).	
	Geometric Data	Terrain Type/Grade	**Use field data to determine what grade is appropriate:** **Level:** Any combination of vertical or horizontal alignment changes that do not affect heavy vehicle speeds in relation to passenger vehicles (grades	

			≤2%) **Rolling:** Any combination of vertical or horizontal alignment changes that affect heavy vehicle speeds in relation to passenger vehicles (grades 3-5%) **Enter Specific Grade %:** Use for extended segments that follow a constant incline/decline that affects heavy vehicle speeds in relation to passenger vehicles. If studying a segment that contains varying steep grade changes (≥6%), then individual analysis subsegments should be broken out by grade %.	
	Input/Demand Data	Peak Hour Factor (PHF)	Peak hour traffic volumes are divided by the PHF to calculate the traffic flow rate during the busiest 15-minute period during the hour.	**Current Conditions:** Use traffic data, if available, to calculate PHF. **Current Conditions with no data and Future Conditions:** Use default value of 0.92

Streets Module (Signals)

An intersection's traffic, phasing, and timing attributes are input into this module to calculate volume-to-capacity, delay, queuing, and other key MOE outputs using HCM 6 methodologies. Input data can be entered using a combination of "Classic Mode" input data boxes and "Visual Mode."

Additionally, the module provides the ability to optimize a signalized intersection. For optimization, it is advised that the minimum cycle be set to 60 seconds, the maximum cycle be set to 190 seconds, the number of generations be set to 200 (HCS default), and that the mutation probability be set to 4%.

Stop Module (TWSC and AWSC)

These modules are ideal for analyzing isolated, stop control intersections by lane group and approach. For intersections closely spaced together with upstream signals, it is recommended that microsimulation models be used to account for the influences of queuing. The modules allow for no more than four approaches to be input and for no more than three lanes on an approach. Key attributes to be aware of for these modules include:

- **Percent Thrus Using Shared Lane:** Can be input for an approach with more than one thru lane, though this is not typical to AWSC intersections and TWSC intersection minor approaches. A value of 50% should be used for rural major streets where drivers are less likely to pre-maneuver to the exclusive thru lane prior to the intersection. A value of 40% should be used in an urban setting where vehicles are familiar with the lane configuration.

- **Major Street Median Storage:** The number of minor street vehicles that can refuge in the median during a two-stage crossing of the major street. Use one vehicle of storage space per 25ft of median. If undivided, this value is zero.
- **Short Left-Turn Pocket:** Check box if no exclusive left turn lane is provided on the major street and it is possible for major street thru or right traffic to be delayed by left turning vehicles waiting for an acceptance gap. If left turn storage is available, enter the number of vehicles in Left-Turn Storage.

Roundabouts Module

Typically, MoDOT will analyze roundabouts using SIDRA software; however, the use of HCS may be considered for preliminary, coarse analysis. Note that this module is limited to one or two-lane entries, single bypass lanes, no more than two circulating lanes, and no more than four approaches.

Highways Module (Two-Lane and Multi-Lane)

HCS7 Highway analysis applies to uninterrupted flow segments of highway that are more than two miles from the nearest point of fixed operation. The highway analysis facility types are:

1. Two-Lane – One lane in each direction, typically rural.
2. Multi-Lane – Two to three lanes in each direction.

Freeways Module

HCS7 Freeway analysis is performed through segmentation due to the static, equation-based analysis limitations of HCM6. Segments are broken into the following facility types:

1. Basic Freeway
2. Merge/Diverge Ramp
3. Weaving

Each freeway segment is established by boundaries, or influence areas. The Merge/Diverge ramps have an influence area length of 1,500 feet from the physical gore, while weaving segments have an influence area of up to 3,000 feet between each physical gore plus 500 feet upstream and downstream from each physical gore (see Fig. 905.3.5.2.1.2). Basic freeway segments typically fall in between the influence areas of merge/diverge or weaving segments. However, basic freeway segments can also have boundaries established by changes in traffic characteristics or geometrics such as changes in number of lanes, lane or shoulder width, grade percentage, terrain type, or posted speed.

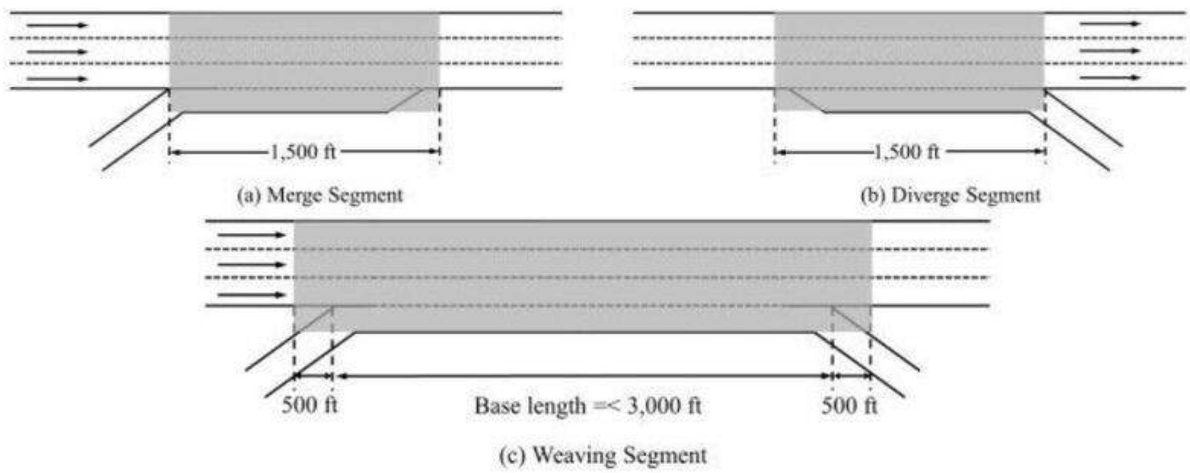


Fig. 905.3.5.2.1.2, Freeway Ramp Influence Area Boundaries

Merge/Diverge attributes to be aware of in the Freeway module include:

• **Number of Freeway Lanes:** Enter the number of lanes in the travel direction of the freeway segment immediately before (upstream of) the merge or diverge influence area.
• **Freeway Length:** Enter a value of 1500', the typical distance for a freeway influence area.
• **Length of First Accel/Decel Lane (LA1, LD1):** Enter the length of the first acceleration or deceleration lane. Lengths include the full taper length. See Fig. 905.3.5.2.1.3 and Fig. 905.3.5.2.1.4.
• **Length of Second Accel/Decel Lane (LA2, LD2):** Enter the length of the second acceleration or deceleration lane. Lengths include the full taper length. See Fig. 905.3.5.2.1.3 and Fig. 905.3.5.2.1.4.
• **Upstream/Downstream Ramp:** Select type of ramp (Merge or Diverge) that is upstream or downstream of the ramp influence area.
• **Distance to Upstream/Downstream Ramp:** Enter the distance to the adjacent ramp, measured between the points at which the left edge of the leftmost ramp lane meets the right-lane edge of the freeway. The maximum distance that HCS allows between adjacent ramps is 99,999 feet (approximately 19 miles), which is an arbitrary allowance of distance, given that merge/diverge ramps have an influence area of 1,500 feet from the physical gore.

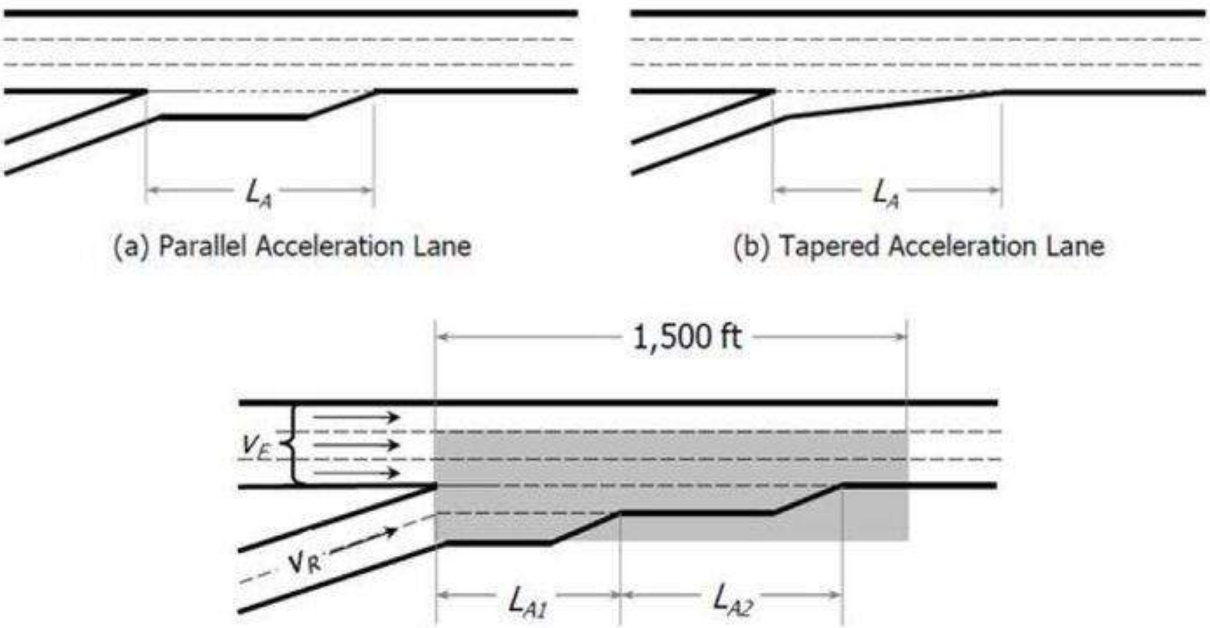


Figure 905.3.5.2.1.3, Merge Ramp Acceleration Lanes

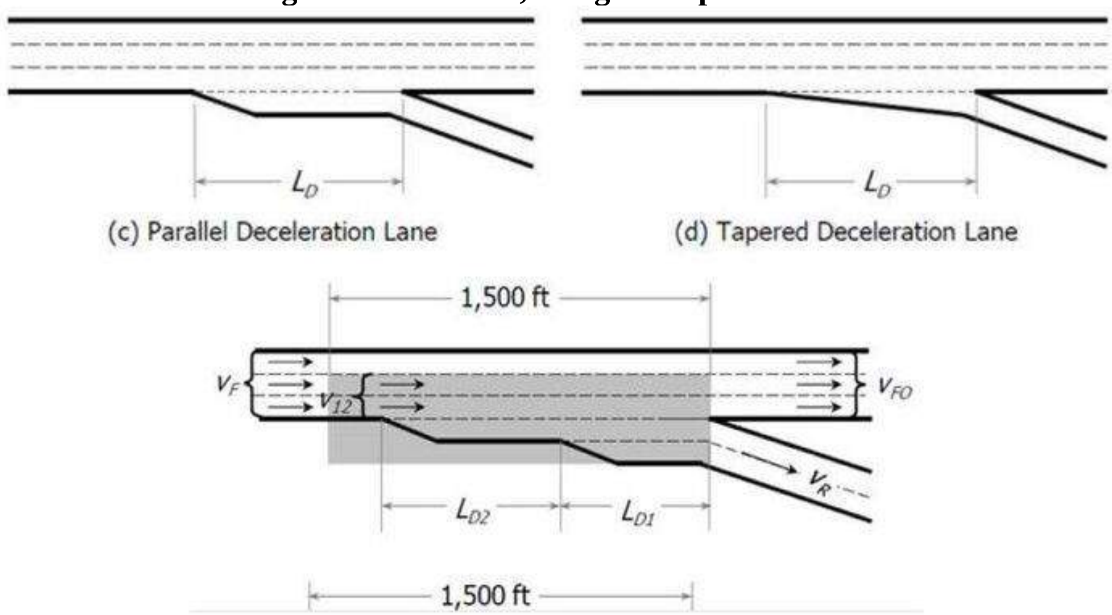


Figure 905.3.5.2.1.4, Diverge Ramp Deceleration Lanes

Weaving attributes to be aware of in the Freeway module include:

- **Weaving Configuration:** Select One-Sided or Two-Sided. See Figure 905.3.5.2.1.5.

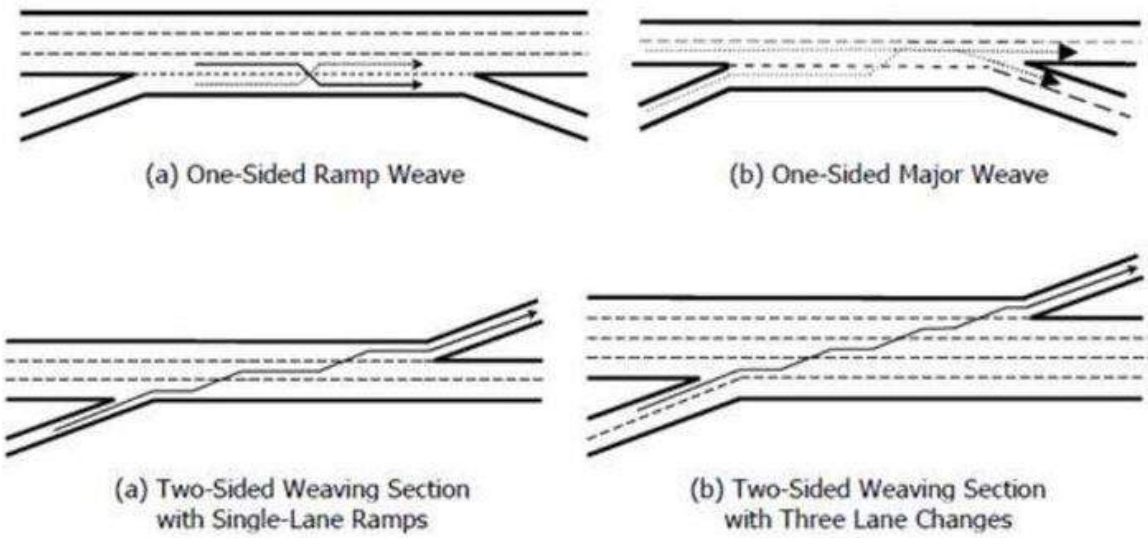


Figure 905.3.5.2.1.5, Weaving Segment Configuration

• **Number of Maneuver Lanes:** Enter the number of lanes from which weaving maneuvers may be made with either one or no lane changes. This value will range from 2-3 for One-Sided and will always be 0 for Two-Sided.

• **Short Length (LS):** Enter the distance between the end points of any barrier markings that prohibit or discourage lane changing. See Figure 905.3.5.2.1.6.

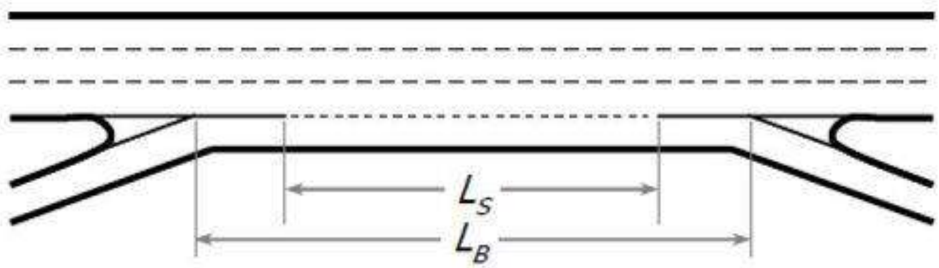


Figure 905.3.5.2.1.6, Weaving Segment Lengths

• **Interchange Density:** Enter the average number of interchanges 3 miles upstream and 3 miles downstream of the middle of the weaving segment.

• **Terrain Type:** Select Level, Rolling, or Enter Specific Grade %. Refer to Basic Freeway Segment analysis for guidance on Terrain Type.

• **Minimum FR Lane Changes:** Minimum number of lane changes that a vehicle must make to complete a Freeway to Ramp movement. See Figure 905.3.5.2.1.5.

• **Minimum RF Lane Changes:** Minimum number of lane changes that a vehicle must make to complete a Ramp to Freeway movement. See Figure 905.3.5.2.1.5.

• **Minimum RR Lane Changes:** Minimum number of lane changes that a vehicle must make to complete a Ramp to Ramp movement. This only applies to a Two-Sided configuration. See Figure 905.3.5.2.1.5.

• **Weaving Demand Data Inputs:**

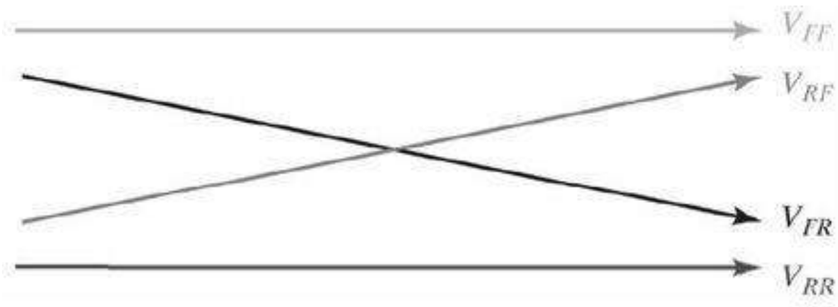


Figure 905.3.5.2.1.7, Weaving Segment Volumes

i. Freeway-to-Freeway – See $\mathbf{V_{FF}}$ in Figure 905.3.5.2.1.7.
1. Enter the Demand (Traffic Volumes).
2. Demand Adjustment Factor – Use default value of 1.0.
3. PHF – Use mainline PHF.
4. Total Trucks % – Use mainline Heavy Vehicle %.

ii. Ramp-to-Freeway – See $\mathbf{V_{RF}}$ in Figure 905.3.5.2.1.7.
1. Enter the Demand (Traffic Volumes)
2. Demand Adjustment Factor – Use default value of 1.0.
3. PHF – Use mainline PHF.
4. Total Trucks % – Use mainline Heavy Vehicle %.

iii. Ramp-to-Ramp – See $\mathbf{V_{RR}}$ in Figure 905.3.5.2.1.7.
1. Enter the Demand (Traffic Volumes)
2. Demand Adjustment Factor – Use default value of 1.0.
3. PHF – Use mainline PHF.
4. Total Trucks % - Use mainline Heavy Vehicle %.

iv. Freeway-to-Ramp – See $\mathbf{V_{FR}}$ in Figure 905.3.5.2.1.7.
1. Enter the Demand (Traffic Volumes)
2. Demand Adjustment Factor – Use default value of 1.0.
3. PHF – Use mainline PHF.
4. Total Trucks % – Use mainline Heavy Vehicle %.

Note: If weaving movement demand volumes are unknown, take the ramp with the lower volume and apply the proportion of the upstream or downstream ramp and mainline volumes to determine the $\mathbf{V_{RF}/V_{RR}}$ or $\mathbf{V_{FR}/V_{RR}}$ volume splits. Once the volume split is determined, the remaining movement volumes can be determined through volume balancing.

Freeway (Facility) Module

The HCS7 Freeways Facility module is recommended when studying a freeway corridor. It analyzes a freeway facility by linking the analysis segments of Basic Freeway, Merge/Diverge, and Weaving into a single interface. Jam density and queue discharge values are applied to the string of analysis segments to determine potential bottleneck locations and adjust the capacity of adjacent upstream analysis segments to simulate the effects of queuing. Due to the static limitations of HCS7, it is not recommended to analyze oversaturated scenarios along freeway facilities with dynamic queuing interactions, but it’s a good way to look at an undersaturated freeway corridor over multiple time intervals.

When starting a Facility analysis, the General tab contains basic information and the ability to apply certain parameters globally to the facility.

The Segments tab is where the facility is segmented into the traditional basic, merge/diverge, and weave freeway segments. The overlap segment also is introduced in the Facility module (refer to Figure 905.3.5.2.1.8 for an example). An overlap segment is used when the following three criteria are met:

1. A merge segment is followed by a diverge segment,
2. The ramp gores are between 1500’ and 3000’ apart, and
3. There is no continuous auxiliary lane between the ramps, which would classify it as a weave.

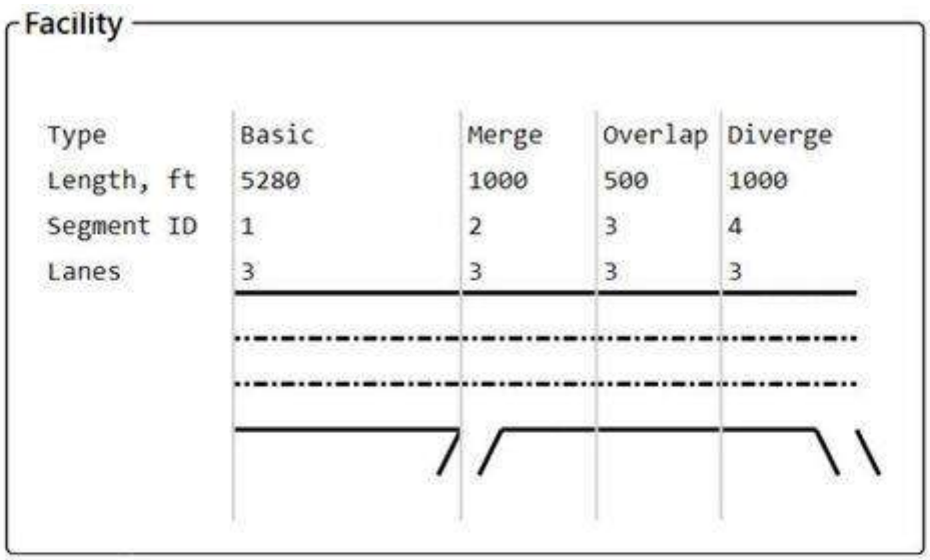


Figure 905.3.5.2.1.8, Overlap Segment Example

In these cases, the overlap segment is treated similarly to a basic segment, but the length is defined as 3000’ minus the distance between the ramp gores. The facility can be automatically segmented by using the segmentation button at the top of the window. This allows the user to enter basic information like the presence of on- and off-ramps, the distances between them, and the number of lanes. The information is then used to automatically segment the facility into basic, merge/diverge, weave, and overlap segments.

The details tab is where the typical input parameters for each freeway segment are entered.

The results tab shows the typical outputs for each freeway segment.

The report tab displays the analysis results with options to show a segment or facility report or a heat map of the results for various measures of effectiveness.

Facility by segmentation starts a new Facility analysis through automatic segmentation, as described above.

Facility Planning is based off HCM Chapter 25 Section 6 and has fewer data requirements than the Facility module. It is intended for a higher-level analysis.

Special Cases of Freeway Segmentation

There are a variety of unique, special cases that can occur in the analysis of freeway segments. As a general rule of thumb, it is always best to review the HCM to see if the unique situation is directly addressed, and if not, to subdivide the segment of concern into multiple segments to analyze. Special cases that can occur often include, but are not limited to the following list:

• **Weaving Segments that exceed the weaving maximum length:** The weaving maximum length (LMAX) is the length at which weaving turbulence no longer has an impact on the capacity of the weaving segment. The HCM 6 provides Equation 13-4 for calculating LMAX and Exhibit 13-11 (Table 16 below) with estimated LMAX values. When the segment length (LS) is less than LMAX, the HCS weaving module is appropriate to calculate segment capacity. However, when LS is greater than or equal to LMAX, the merge and diverge junctions should be treated separately with ramp capacity checks for those segments. Additionally, any distance falling outside the influence area of the merge and diverge segments would be considered a basic freeway segment and analyzed accordingly.

HCM Equation 13-4

$$L_{MAX} = [5{,}728\ (1 + VR)^{1.6}] - [1{,}566\ N_{WL}]$$

where

Lz,sub>MAX = Maximum weaving segment length (in feet, using the short length definition)

VR = volume ratio (weaving demand flow rate / total demand flow rate)

N_{WL} = # of lanes from which weaving maneuvers may be made with either one or no lane changes

L_S = Length of the segment

If $L_S < L_{MAX}$, then Determine the Weaving Segment Capacity; OR

If $L_S \geq L_{MAX}$, analyze the merge and diverge junctions as separate segments by using HCM 6 methodology in Chapter 14

Table 905.3.5.2.1.9, Variation of Weaving Length

VR	Maximum Weaving Length (ft)	
	N_{WL} = 2	N_{WL} = 3
0.1	3,540	1,974
0.2	4,536	2,970
0.3	5,584	4,018
0.4	6,681	5,115
0.5	7,826	6,260
0.6	9,019	7,453

0.7	10,256	8,690
0.8	11,538	9,972

• **Acceleration/Deceleration Lanes Longer than 1,500 feet:** HCS allows only merge and diverge lanes to be entered that range from 0 feet to 1,500 feet. Ramp lanes that are shorter than 1,500 feet are not an issue for HCS analysis. However, for lanes that are longer than 1,500 feet, it is advised that the merge/diverge segment be broken up into multiple segment types for analysis. For instance, a diverge lane that is longer than 1,500 feet should be subdivided into a diverge segment of 1,500 feet and then another diverge segment with a continuous lane drop (analyzed as a basic freeway segment). Also, certain merge/diverge segments can be can analyzed with a continuous lane add or lane drop because those segments are eventually analyzed operationally as a basic freeway segment, per methodology from Chapter 12 of the HCM 6.
• **Back-to-back merge or diverge segments less than 1,500 feet apart:** Use the HCS Facility module to analyze back-to-back merge and/or diverge segments. In these situations, certain merge/diverge segments can be analyzed as merge/diverge segments with a freeway length of less than 1,500 feet.
• **Taper Exit Only:** A taper only exit would be analyzed in the diverge module using the same approach and methodologies as a typical diverge segment, but with a deceleration lane length of zero. The "taper only" exit would not impact the calculations.

Travel Time Reliability in HCS

FHWA defines travel time reliability as "the consistency or dependability in travel times, as measured from day-to-day and/or across different times of the day." Conventional capacity analysis methods evaluate average weekday peak period traffic operations. Generally, commuters do not experience "average" travel conditions on any given day, rather they experience a range of travel times. Only the longest commutes are remembered because travelers must base their plans on them to ensure on-time arrival. Improving travel time consistency can improve user perspective of operations even if the average travel time does not decrease. A paradigm shift from capacity addition to capacity efficiency is occurring as congestion continues to grow amid limited resources to add capacity.

Travel time reliability (TTR) analysis focuses on the influence factors on the variability of travel times, demand fluctuations, weather events, incidents, work zones, and special demand events. The only variable in density/delay-based analyses is demand, however, travel times can fluctuate even on a facility with consistent weekday peak period demand levels. Analytical methods of TTR use existing data sources to evaluate facility reliability based on historical data. Predictive methods use variable distributions calculated from historical data to predict the future reliability of a facility.

For the first time, the HCM (6th Edition) includes a predictive method to evaluate TTR. Dedicated chapters for both freeway reliability and urban street reliability, Chapters 11 and 17 respectively, provide a methodology to implement predictive TTR analysis as an extension of existing freeway facility and signalized corridor analysis methodology. HCS7 implemented the new methods via new modules, Freeway Reliability and Streets Reliability, that use Freeway Facility and Streets as a base model to be analyzed for reliability.

Predictive Reliability Analysis Fundamentals

HCS7 generates at least one 24-hour scenario for every month/day-of-week combination. Influencing events are applied to each scenario to generate a sample of travel times over a specified period (typically one year). Work zones and special demand events are applied to the scenarios deterministically; an event is recorded for each time/segment combination that falls within the scheduled start and end times. Weather and incident events occur with some randomness and thus treated as a stochastic variable. These events are assigned to scenarios based on default event distributions applied directly or modified by the analyst to reflect local data.

Speed, demand, and capacity adjustment factors are used to adjust the predicted travel time of each scenario to account for occurrence of influencing factor events. Once scenario travel times have been adjusted, the output of the HCS7 reliability modules are derived from the cumulative density function (CDF) of scenario travel times and travel time probability distribution function (PDF) plots. Figure 905.3.5.2.1.10 is a simple flow chart of the reliability methodology.

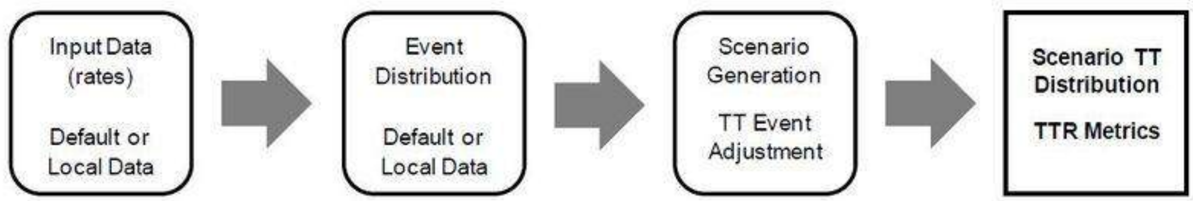


Figure 905.3.5.2.1.10, High-Level HCM Predictive Method Flow Chart

Freeway Reliability

Deterministic analysis of a sequence of HCM segments (basic, diverge, merge, and weaving) as an entire freeway facility was introduced in HCM 2010 and expanded in HCM 6th edition. The HCS7 Freeway Reliability module inherits facility analysis parameters from the Freeway Facilities file on which it is based. Segment data (type, length (ft), number of lanes, free-flow speed, terrain, etc.), base demand data (single day demand data used in the facilities analysis), and analysis parameters (start/end time, urban/rural, etc.) can only be modified in the underlying Facilities file and reimported into the Freeway Reliability module.

Freeway Reliability Analysis Parameters

After a base freeway facilities file is either loaded or created, the analyst completes general information fields not already imported from the Facility file (analyst, agency, analysis year, etc.). The reporting period refers to the range of dates included in the TTR analysis. An additional section allows the analyst to select which days of the week (DOW) are included in the reporting period. The influencing variables used in the analysis can be modified by the analyst to tailor the study to the project. Individual demand scenarios (month/DOW combination) can be repeated several times to increase the sample size of stochastic influencing events. The HCS7 default is four.

Weather Events

Adverse weather events may negatively affect travel times directly by forcing drivers to reduce their speed and/or indirectly by increasing incidents. HCS7 considers rain (medium or heavy), snow (light-medium, medium heavy, or heavy), severe cold, visibility (low, very low, and minimal), and non-severe weather. A nationwide default monthly weather event distribution is built-in to HCS7 as are monthly weather event distributions for approximately 100 cities in the US. Table 905.3.5.2.1.11 shows a list of regions within or near Missouri with built-in weather event data. Default capacity and speed adjustment factors for various freeway speed limits can be adjusted by the analyst if warranted by local or regional conditions.

Demand Data Parameters

HCS7 provides default freeway demand ratios for each month/DOW combination to adjust for demand variation over the course of the reporting period for both urban and rural freeways. These default ratios are automatically adjusted to become relative to the date for which demand in the base Freeway Facilities file applies. The analyst can also update the default demand ratio if more specific data exists.

Table 905.3.5.2.1.11,
Regions with Pre-loaded Weather Event Data Within or Near Missouri

Regional Weather Regions
Kansas City, MO
St. Louis, MO
Tulsa, OK
Omaha, NE
Memphis, TN
Des Moines, IA

Incident Data Parameters

Within the TTR context, incidents are events along the roadway that impact the rest of the traffic stream. Examples include crashes, disabled vehicles, emergency work zones, fallen trees, etc. that are common, but the exact time/place is unpredictable. Incidents reported to the closest Traffic Management Center are a common source for this data because they are generally only reported if there is an impact to traffic flow.

HCS7 provides three possible input methods: local incident frequency, local crash frequency, and calculated crash frequency. If sufficient incident data is available a frequency/rate can be calculated and directly input into the module. If incident data is unavailable but crash data is available, crash data and an incident-to-crash ratio (ICR) can be used to indirectly calculate the incident frequency. In the event no data is available, or the facility being analyzed is proposed new construction, the Highway Economic Requirements System (HERS) crash rate model can be used with an ICR to estimate the incident frequency per 100 million VMT. The default ICR is 4.9.

Work Zone Data Parameters

Known work zones, either past or future, can be explicitly added to the reliability analysis by providing the start/end date, start/end time each day, type of lane closure, area type (urban/rural), day/night, and speed limit. Each event has a default capacity reduction populated (13.7% for freeway work zones) that can be modified by the analyst if warranted. Additionally, EPG 616.25 MoDOT Work Zone Guidelines includes anticipated work zone capacity reductions.

Special Events Parameters and Capabilities

The special event component of the reliability methodology is primarily used to exclude from the TTR analysis day/time periods impacted by an abnormal event such as a sporting event, concert, fair, or other high capacity venue with projected traffic far in excess of normal peak period conditions. The traffic demand generated by such events should overwhelm the adjacent roadway network such that operations bear no resemblance to typical peak periods. To include these observations in the distribution of travel times may compromise the conclusions produced by the methodology.

If the analysis will include special events, HCS7 also has the capability to import a different facilities file for use during the duration of the event. This could be used to reflect modified traffic patterns, especially for longer events such as festivals and fairs that limit the ability of commuters to adjust their travel plans. In the event of a major work zone, this tool could also be used to implement temporary work zone traffic control measures while the work zone is active.

Urban Streets Reliability

HCS7 includes a dedicated module to implement the urban streets reliability methodology included in the 6th edition of the HCM. The Urban Streets methodology in the HCM analyzes signalized arterial corridors with multiple signalized intersections. Many of the TTR concepts presented in the freeway reliability methodology are applied to the street's methodology, however there are some parameters unique to the street's reliability methodology.

After a base streets file is uploaded into the reliability module, the analysis page is structured like its freeway reliability counterpart. The start and end date of the reporting period are specified, and the days of the week are selected. The number of study days during each month, study period start and end times, and the number of scenarios are tabulated and displayed automatically.

Urban Streets Weather Data

Like the freeway reliability methodology, weather data for many US cities is preloaded into the reliability. In addition to the relevant cities listed in Table 18, the Missouri cities of Columbia and Springfield are included in the Streets Reliability module in HCS7.

The weather metrics utilized for the Streets methodology are different than the freeway reliability module. In addition to the weather data points, the streets reliability module includes a parameter to account for the length of pavement runoff after a snow event and demand factors for dry weather, rain events, and snow events.

Table 905.3.5.2.1.12,
Weather Data Points for HCS7 Streets Reliability Module

Weather Data Metric	Units
Total normal precipitation	Inches
Total normal snowfall	Inches
Days with precipitation	Days
Daily mean temperature	°F
Precipitation rate	In/hr

Urban Street Demand Ratios

HCS7 Streets provides three possible functional classes: expressway, principal arterial, and minor arterial. Default hourly demand ratios are provided for weekdays and weekends. Like the Freeway Reliability module, day of week and monthly demand adjustments are provided as is the base demand ratio for the date on which the base streets file was analyzed. Local data can be used if available for all demand ratios.

Urban Street Incident Data

Streets Reliability incident data differs the most from the Freeway Reliability module among the input components. An annual average crash frequency is specified for all intersections and segments comprising the Streets network. Default crash frequency adjustment factors are provided for different weather events (rain, wet pavement, snow, ice, etc.). Incident detection time and the response time for different weather events are pre-populated with default values but can be adjusted for a specific facility or application.

A table of default clearance times is based on the street location (segment or intersection), event type (crash or non-crash), lane location, and severity (injury or non-injury for crashes, breakdown or other for non-crash events) for various weather conditions (dry, rain, wet pavement, or snow/ice). Another table provides a default distribution for all the combinations included in the clearance timetable and proportions for each category individually.

Urban Street Scenario Generation

Scenario generation parameters are set at the end of the procedure in the Streets Reliability module. The analyst can select to include weather, demand, and incidents in the reliability analysis. All three variables are stochastic so a random seed can be defined for each variable. The analyst can also select to randomize the demand volume for each analysis period. The number of replications of each scenario is also specified at this point.

Travel Time Reliability Measures of Effectiveness

Unlike traditional density or delay based MOEs that use a LOS scale, TTR utilizes a set of measures to tailor output to the specific analysis. Changes in travel times resulting from operational-level improvements are best reflected by 80th percentile travel times. The 95th percentile travel time is commonly referred to as the planning time, the time most commuters allow to achieve an acceptable on-time arrival rate. Graphical plots of the travel time distribution can also provide a visual indicator and comparison of TTR.

Most TTR metrics are based on the Travel Time Index (TTI), the scenario travel time divided by the base free-flow travel time. TTI is preferred over the actual travel times because it allows for comparisons between facilities of different lengths. HCS7 reports percentiles in TTI along with the base free-flow travel time imported from the base Sheets file. Table 905.3.5.2.1.13 lists several TTR metrics reported in the TTR modules of HCS7.

Table 905.3.5.2.1.13, Common Travel Time Reliability Metrics

Reliability Metric	Description
Base free-flow travel time (seconds)	Corridor travel time at free-flow speed, used as the denominator of the TTI calculation.
Mean TTI	Average TT/base free-flow TT; usually close to the 50th percentile TTI unless very high TT outliers are included in the data.
80th Percentile TTI	80th percentile TT/base free-flow TT; best measure of operational improvements
Planning Time Index (PTI)	95th percentile TT/base free-flow TT; time allotted to achieve an acceptable on-time arrival rate, typically for work or appointment.
Reliability Rating (%)	Percentile of scenarios with a TTI < 2.5; 2.5 is a common reliability threshold.
Total Delay (veh-hr)	Allows for overall performance comparison between different facilities or different operational strategies.

905.3.5.2.2 SIDRA

The *Signalized & Unsignalized Intersection Design and Research Aid* (SIDRA) software is a deterministic tool that can be used to analyze roundabout operations, signalized and unsignalized intersections, single-point urban interchanges, and signalized midblock crossings for pedestrians. In the United States, SIDRA is primarily used to analyze roundabout operations because of its ability to model the effects of gap-acceptance (including roundabout geometry) on roundabout Level of Service (LOS). The software references here are to SIDRA 8.

MoDOT recommends SIDRA as a tool for analyzing roundabout operations.

SIDRA software uses two roundabout capacity models: the US HCM model and the SIDRA Standard model. These two models are summarized below:

1. **US HCM 6 Roundabout Capacity Model** – Based on the calibration of most model parameters using HCM, 6th Edition, default values as applicable

2. **SIDRA Standard Roundabout Capacity Model** – Based off the HCM, but provides additional, detailed analysis for the following:

a. The effect of roundabout geometry parameters (roundabout size, circulating road width, entry radius, and angle, etc.) on capacity

b. Critical gap and follow-up headway reduction with increasing demand flows in its design life analysis

c. The effects of vehicle arrivals based on adjacent traffic control devices.

Therefore, MoDOT recommends that the "SIDRA Standard Roundabout Capacity Model" be the capacity model used for analysis in SIDRA. The HCM 6 Capacity Model is also available for additional analysis if desired. The ability to select the capacity model is available in the "Roundabouts" dialog box in SIDRA. For roundabouts near or over capacity, consider using VISSIM as an additional check.

Model Development

Table 905.3.5.2.2.1 summarizes key parameters with specific MoDOT guidance for proper application. The table includes the SIDRA parameter, the dialog box the parameter is in, the parameter description, and the MoDOT suggested default value. Additionally, Fig. 905.3.5.2.2.2, Table 905.3.5.2.2.3 and Table 905.3.5.2.2.4 provide more detailed information on parameters relating to roundabout geometry measurements, general roundabout design and operational elements, and extra bunching percentages, respectively.

There are additional SIDRA input parameters not included in EPG 905.3.5.2.2 because they are predominantly user-defined values based on existing conditions, recent traffic count data, or project design plans. For a detailed introduction to SIDRA and how to enter all parameters, it is recommended that the user access the SIDRA User Guide using "File\User Guide, Glossary, & Help" in the SIDRA interface.

Table 905.3.5.2.2.1, SIDRA Lane Geometry: Typical User-Adjusted Parameters (When Field Data is Not Available)

Dialog Box	Parameter(s)	Parameter Description	Suggested/Typical Value(s)
Settings	Current Setup	"US HCM (customary)" should be selected in the Settings tab of the ribbon at top of the SIDRA interface before a roundabout is created.	
Roundabouts ("Options" Tab)	Roundabout Capacity Model, Roundabout LOS Method, Delay Model Refer to Figure	**Roundabout Capacity Model:** Select the "SIDRA Standard" model. **Roundabout LOS Method:** Select the "Same as Sign Control" option. **Note:** For roundabouts, it is important to assess other MOEs in addition to LOS. Common MOEs for roundabouts include v/c ratios, LOS (based on delay), and queuing. **Delay Model:** Uncheck both "HCM Delay Formula" and "Exclude Geometric Delay."	

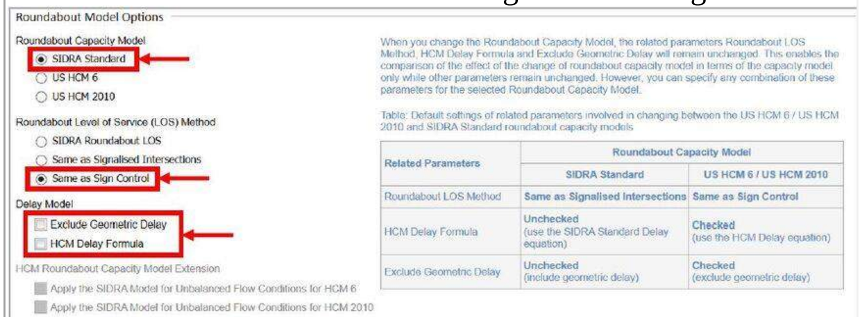
<table>
<tr>
<td></td>
<td>905.3.5.2.2.1, to the right, for a dialog box graphic.</td>
<td colspan="2">Additional Information: The “HCM Delay Formula” checkbox influences if back of queue or cycle average queue lengths will be calculated/displayed using HCM equations.
Geometric delay is the delay caused by vehicles slowing down when entering, negotiating, and exiting the roundabout. Since the HCM roundabout LOS delay does not consider geometric delay (it calculates delay solely based on unsignalized intersection control delay), the “Exclude Geometric Delay” checkbox is automatically checked whenever “HCM Delay Formula” is checked. Therefore, it is helpful to ensure that geometric delay is considered when comparing the operations of different intersection alternatives with different geometric designs.


Figure 905.3.5.2.2.1, Roundabout LOS Method</td>
</tr>
<tr>
<td rowspan="4">Roundabouts (“Roundabout Data” Tab)</td>
<td>Number of Circulating Lanes</td>
<td>The number of lanes circulating around the roundabout</td>
<td>User-defined values from field data and design plans.</td>
</tr>
<tr>
<td>Circulating Width</td>
<td>The total width of all lane(s) as it circulates the roundabout.</td>
<td>Single-Lane Roundabout: 20 feet (SIDRA default)
(NCHRP 672 single-lane acceptable range: 16 to 20 feet)
Multi-Lane Roundabout: 15 feet per lane
(NCHRP 672 acceptable range: 14 to 16 feet per lane)</td>
</tr>
<tr>
<td>Inscribed Diameter</td>
<td>Refer to Fig. 905.3.5.2.2.2</td>
<td>Refer to Fig. 905.3.5.2.2.2</td>
</tr>
<tr>
<td>Island Diameter</td>
<td>User-defined values from field data and design plans. Refer to Table 905.3.5.2.2.3 for typical ranges for roundabout types.</td>
<td>User-defined values from field data and design plans. Refer to Table 905.3.5.2.2.3 for typical ranges for roundabout types.</td>
</tr>
</table>

	Environment Factor[1]	Using this factor, you can calibrate the SIDRA Standard capacity model to allow for less restricted (higher) capacity and more restricted (lower) capacity. This parameter is only applicable/displayed for the "SIDRA Standard Capacity Model." The Environment Factor allows for the effect of different driver behavior (driver aggressiveness and alertness affecting driver response times) and general characteristics of the roundabout environment in terms of roundabout design type, visibility, significant grades, operating speeds, size of light and heavy vehicles, etc. Values range from 0.5 to 2.0.	**Single-Lane Roundabout:** Use 1.1 where drivers are generally familiar with roundabouts (e.g., at least one other roundabout is already in use in the general vicinity). Use 1.2 for anywhere else. **Two-Lane Roundabout:** Use 1.2 **Additional Notes:** MoDOT advises that no environment factors less than 1.0 should be used. Typically, a range of 1.1 to 1.2 should be used. Future years could use 1.1 assuming more familiarity in future. "Model Calibration Factors" are the parameters corresponding to the Environment Factors and are only applicable when the HCM capacity model is used.
	Entry Radius	The *minimum radius of curvature* of the outside curb line at entry	**Single-Lane Roundabout:** 65 feet (SIDRA default) (NCHRP 672 single-lane acceptable range: 50 to 100 feet) **Two-Lane Roundabout:** 100 feet (NCHRP 672 acceptable range)
	Entry Angle	The *angle of conflict between the entering and circulating streams*	**SIDRA Default Value:** 30 degrees (NCHRP 672 acceptable range: 20 degrees to 40 degrees.)
Intersection	Site Data, Approach	Dialog box to input intersection and road names to determine number of intersection legs (can add up to 8 legs), input each	

	Geometry, & Approach Data	approaching link's distance, and input if legs allow one-way or two-way traffic.	
	Extra Bunching	The effect of upstream signals on gap-acceptance capacity of roundabouts by increasing the bunching. The distance to the upstream signal should be measured from the downstream side of the traffic signal to the stop bar of the roundabout approach.	**If no traffic signal on approach that is within 2,600 feet:** 0% **Otherwise:** Refer to Table 905.3.5.2.2.4
Lane Geometry	Lane Type	Parameter setting to determine if entry lanes are "normal" entry lanes or slip/bypass lanes with either short angles or high angles.[2]	
Pedestrians	Pedestrian Movement Definition	If including pedestrian data as part of analysis, select "Staged Crossing" as the "Main Crossing" type. Enter data separately for both stages of the crossing.	
	Pedestrian Walking Speed	Set the pedestrian walking speed to 3.5 feet/second (per the HCM).	
Volumes	Heavy Vehicle Percentages	SIDRA defines this as any vehicle with more than two axles or with dual tires on the rear axle.	Use traffic count data
	Peak Flow Factor	The equivalent of the Peak Hour Factor when the timeframe is equal to one hour.	**SIDRA Default Value:** 0.92
Vehicle Movement Data	Approach Cruise Speed/Exit Cruise Speed	The average uninterrupted travel speed (i.e., the speed of a vehicle without the effect of delay at the intersection).	If available, use speed data of vehicles, as collected in the field. Otherwise use the posted speed limit.
Parameter Settings	Site Level of Service Method (in "Options" tab)	Set to "Delay & Degree of Saturation (SIDRA)"	
	Delay and Queue (in "Model Parameters" tab)	Uncheck the "Exclude Geometry Delay" and "HCM Formula Delay" checkboxes	

[1] Environment factors of 1.1 and 1.2 (for both current and future conditions) are conservative estimates of driver behavior. SIDRA provides hypothetical comparisons between 1.2 and 1.1

environment factors to show the impacts of a 0.1 environment factor change on capacity and driver response time. Refer to SIDRA User Guide.
[2] The impacts to traffic on the overall roundabout from the slip/bypass lane may not be fully reflected in the SIDRA outputs. It is advised that the user be cognizant of this if slip/bypass lane volumes are high. Different roundabout geometric options or analysis tools (such as VISSIM) should be considered.

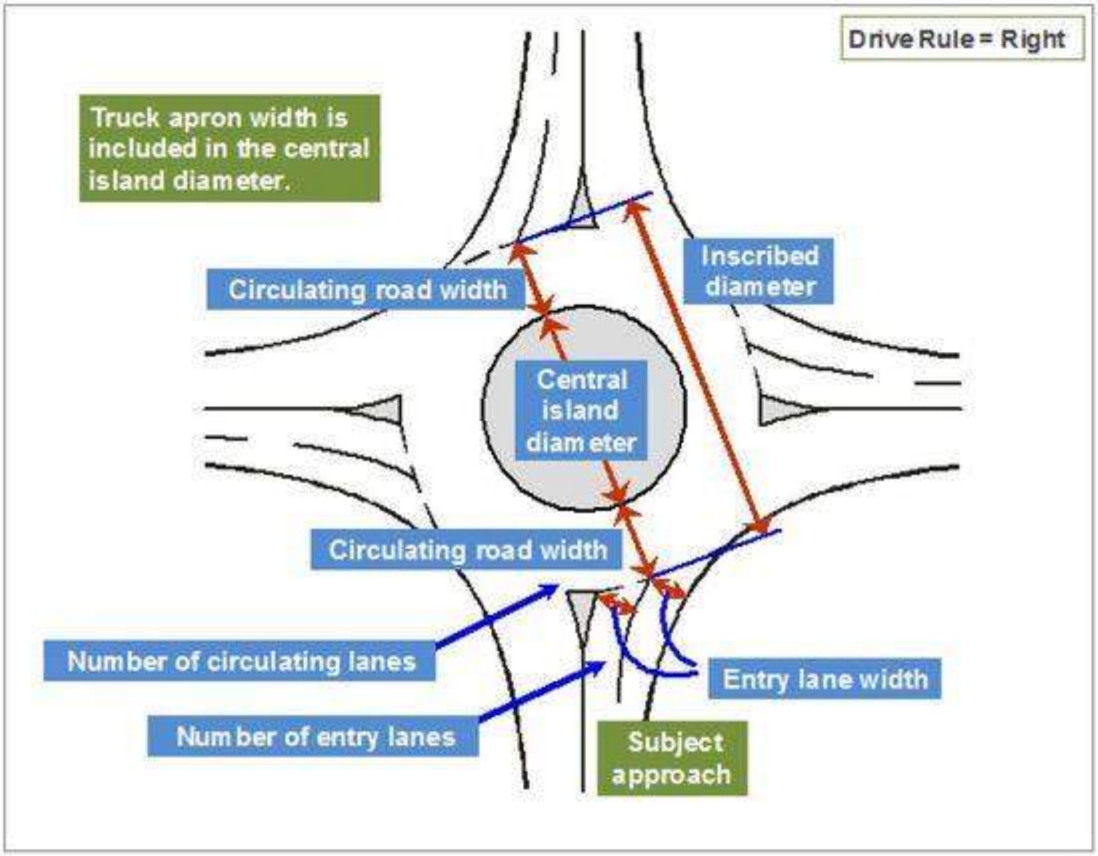


Fig. 905.3.5.2.2.2, Roundabout Geometry
Note: Exhibit based on SIDRA 8 User's Guide

Table 905.3.5.2.2.3, General Roundabout Design & Operational Elements

Design Element	Mini-Roundabout	Single-Lane Roundabout	Multi-Lane Roundabout
Desirable maximum entry design speed	15 to 20 mph	20 to 25 mph	25 to 30 mph
Maximum number of entering lanes per approach	1	1	2+

Typical inscribed circle diameter	45 to 90 feet	90 to 180 feet	150 to 300 feet
Central island treatment	Fully traversable	Raised (may have traversable apron)	Raised (may have traversable apron)
Typical daily service volumes on four-leg roundabout (vehicles/day)[1,2]	Up to 15,000	Up to 25,000	Up to approximately 45,000 for two-lane roundabout
Note: Table based on Exhibit 1-9 from the NCHRP 672			
[1] Traffic volumes are total daily volumes of all legs that are entering the roundabout. Operational analysis needed to verify upper limit for specific applications or for roundabouts with more than two lanes or four legs.			
[2]For additional clarity on when different roundabout types are appropriate, refer to Figure 905.3.5.2.2.5 and/or Table 905.3.5.2.2.6.			

Table 905.3.5.2.2.4, Extra Bunching Percentages

Distance to Upstream Signal (feet)	< 350’	350’ – 700’	700’ – 1,300’	1,300’ – 2,000’	2,000’ – 2,600’	>2,600’
Extra Bunching (%)	25	20	15	10	5	0
Note: Table based on SIDRA 8 User’s Guide						

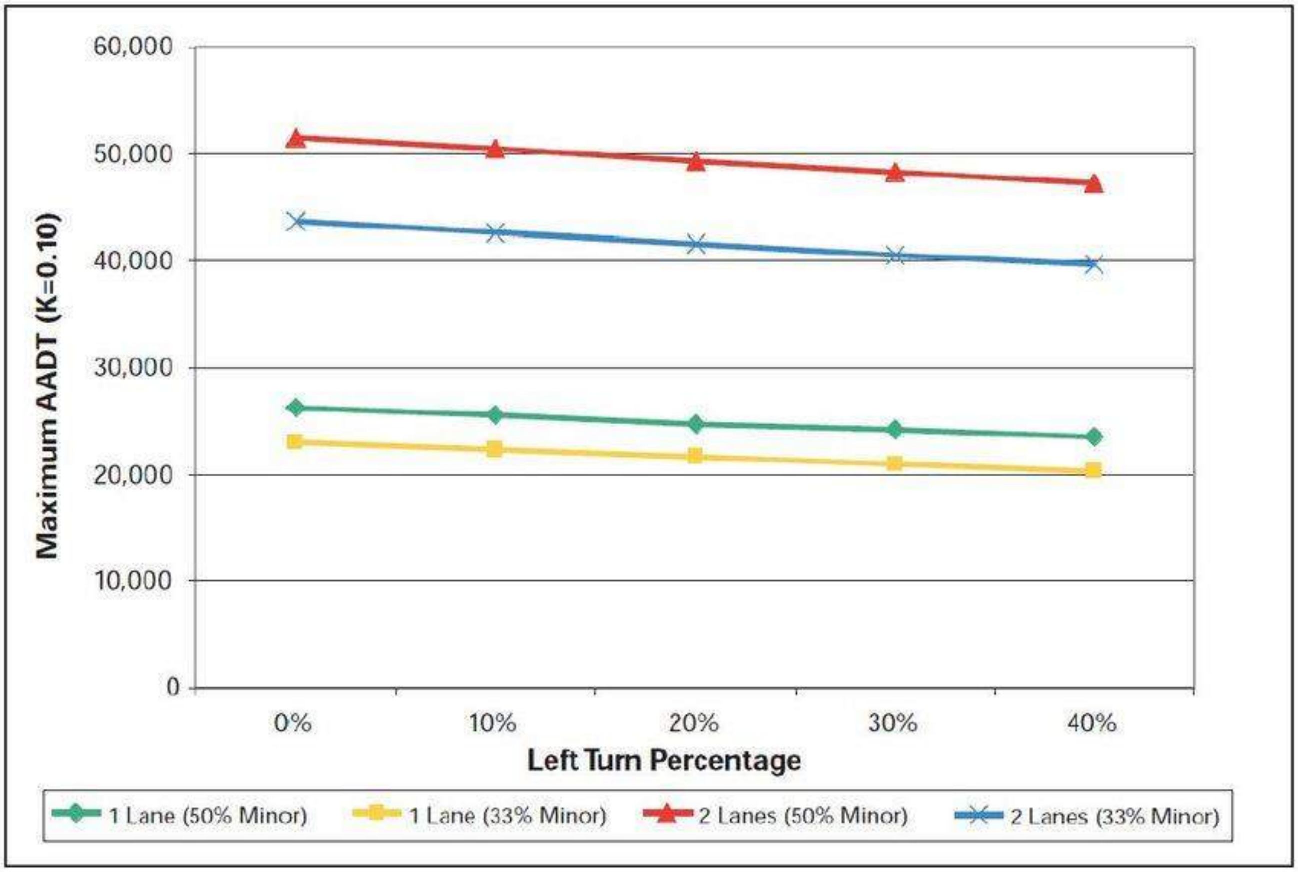


Fig. 905.3.5.2.2.5, Maximum Daily Service Volumes for a Four-Leg Roundabout

Note: Exhibit 3-1 from the FHWA's *Roundabouts: An Informational Guide*. Displayed AADT are total roundabout entering volumes. For a three-leg roundabout, use 75% of the maximum AADT volumes shown.

Table 905.3.5.2.2.6, Hourly Volume Thresholds for Estimating the Number of Entry Lanes Required

Volume Range (Vehicles per Hour, vph)[1]	Estimated Number of Lanes
0 to 1,000 vph	Single-lane entry likely to be sufficient.
1,000 to 1,300 vph	• Two-lane entry may be needed. • Single-lane entry may be sufficient based upon more detailed analysis.
1,300 to 1,800 vph	Two-lane entry likely to be sufficient.
Above 1,800 vph	• More than two entering lanes may be required. • A more detailed capacity evaluation should be conducted to verify lane numbers and arrangements.

Note: Table based on Exhibit 3-14 from the NCHRP 672 [1] Traffic volumes displayed are the sum of the entering (ve) and circulating/conflicting (vc) volumes for each, individual approach at a roundabout. Refer to Figure 905.3.5.2.2.7.

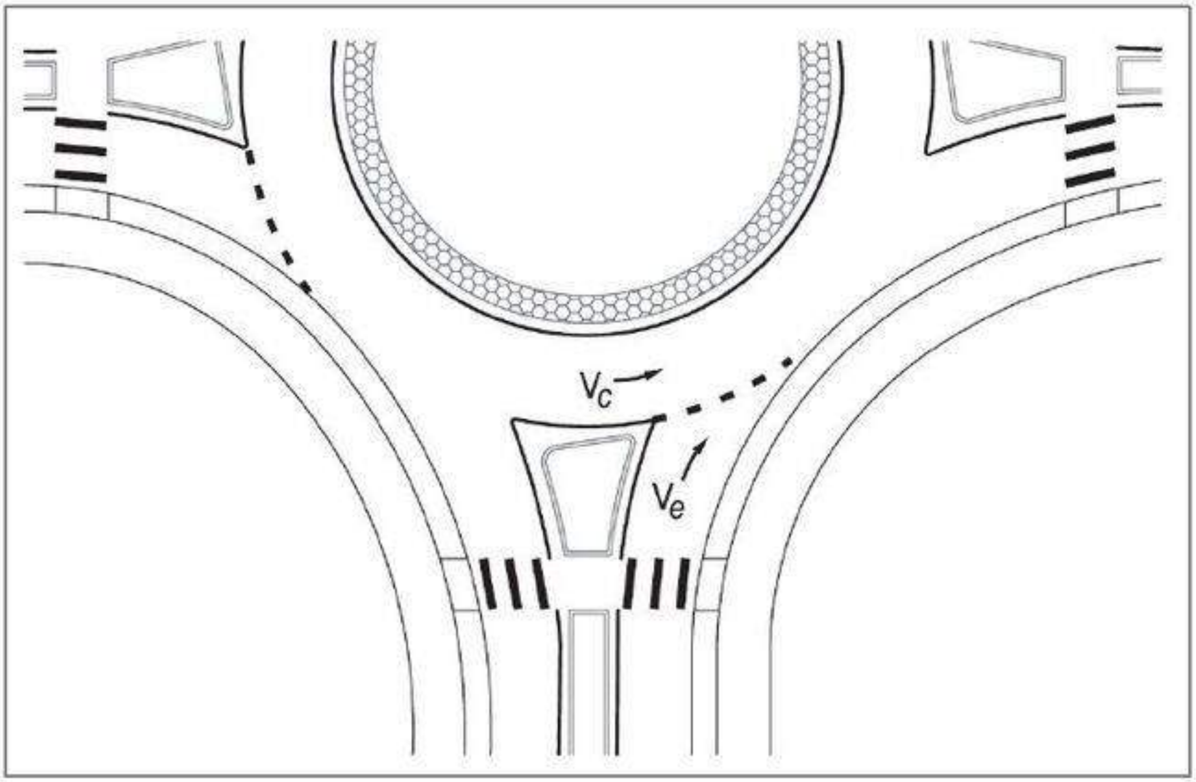


Fig. 905.3.5.2.2.7, Traffic Flows at a Roundabout Entry
Note: Based on Exhibit 3-13 from the NCHRP 672.

SIDRA Calibration

SIDRA provides the following parameters for the calibration of the roundabout capacity model. These parameters affect the follow-up headway and critical gap values (and subsequently, capacity) of all lanes on the selected leg of a roundabout. Note that the SIDRA default value should generally be used for these parameters unless calibrating the SIDRA model to field data.

- **Roundabout Model Calibration Factor (HCM methodology)/Environmental Factor (SIDRA methodology):** Using this factor, you can calibrate the SIDRA Standard capacity model to allow for less restricted (higher) capacity and more restricted (lower) capacity. Increasing the factor will provide reduced roundabout capacity, whereas lowering the factor will increase available roundabout capacity. For most analyses, this value should be increased to 1.1 or 1.2. Refer to Table 905.3.5.2.2.1 for full description.
- **Lane Blockage Calibration Factor** (located in the “Lane Movements” dialog box): The factor is specified for each lane movement and is used to adjust the effect of the downstream lane blockage (queue spillback) on the upstream lane capacity.
  - o SIDRA default value is 1.0.
  - o Values below 1.0 will decrease the effects of lane blockage

  - o Values over 1.0 will increase the effect of lane blockage.
- **Entry/Circulating Flow Adjustment** (located in the "Roundabouts" dialog box): The user can calibrate SIDRA for unbalanced flow conditions by specifying an adjustment level for the ratio of arrival flow rate to circulation flow rate. According to the level chosen, the follow-up headway and critical gap values are decreased (therefore capacity increased) as a function of the ratio of arrival flow to circulating flow in order to avoid underestimation of capacities at low circulating flows when the arrival flow rate is high. The user can choose the level of this adjustment (high, medium, low, none) according to the observed or expected local driver behavior characteristics. The default value is "None" for the "US HCM (Customary)" setup.

SIDRA Results and Presentation

After verifying that all input parameters into SIDRA are correct, it is important to run the "Process All Site(s)" button in the top left of the SIDRA interface. This will process all output information for the SIDRA intersection(s). Additionally, any subsequent revisions to an intersection after it has been processed will require the site to be processed again.

SIDRA produces several output summaries and displays that can be accessed in the bottom left of the user interface. MoDOT recommends using the Movement Summary to document roundabout measures of effectiveness (MOEs). The Detailed Output is also available if more detail is needed for a particular result.

If using illustrative outputs, the following outputs may be considered:

- Control Delay Movement Display
- LOS Movement Display
- Degree of Saturation Movement Display
- 95th Percentile Vehicle Queue Movement Display.

The primary MOEs for a roundabout include degree of saturation (v/c ratio), delay, LOS, queuing, and stop rates. These MOEs are summarized in a SIDRA Movement summary table and are highlighted in Figure 905.3.5.2.2.8. The user should take a comprehensive approach to roundabout analysis and be sure to assess all primary MOEs as part of the big picture of roundabout operations. For instance, if a LOS is reported as a D or better while v/c or queue lengths reflect poor operations, then the intersection or lane group could be considered as having the equivalent of a failing LOS.

Note: A degree of saturation of 0.85 v/c or less is desired for each lane group. If the degree of saturation is greater than 0.85, then the analyst is encouraged to perform sensitivity analysis to determine the influence of volumes on roundabout delays and queues.

Movement Performance - Vehicles												
Mov ID	Turn	Demand Flows Total veh/h	Demand Flows HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Prop. Queued	Effective Stop Rate	Aver. No. Cycles	Average Speed mph
South: Road Y												
3	L2	4	3.0	0.066	3.4	LOS A	0.3	8.3	0.20	0.08	0.20	36.0
8	T1	54	3.0	0.066	3.4	LOS A	0.3	8.3	0.20	0.08	0.20	36.0
18	R2	25	3.0	0.066	3.4	LOS A	0.3	8.3	0.20	0.08	0.20	34.9
Approach		84	3.0	0.066	3.4	LOS A	0.3	8.3	0.20	0.08	0.20	35.6
East: Road X												
1	L2	5	3.0	0.060	3.3	LOS A	0.3	7.6	0.20	0.08	0.20	36.0
6	T1	61	3.0	0.060	3.3	LOS A	0.3	7.6	0.20	0.08	0.20	35.9
16	R2	10	3.0	0.060	3.3	LOS A	0.3	7.6	0.20	0.08	0.20	34.9
Approach		76	3.0	0.060	3.3	LOS A	0.3	7.6	0.20	0.08	0.20	35.8
North: Road Y												
7	L2	9	3.0	0.043	3.2	LOS A	0.2	5.3	0.21	0.08	0.21	35.8
4	T1	23	3.0	0.043	3.2	LOS A	0.2	5.3	0.21	0.08	0.21	35.7
14	R2	22	3.0	0.043	3.2	LOS A	0.2	5.3	0.21	0.08	0.21	34.6
Approach		53	3.0	0.043	3.2	LOS A	0.2	5.3	0.21	0.08	0.21	35.2

Figure 905.3.5.2.2.8, SIDRA Movement Summary Table Example

905.3.5.2.3 Synchro

Trafficware's Synchro is a deterministic software application that supports HCM methodologies and the Intersection Capacity Utilization method for determining intersection capacity. Synchro is ideally used to analyze arterials and networks of multiple signalized and/or stop/yield-controlled intersections. The Synchro software application allows users to code roadway networks in a map-based interface (with aerial imagery overlays if desired) in addition to specifying key parameters in roadway link and intersection node tables. Then the user can specify the types of MOEs to quantify in auto-generated summary reports (refer to Accompaniment to Synchro/SimTraffic for more information).

HCM vs. Synchro

Synchro calculations are based off HCM methodologies. However, Synchro delay calculations will differ from the HCM results due to some differences. The HCM method uses one cycle length and one average traffic volume to represent the analysis period. In contrast, Synchro uses a percentile delay method for calculating the delay for signalized intersections, which is based on five different volume and cycle lengths (percentile volumes and green times). The final Synchro calculated delay is a weighted average of five representative delays.

The five representative delay scenarios modeled include the 90th, 70th, 50th, 30th, and 10th percentiles. Traffic volumes for each approach are adjusted up or down to model these percentile scenarios. For instance, if traffic were to be observed for 100 cycles, 90th percentile would be busier than 89 other cycles. Generally, HCM and Synchro results will be similar (refer to Table 905.3.5.2.3.1) if the actuated green times are used in the HCM method. SimTraffic results, however, are based on the "observed" delay in the SimTraffic microsimulation model runs and could reasonably deviate from the HCM and Synchro results. Therefore, it is reasonable for different methodologies and/or tools to produce different results.

Project Purpose

The purpose for which Synchro/SimTraffic is being used will determine the level of detail, precision of the input data, the number of default values, and the desired accuracy of results. The Synchro/SimTraffic parameters described in EPG 905.3.5.2.3 Synchro and EPG 905.3.5.3.1 SimTraffic are intended primarily for capacity analysis. The setting parameters identified in this guidance can be applicable to optimizing traffic signals, but signal timing optimizing projects typically utilize more field and signal timing plan data that is context-sensitive to the particular signal(s). It is recommended that Synchro/SimTraffic should NOT be used for freeway analysis.

Synchro Report Settings

Synchro uses two different methods to calculate and report signalized intersection delays: the HCM method and the Synchro Percentile delay method. In most situations, the delays calculated by both methodologies are similar and will be within a few seconds of each other. Table 905.3.5.2.3.1 highlights the key differences in these two methods. The method to be used should be discussed during scoping and documented in the analysis report.

Table 905.3.5.2.3.1, Methodology Differences in Synchro

Limitation	Synchro Percentile Delay Method	HCM 6th Edition
Spillback and Starvation Delay (caused by closely spaced intersections)	Includes a method to model this delay when intersections are close to each other	Does not include any delay for queue spillback or starvation
Actuated Green Time Calculations	Synchro determines actuated green times	Includes computational engines
Right Turn on Red (RTOR)	Synchro calculates a RTOR saturation flow rate, and increases the right-turn capacity.	The RTOR is a volume input by the user and is used as a volume reduction (not a capacity increase).
Turn Pocket Overflow	Both methods have this limitation. If vehicles are spilling out of a turn pocket or through vehicles are blocking a turn pocket, the delay that would occur in the field is not included in the models' delay output.	
Note: Based on Table 19-2 in *Synchro 10.1 User's Guide*.		

Refer to Section D. 11 in Accompaniment to Synchro/SimTraffic for more information on selecting the analysis method in the Synchro Report Settings dialog box.

Synchro Coding Recommendations

Coding roadway networks in Synchro is intuitive and can primarily be accomplished using icons in the Home tab. For a detailed introduction to coding, it is recommended that the user access the Synchro User Guide in the Help tab of Synchro. (Refer to Figure 905.3.5.2.3.2).

Figure 905.3.5.2.3.2, Synchro User Guide

Since effective network coding can be nuanced, best practices to be aware of include the following:

- Intersection approaches should be coded using cardinal directions only (e.g., north, south, east, and west). Other approach directions (e.g., northeast, southeast, northwest, and southwest) could potentially prevent Synchro from discerning turn movements from through movements. This would lead to inaccurate capacity and queueing results. However, if non-cardinal directions are needed for an intersection (an example would be an intersection with more than 4 legs), then be sure to thoroughly check that all appropriate traffic movements are properly assigned.
- The analysis period should remain at the Synchro-default of 15 minutes.
- The absence of traffic volumes on certain traffic movements could potentially lead Synchro to incorrectly calculate one or more movements as being prohibited. It is advised that traffic volumes should be changed from any value less than 4 vehicles per hour (vph) to 4 vph for non-restricted movements (**Note:** this is a Synchro-only issue and is not a concern for other tools such as HCS).
- All external links should extend reasonable distances from an intersection (at least 1,000 feet if not constrained by nearby intersections) to ensure adequate queueing can be calculated in subsequent SimTraffic runs.

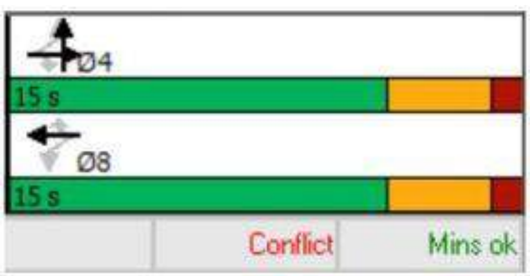


Figure 905.3.5.2.3.3, Conflicting Movements Example

- The link speed should represent the posted or proposed speed limit of the actual roadway.
- Overlaps between conflicting traffic movements should be avoided. Figure 905.3.5.2.3.3 shows an example of how conflicting movements can be identified using both the ring-and-barrier diagram and error notifications that will appear at the bottom of the Timing Settings table. Additionally, a common error to avoid is the coding of conflicts between U-turn and right-turn movements.

• If analyzing median-controlled facilities where each bound is coded as a separate link, then left turns or U-turns should be modeled on separate links. On these short turn-only median links, both the “Simulation Left Turn Speed” entering the link and the link speed should be 10 mph below the speed limit. Refer to Figure 905.3.5.2.3.4.

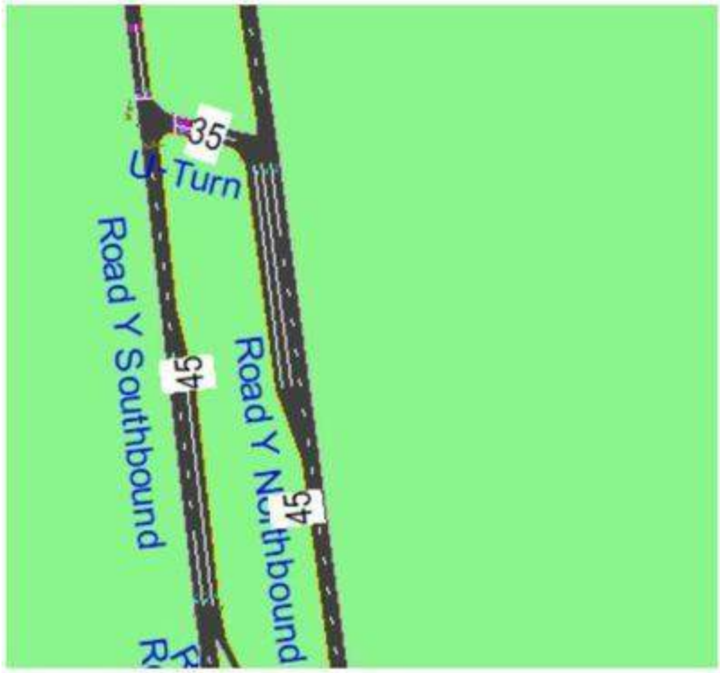


Figure 905.3.5.2.3.4, U-Turn Speed Example
Note: Link speeds displayed on links

• Be aware of and document locations that could impact lane usage (e.g., a lane merge beyond an intersection or an advanced turn lane at a diamond interchange). Modify the lane utilization factor where appropriate (see Table 905.3.5.2.3.6).
• Use the Coding Error Check. Click on “Options” and then “Error Check” to identify all errors and warnings by location (e.g., node number and traffic movement) and error type. Try to address all errors and warnings if possible.

Coding with Cluster Editor

The cluster editor can be activated by selecting the “Cluster Editor” button from the Signal Timing group on the Home tab. The cluster editor allows multiple intersections to share one controller (Group control) through interactive selections and color coding in a dialog box. The cluster editor is often used in conjunction with the Ring and Barrier Designer. The cluster editor is especially useful for assigning group control to diamond interchanges, closely spaced intersections, and arterials with wide medians modeled as two nodes. Some important items to be aware of for cluster editor include:

• The smallest node number in the cluster is the controller number that will be used for data exchange.
• With group control, it is recommended that each intersection use phases in one ring only. All phases for one node should, ideally, be contained in one ring.

Key Synchro Parameter Recommendations

Table 905.3.5.2.3.5, Table 905.3.5.2.3.6, and Table 905.3.5.2.3.7 summarize key Synchro parameters with specific MoDOT guidance for proper application. In general, field data should be used when available. In the absence of field data, the tables below provide some suggested parameter values.

Note: Simulation Settings parameters are summarized in EPG 905.3.5.3.1 SimTraffic. Although Simulation Settings values are entered in the Synchro user interface, these parameters tend to be either visual or non-applicable in Synchro, but influence driver simulation settings in SimTraffic.

Table 905.3.5.2.3.5, Synchro Intersection Signal/Node Settings: Typical User-Adjusted Attributes (When Field Data is Not Available)

Parameter(s)	Parameter Description	Suggested/Typical Value(s)
Node#[1]	Unique number assigned to all intersections and non-intersection nodes in Synchro. The Node# can contain a maximum of 4 digits.	**Signalized Intersection:** Use the first 4 digits of a signal ID number (MoDOT signal IDs range from 1xxx to 8xxx). **Unsignalized Intersection:** Use a 4-digit value that starts with a "9" (9xxx).
Z Elevation (ft)	The elevation (in feet) of the nodes relative to the project-specific baseline elevation (the default Synchro value is 0 feet).	To create an overpass, assign higher Z coordinate elevation values to the nodes adjacent to the overpass link (used for visual purposes only).
Referenced to	The defined point that creates an association between a local, signalized intersection's clock and the master clock for multiple, signalized intersections in a coordinated signal system. Selection options include: **Begin of Green:** Offsets are referenced to the beginning of the last reference phase to turn green (Traditional NEMA referencing and the Synchro default for new intersections). **Begin of Yellow:** Offsets are referenced to the beginning of the first reference phase to turn yellow (this is 170 style referencing). **Begin of Red:** Offsets are referenced to the beginning of the first reference phase to turn red.	The Synchro model should match the controller where possible. For additional information about how to appropriately match to the controller, refer to the sources: • *FHWA Signal Timing Manual 1st Edition*: Refer to Section 6.3.4 and Figure 6-7. NCHRP 812 supersedes this document. • *NCHRP 812: Signal Timing 2nd Edition*

	TS2 – 1st Green: Offsets are referenced to the beginning of the first reference phase to turn green (used with some NEMA TS2 controllers). **170 Style:** Referenced to start FDW or start of yellow.	
Reference Phase	The Reference Phase is used to determine the coordinated phase(s) for an actuated signal.	Select the appropriate reference phase as determined in the coordinated signal plan (if nothing specified, refer to phases 2 and 6).
Coordination Mode	The coordinated phases associated with the arterial street.	Select one of the two options below that is most appropriate for the intersection(s) being analyzed: **"Fixed" Force-Off (Synchro default):** A mode of split management used with coordinated operations under which force-off points cannot move. Under this mode, uncoordinated phases can utilize unused time from previous phases. **"Floating" Force-Off:** Force-off points can move depending on the demand of previous phases. Under this mode, uncoordinated phases are limited to their defined split times, and all unused time is dedicated to the coordinated phases.
[1] **If there are multiple intersections with other, similar Node #'s:** Use the "Select Int." button to confirm that the desired new node # does not already exist and to adjust the other intersection's node # as needed. If Synchro identifies two nodes with the same ID #, then it will automatically swap intersection node #'s.		

Table 905.3.5.2.3.6, Synchro Lane Settings: Typical User-Adjusted Attributes (When Field Data is Not Available)

Parameter(s)	Parameter Description	Suggested/Typical Value(s)
Grade (%)	The grade will impact the saturation flow rate. For instance, a negative grade (downhill) will increase the saturation flow rate. An example would be a one lane approach with a saturated flow rate of 1,780 pc/h/ln (0% grade) increasing to 1,833 pc/h/ln with a -6% grade. So, in this example, an	**Flat Grade:** 0% **Moderate Grade:** 3% **Steep Grade:** 6%

	approximate 3% saturation flow rate increase provides a 6% reduction in grade. MoDOT TMS and Google Earth are potential data source for grades.	
Lane Utilization Factor	Determines how the traffic volumes assigned to a lane group are distributed across each lane. A value of 1 means equal distribution across all lanes and less than 1 means the saturation flow rate is low because all lanes are not working at full capacity. The available range to override in Synchro is from 0.2 to 1.0. Synchro automatically defaults to lane utilization factor values to match the number and type of lanes in a lane group. These factors are based on Exhibit 19-15 in the HCM, 6th Edition, and can be found in Table 8-2 of the *Synchro 10.1 Users Guide*. Common situations that would lead to the user needing to override default values include the dropping of downstream lanes and downstream turning locations that would cause a higher proportion of vehicles to be in a particular lane to turn, such as a diamond interchange with advanced left turn lanes. The NCHRP 707, *Guidelines on the Use of Auxiliary Through Lanes at Signalized Intersections*, provides good information on this topic, including a spreadsheet to help calculate auxiliary through lane utilization: **NCHRP 707 PDF Report** **NCHRP 707 Spreadsheet**	
Saturation Flow Rate	The equivalent hourly rate at which previously queued vehicles can traverse an intersection approach under prevailing conditions, assuming the green signal is available at all times and no lost times are experienced. Saturation flow rate is expressed as an expected average hourly rate in units of passenger car equivalents per hour per lane (pc/h/ln). The HCM states that the base saturation flow rate for a metropolitan area (greater than 250,000 population) is 1,900 pc/h/ln and the base saturation flow rate non-urban areas is 1,750 pc/h/ln (the Synchro default is set to be 1,900 pc/h/ln).	The base/ideal saturated flow rate is then adjusted by various factors to account for prevailing geometric and traffic conditions in the field. This adjustment will calculate the saturated flow rate, which typically results in a final rate that is lower than the base/ideal rate. Synchro will automatically calculate saturated flow rates for every traffic movement and display these auto-calculated values in the Lane Settings table and in Synchro reports. The saturated flow rate can be overridden using field data and/or for calibration purposes.
Right Turn Channelized	**None:** No right-turn channelization; **Yield:** Yield sign with no phases assigned; **Stop:** Stop sign with no phases assigned; **Free:** Phase is "free" (100% green time); **Signal:** Movement is controlled by the signal	

Curb Radius (ft)	Value only appears if Right Turn Channelized is selected. Curb Radius specifies the horizontal curvature of the street intersection.	Note that this is strictly a visual item that does not impact traffic calculations, so long as the same traffic control measure is applied for the movement (signal, yield, free, etc.)

Table 905.3.5.2.3.7, Synchro Volume, Timing, & Phasing Settings: Typical User-Adjusted Attributes
(When Field Data is Not Available)

Dialog Box	Parameter(s)	Parameter Description	Suggested/Typical Value(s)
Volume Settings	Adjacent Parking Lane and Parking Maneuvers (#/hr)	Check the box and enter data if there is on-street parking AND that it impedes traffic flow.	
	Traffic from Mid-Block (%)	Use default value of 0%. (Using mid-block volumes can be evaluated on a case-by-case basis as necessary.)	
	Link OD (Origin-Destination) Volumes	All approaches that connect to an adjacent intersection have a button available in the Link O-D Volumes row. The user can activate the settings by clicking on this button:  Link OD volumes allow detailed control over the origin and destination flows between two adjacent intersections. Volume balancing can reduce or eliminate certain turn combinations. In most cases, Link O-D volumes are not needed since O-D volumes make little difference to the timing plan optimization. The most common use is to prevent vehicles from turning left twice (i.e., a U-turn) at a freeway or wide median arterial. For a full, detailed guide on how to use the Link OD Volumes feature, refer to pages 9-6 through 9-9 in the *Synchro Studio 10 User Guide*.	
Timing Settings	Permitted Flashing Yellow Arrow	The "Permitted Flashing Yellow" parameter is a checkbox in the Synchro Timing Settings grid that is only available when the signal turn type is selected to be Dallas Permitted plus protected ("D.P+P"), permitted plus protected ("pm+pt"), or "Reserved." For the purposes of SimTraffic, a flashing yellow arrow turn will operate the same as a permissive turn, so the selection of the "Permitted Flashing Yellow" checkbox will not affect analysis results and will only be displayed visually in SimTraffic.	
Phasing Settings[1]	Pedestrian Phase	Select checkbox if there is a pedestrian movement for a phase.	

[1] To model a leading pedestrian interval (LPI) in Synchro, the analyst would assign a separate phase for the pedestrians (such as phase 9 and 10) and edit the ring/barrier structure for it to be

serviced before the side street vehicle phase. However, for this to model correctly in SimTraffic it is important to note that pedestrian volumes would need to be coded into Synchro and the proper detector settings be entered so that the phase(s) will be serviced in simulation. With this method, the split shown in Synchro for the side street vehicular phase will not be the split that is programmed into a signal controller, which could be confusing when exporting timings. There are other nuances that would need to be addressed so any context as to how the analyst desires to use LPIs would help determine if other software would be appropriate (i.e., will the analysis be used for capacity or signal timing coordination?). LPIs can have safety benefits for pedestrians but can also negatively impact the operations of signals.

Optimizing Signals in Synchro

Synchro contains a number of optimization functions. It is important to understand what each function does and use the optimization steps in the correct order:

1. **Develop Intersection Timing Plans** – Develop timing plans for individual intersections through the following steps:
    a. Enter lane data
    b. Enter volume data
    c. Set up phase numbers for each movement
    d. Optimize cycle lengths and splits using the "Optimize" buttons in the Node Settings dialog box
    e. Check capacity
    f. Check for coding errors.
2. **Partition Network (Optional Step)** – Use the "Partition Network" command under the Optimize tab in Synchro to divide the network into multiple zones. Assigning zone numbers can also be assigned manually in Node Settings.

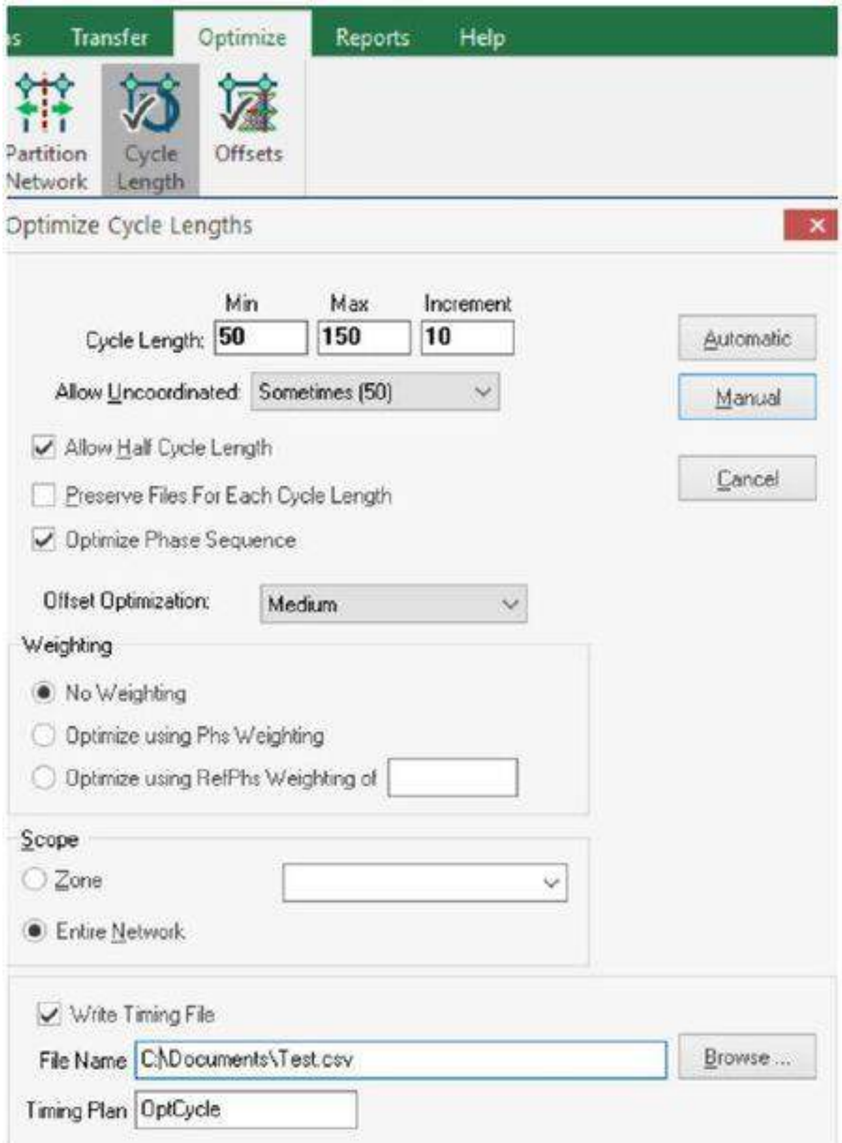


Figure 905.3.5.2.3.8, Synchro *Optimize Cycle* Lengths Dialog Box

3. **Optimize Network Cycle Length** – Determine a system cycle length (if zones are created, then a consistent cycle length for each zone). Optimize using the following steps, which inform how to complete the Optimize Cycle Lengths dialog box (refer to Figure 905.3.5.2.3.8):

a. **Minimum, Maximum, and Increment Cycle Length:** The optimizer will evaluate every cycle length between the minimum and maximum at increment intervals. If the values are set to 80, 100, and 10, the optimizer will evaluate cycle lengths of 80, 90, and 100 seconds. Recommend 60, 240, 10.

b. **Allow Uncoordinated:** This option setting determines how frequently signals will be recommended to remain uncoordinated. Recommend “Sometimes (50)”

c. **Allow Half Cycle Length:** With this option, some intersections would be tested at half cycle length. Recommend “checked”

d. **Preserve Files:** With this option, a file is saved for each cycle length. Recommend “unchecked”

e. **Optimize Phase Sequence:** If this is checked, leading and lagging left-turn combinations will be tested. However, lead/lag combinations will NOT be tested if the "Allow Lead/Lag Optimize?" setting is not checked in the Phasing table. Recommend "checked"

f. **Offset Optimization:** The options ("Quick," "Medium," or Extensive") determine the level of detail and speed that will be used for analysis. Recommend "Extensive"

g. **Weighting:** Choose the default "No Weighting" option

h. **Scope:** Choose if the analysis is for a particular zone or the entire network

i. **Manual/Automatic:** Selecting manual will create a summary table of cycle length and MOE combination options that the user can select from. Recommend "Manual".

4. **Optimize Offsets and Lead/Lag Phasing** – Tests all possible offset and lead-lag combinations to select a timing plan that minimizes delays on the links between the intersections. This function allows for the following options:

a. Splits to remain the same or to be optimized. Recommend "Optimize"

b. For a quick or longer, more detailed optimization. Recommend "Best Timing Plans"

c. For the "Weighting the Reference Phase" option to be selected (which would focus the offset optimization routine on minimizing delay for the reference phases). Recommend "No Weight"

d. A zone or a network scope.

Queue Lengths in Synchro/SimTraffic

Synchro reports calculated 50th percentile and 95th percentile queue lengths. SimTraffic reports the simulated average, maximum, and 95th percentile queue lengths. Both programs estimate queue lengths to the nearest foot. The queue lengths are determined using different methods between Synchro and SimTraffic.

Since SimTraffic is a micro-simulation program, it actually "observes" each individual vehicle and documents whenever a vehicle is traveling less than 10 feet per second and behind a queue of vehicles. This process can often lead to different queuing results than Synchro, especially when queuing vehicles from adjacent intersections are influencing the subject intersection. **It is advised that Synchro 95th Percentile Queue lengths and SimTraffic Maximum Queue lengths be the primary queue metrics that are analyzed and reported.** In particular, Synchro 95thPercentile Queue lengths that are over or approaching capacity should be compared to SimTraffic Maximum Queue results to verify the queuing issue.

Synchro/SimTraffic Storage Lane Review

A mitigating strategy for a project could include recommending longer and/or additional storage lanes. In order to determine appropriate storage lane recommendations, both Synchro and SimTraffic output should be reviewed. Table 905.3.5.2.3.9 provides a summary of the queues reported in Synchro and SimTraffic.

Table 905.3.5.2.3.9, Queue Lengths in Synchro & SimTraffic

Synchro Queues Reported	SimTraffic Queues Reported
Unsignalized Queues – Computed according to the HCM method	**Maximum** – The maximum observed distance from the stop bar to the back of queue over the analysis period. Note that it is limited by the length of the link. It is recorded every two minutes during the simulation.
50th Percentile – The maximum back of queue on a typical cycle. Computed using a formula.	**Average** – The average of the observed maximum queues for each of the recorded two-minute periods
95th Percentile – The maximum back of queue with 95th percentile traffic volumes. Computed using a formula.	**95th Percentile** – A computed queue that is computed as 1.65 standard deviations above the average queue. Therefore, the 95th percentile queue can be greater than the maximum queue and is not limited by the length of the link.
Synchro Analysis Conclusion:	**SimTraffic Analysis Conclusion:**
Use the 95th Percentile Queue to assess delay and/or queueing problems. For locations where this delay and queueing problems are a concern, then compare it to SimTraffic's Maximum Queue.	Use the Maximum Queue since it is a simulated, "observed" queue that accounts for traffic variability and adjacent intersections.

Synchro Review: If an approach or movement has a 95th Percentile Queue length that is flagged with a "#" or "m" or a 50th Percentile flagged with a "~," then the intersection should be thoroughly reviewed for potential improvement opportunities since there could be serious delay and/or queuing problems. Additionally, the Synchro output should be compared to SimTraffic output (or other analysis tools such as VISSIM), if available, to better understand what is causing the delay. Additional documentation should be provided if the following footnotes are displayed in a Synchro report:

- "~" indicates the approach is above capacity for the 50th percentile traffic and the queue length could be longer
- "#" indicates that the volume for the 95th percentile cycle exceeds capacity
- "m" indicates that volume for the 95th Percentile Queue is metered by an upstream signal.

SimTraffic Review: All instances where the SimTraffic maximum queue length (maximum observed queue) exceeds the storage bay length should be addressed. The **SimTraffic Maximum Queue** or the **Synchro 95th Percentile Queue**, whichever is higher, should be used in determining recommended storage lane lengths. **Do NOT use the SimTraffic 95th percentile queue since it is statistically estimated from the mean queue and the standard deviation.** The *Synchro 10.1 User's Guide* states that, "the (SimTraffic) 95th Queue is not necessarily ever observed, it is simply based on statistical calculations." Excessive queuing identified in SimTraffic should be reviewed for appropriateness and unrealistic lane blockages.

905.3.5.3 Microsimulation Models

Microsimulation models simulate the movement of individual vehicles based on vehicle and driver behavior theories. These models are good for large-scale transportation facilities and for analyzing interactions with other vehicles and adjacent intersections to help determine MOEs. An important consideration is determining if the project being assessed is appropriate for the extra levels of effort and large computer processing time and storage requirements often needed for microsimulation models. Common microsimulation tools that will be summarized in EPG 905.3.5.3 Microsimulation Models include SimTraffic and VISSIM.

For all microsimulation models it is important to complete multiple simulation runs per peak hour scenario. Completing multiple simulation runs provides the following benefits:

- Accounts for the variability in traffic flow patterns (to complete only one simulation run would be the equivalent of assuming that peak hour traffic on one day is representative of traffic on all days throughout the year)
- To verify model results by minimizing the influence of "outlier" runs
- To accurately quantify the results of higher delay and queues.

905.3.5.3.1 SimTraffic

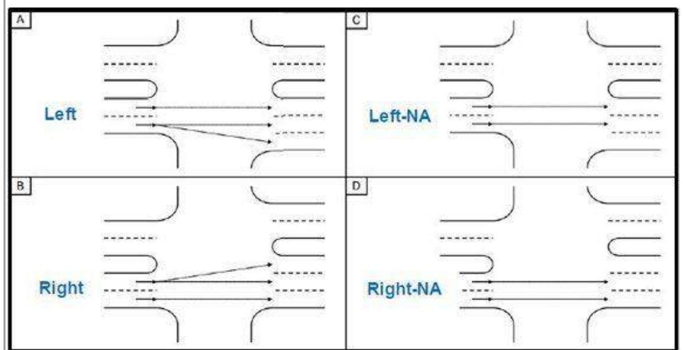
SimTraffic is microsimulation software that simulates the movement of individual vehicles based on vehicle and driver behavior theories. SimTraffic simulates the coded transportation network and measures the performance of each individual vehicle as they move through the system. Since each individual vehicle will react differently to the influences of other vehicles, pedestrians, bicyclists, roadway geometry, and grades, models with the same geometric and volume inputs will generate slightly different results, similar to how an intersection in the field will perform differently day-to-day under otherwise identical conditions.

Key Simulation Settings Recommendations

Tables 29, 30, and 31 summarize key Synchro/SimTraffic parameters with specific MoDOT guidance for proper application. In general, field data should be used when available. In the absence of field data, the tables below provide some suggested parameter values.

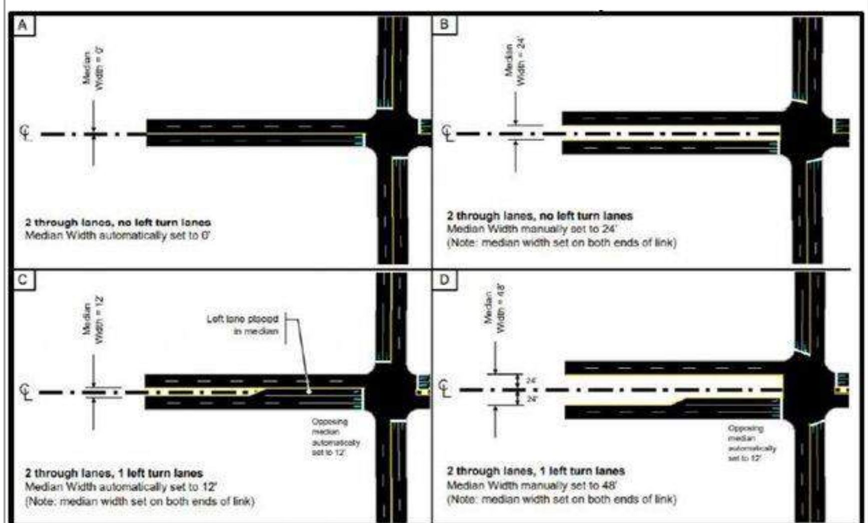
Note: Simulation Settings parameters are summarized in EPG 905.3.5.3.1 SimTraffic. Although Simulation Settings values are entered in the Synchro user interface, these parameters tend to be either visual or non-applicable in Synchro, but influence driver simulation settings in SimTraffic.

Table 905.3.5.3.1.1, Synchro/SimTraffic Simulation Settings: Typical User-Adjusted Attributes (When Field Data is Not Available)

Parameter(s)	Parameter Description	Suggested/Typical Value(s)
Lane Alignment	This setting determines how lanes align through an intersection. Refer to Figure 905.3.5.3.1.1 (Figure 13-2 from *Synchro Studio 10* User Guide) to the right. **Synchro-default values:** "Right" for right turns, "Left" for left turns, & "Right-NA" for U-Turns. For more discussion on the impacts that the Lane Alignment can have on vehicles simulated in SimTraffic, please refer to Trafficware blog.	 **Figure 905.3.5.3.1.1, Lane Alignment Examples** **Note:** Ensure default settings are correct when the number of receiving lanes exceeds the approach lanes.
Enter Blocked Intersection	The "Entered Blocked Intersection" setting controls simulation modeling gridlock avoidance (e.g., a selection of "1" or "2" will allow 1 or 2 vehicles to enter a blocked intersection.) The following node types generally correspond to the following selection values: • **Intersections:** "No" • **Bends/Ramp Junctions:** "Yes" • **High Speed Approaches/Movements:** "No" • **Unsignalized Intersection Side Street:** "1" or "2"	For most MoDOT applications, set the parameter to "1" unless otherwise specified or not appropriate.
Two-Way-Left-Turn-	A visual-only display of a TWLTL median	User-defined selection

Lane (TWLTL) Median	(simulated vehicles will not actually use the TWLTL median).	

Table 905.3.5.3.1.2, Synchro/SimTraffic Simulation Settings: Typical User-Adjusted Attributes (When Field Data is Not Available)

Parameter(s)	Parameter Description	Suggested/Typical Value(s)
Median Width (ft)	This parameter determines the link's median width. Note that left-turn lanes are considered to be positioned in the median even if they are not defined as storage lanes. This setting is Synchro-calculated, but it can be overridden. See Figure 905.3.5.3.1.2 (Figure 13-4 from *Synchro Studio 10* User Guide) for examples.	 **Figure 905.3.5.3.1.2, Median Width Examples**
Link Offset (ft)	Setting is used to offset the roadway alignment to the right or left of the centerline. This can be used to create a dog-leg intersection, if there are no internal stop bars. See Figure 905.3.5.3.1.3 (Figure 13-5 from *Synchro Studio 10*	

	User Guide) for examples. **Synchro-default value:** 0 ft

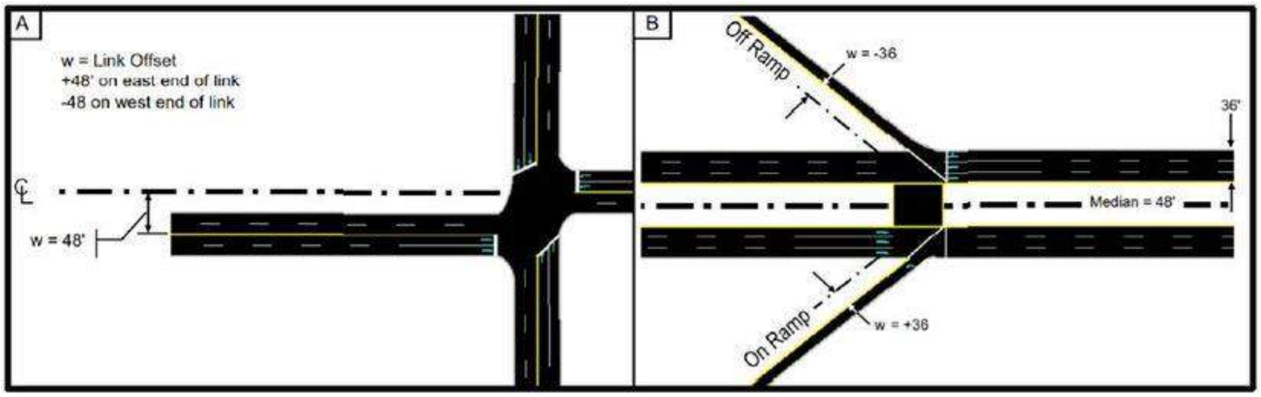


Figure 905.3.5.3.1.3, Link Offset Examples

Table 905.3.5.3.1.4, Synchro/SimTraffic Simulation Settings: Typical User-Adjusted Attributes (When Field Data is Not Available)

Parameter(s)	Parameter Description	Suggested/Typical Value(s)
Turning Speed (mph)[1]	The turning speed of vehicles while inside the intersection (utilized in SimTraffic only, not Synchro).	**Synchro-default left-turn value:** 15 mph **Synchro-default right-turn value:** 9 mph
[1] It is recommended to use the Synchro/SimTraffic default values for this attribute. However, for intersections with large turning radii and for the modeling of intersections with freeway entrance/exit slip ramps, the turning speeds can be adjusted higher IF set to reasonable ranges. The best way to determine a reasonable range is to review field data and to review if the simulated turning movement saturated flow rates are reasonable. Refer to Figure 905.3.5.3.1.5 for a sample of right-turn speeds for different turning types, as observed by MoDOT.		

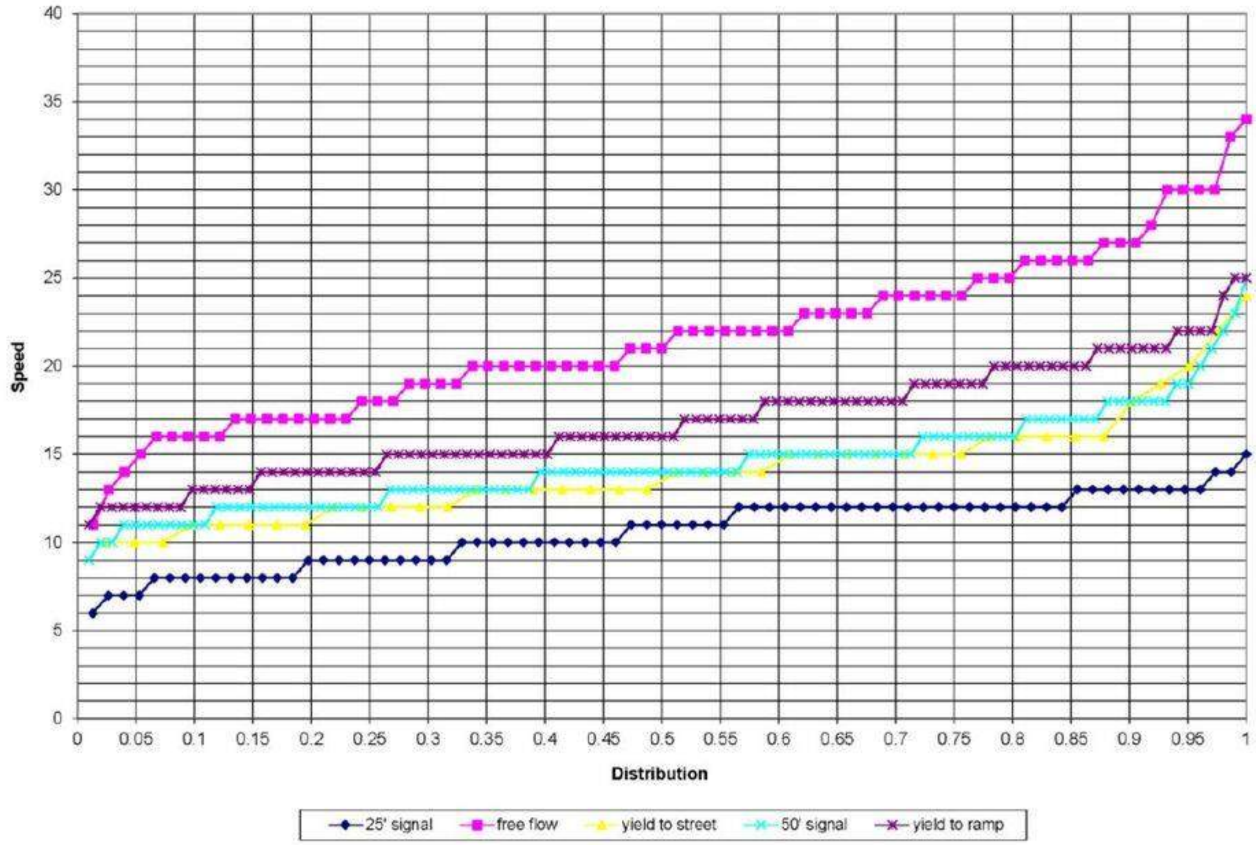


Figure 905.3.5.3.1.5, MoDOT Field Data Sample of Right-Turn Speeds

SimTraffic Calibration

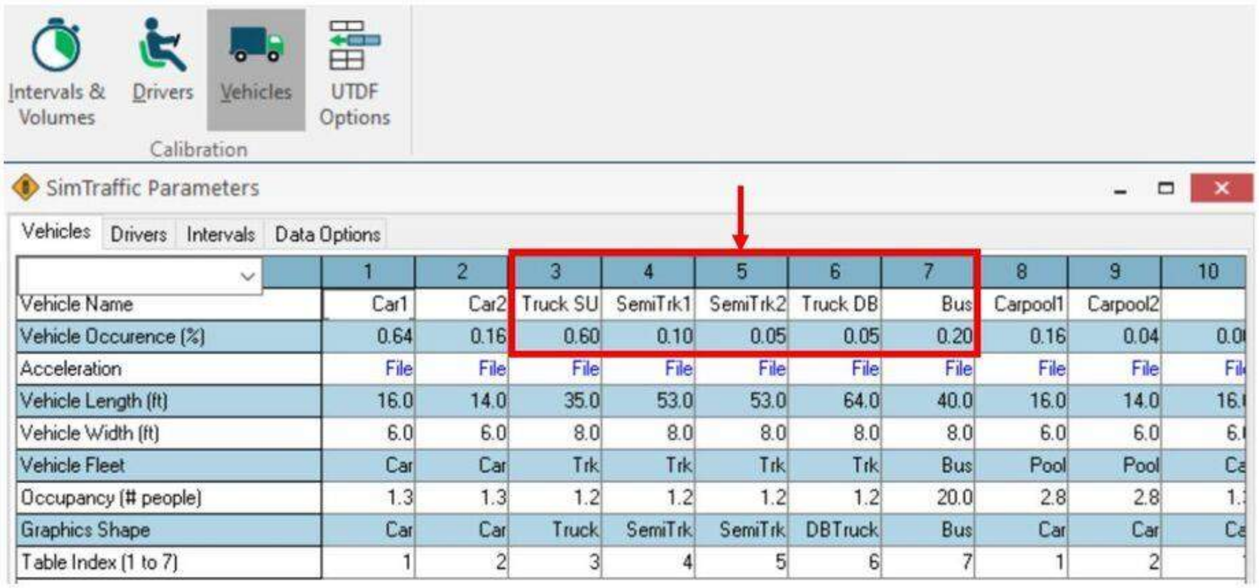
Complete the following steps to utilize SimTraffic simulation and animation:

1. Open SimTraffic by clicking on the SimTraffic icon under "Home"/"Simulation"
2. Coding Error Check – Click on "Options" and then "Coding Error Check" to identify all errors and warnings by location (e.g., node number and traffic movement) and error type. Try to address all errors and warnings if possible, which may require making coding revisions in Synchro.
3. Establish SimTraffic calibration parameters using the following 4 tables under the "Calibration" section:

   a. Intervals & Volumes – Networks should be seeded for a period long enough to traverse the two most distant points of the network, including stops prior to recording, with a minimum of 15 minutes. The seeding time should also be longer than the maximum cycle length used in the network. The recording interval duration used in SimTraffic should be 60 minutes unless otherwise justified. It is recommended to break the recording duration into 15-minute intervals with one of the middle intervals set to "PHF Adjust" of "Yes." The other intervals should be set to "AntiPHF Adjust" of "Yes."

   b. Drivers – ***Start with default values.*** When vehicles are created, they are randomly assigned a driver type between 1 and 10. Each driver type represents 10% of the driving population with driver type 1 being the most conservative and driver type 10 being the most aggressive.

c. Vehicles – ***Start with default values.*** This page can be used to view and edit the vehicle characteristics (refer to Figure 905.3.5.3.1.6). Note that the total proportion of heavy vehicles (among all vehicles) is determined in Synchro and that the vehicle occurrence percentages on this page are among the total number of heavy vehicles established already. To simulate a higher proportion of certain heavy vehicle types on known freight corridors, the proportions of the "Truck SU," "SemiTrk1," "SemiTrk2," "Truck DB," and/or "Bus" could be adjusted higher (while lowering another, lesser occurring heavy vehicle type).



	1	2	3	4	5	6	7	8	9	10
Vehicle Name	Car1	Car2	Truck SU	SemiTrk1	SemiTrk2	Truck DB	Bus	Carpool1	Carpool2	
Vehicle Occurence (%)	0.64	0.16	0.60	0.10	0.05	0.05	0.20	0.16	0.04	0.0
Acceleration	File	File	File	File	File	File	File	File	File	Fil
Vehicle Length (ft)	16.0	14.0	35.0	53.0	53.0	64.0	40.0	16.0	14.0	16.
Vehicle Width (ft)	6.0	6.0	8.0	8.0	8.0	8.0	8.0	6.0	6.0	6.
Vehicle Fleet	Car	Car	Trk	Trk	Trk	Trk	Bus	Pool	Pool	Ca
Occupancy (# people)	1.3	1.3	1.2	1.2	1.2	1.2	20.0	2.8	2.8	1.
Graphics Shape	Car	Car	Truck	SemiTrk	SemiTrk	DBTruck	Bus	Car	Car	Ca
Table Index (1 to 7)	1	2	3	4	5	6	7	1	2	

Figure 905.3.5.3.1.6, SimTraffic Vehicle Parameters

d. UTDF (Data) Options – This page allows volume counts and timing plans to be read from an external data source.

4. Refer to both **SimTraffic Model Runs** and **SimTraffic Report Settings** for documentation and establishing multiple runs.

SimTraffic Model Runs

EPG 905.3.5.3 Microsimulation Models summarizes the importance of completing multiple model simulation runs. It is advised that between 5 and 9 simulation runs be completed in SimTraffic for each peak hour scenario (e.g., a minimum of 10 cumulative runs should be completed if analyzing both AM and PM peak hours).

If determining when to complete 5 Simtraffic runs as opposed to 9 runs, it is advised that the modeler stick to the lower end of the range if there is a low volume demand and minimal congestion on the transportation network. It is advised that the modeler run a higher quantity of runs (in the acceptable range) if there is high delay and excessive queuing on the transportation network. No more than 9 runs per peak hour scenario would be needed since SimTraffic has a partner tool in Synchro, which results can be compared to for reasonableness.

SimTraffic Report Settings

Complete the following steps to document SimTraffic results through auto-generated reports created in the software.

1. Select the appropriate report items by clicking on "Reports" and then "Create Reports" (multiple items can be selected using the "CTRL" button)
2. Under the "Reports" tab, select the desired summaries as needed for the specific analysis type:
    a. For a queueing and blocking report, select the "Queuing Information" checkbox
    b. Select "Performance Report" to document network MOEs. Once selected, the user can select options in the "MOEs to include" list by holding CTRL and choosing multiple MOEs. For a capacity analysis, the following MOE items, at a minimum, should be selected:
        i. All "Delay" options
        ii. All "Network" options
        iii. Under "Other," select "Total Travel Distance," "Total Travel Time," and "Average Speed"
        iv. Under "Section, Columns," select "Intersection, Movement." To see variability by run, select an option ending with "Run Number"
3. Select the checkbox for multiple runs
4. Under "Scope" (bottom of dialog box), select either a single intersection, zone, or the entire network
5. Under the "Header" tab, establish header and footer project information in a similar manner as Synchro.
6. Select the "Record Now" button to establish the number of desired simulation runs and to begin recording in SimTraffic (refer to guidance above on the number of model runs to complete).

Using SimTraffic to Mitigate Excessive Queuing

If determining appropriate storage bay lengths to use in a project's "mitigation" scenario, then SimTraffic can be used to help determine the appropriate lengths to use. The user would complete the following steps:

1. Develop a copy of the Synchro/SimTraffic file specific to this "Mitigation" scenario.
2. In Synchro, remove the storage bay distance attributes at all intersections (**Note:** this removes the storage bay distance constraints and transforms the former storage lanes into full travel lanes). This will provide the turning movement with the storage capacity of the length of the roadway link. It will also allow SimTraffic to analyze what the queue lengths will be without the constraint of the storage bays lengths.
3. Run SimTraffic at least five times for each peak hour scenario.
4. Review the longest SimTraffic Maximum Queues for each location to determine a preliminary length to set the storage bay for these locations.
5. Re-code the network to include new storage bay lengths, rounded up to the nearest 25' from the Maximum Queue lengths.

6. Finalize the Documentation.

905.3.5.3.2 VISSIM

905.3.5.3.2.1 Introduction

905.3.5.3.2.1.1 VISSIM Protocol Purpose

The purpose of this protocol is to guide those using VISSIM through the processes of model development, calibration, and post-processing. The goal of this VISSIM protocol, however, is not to provide an in-depth procedure for conducting microsimulation. Rather, the intent is to inform modelers of MoDOT's preferred practices, thereby fostering quality and consistency among MoDOT projects and project deliverables.

The version of VISSIM used should be discussed and documented during the scoping phase of the project. It will not necessarily be the latest version of VISSIM that is available but will be affected by the version of VISSIM available to MoDOT as well as the version in which other existing models are coded. Once a model is calibrated, it is recommended to keep that model in the same version of VISSIM for the remainder of the project. VISSIM has numerous additional licenses for add-on features, so it is important to ensure that all necessary features are available to all parties at the outset of the project.

905.3.5.3.2.1.2 Summary of VISSIM Guidance Structure

This protocol presents:

EPG 905.3.5.3.2.2 Base Model Development provides guidance on setting up a microsimulation model in VISSIM, more specifically listing recommended parameter values that should be used when coding a VISSIM model as part of a MoDOT project.

EPG 905.3.5.3.2.3 Error Correction, Calibration and Validation describes how analysts should refine models before submitting them to MoDOT. EPG 905.3.5.3.2.3 provides some guidance on model troubleshooting, then gives recommendations on how analysts should calibrate their models to better replicate real-world traffic conditions. Lastly, EPG 905.3.5.3.2.3 explains how analysts can prove their model is calibrated through validation.

EPG 905.3.5.3.2.4 Results and Presentation outlines what information should be submitted to MoDOT upon completion of a traffic study and how that information should be presented in a final report.

Technical References lists all documents used to guide the creation of this protocol, including transportation analysis guidance at the state and federal levels.

Typical VISSIM Parameters documents typical VISSIM input parameters that aid in communicating MoDOT's VISSIM guidelines.

905.3.5.3.2.2 Base Model Development

905.3.5.3.2.2.1 Model Boundary

Because of the complexity of microsimulation and the amount of time required to complete traffic models, defining a clear model boundary at the outset of every project is vital. Selecting a boundary that is too large unnecessarily extends the amount of time required to complete the model, while selecting a boundary that is too small may not reasonably account for the influences of the surrounding transportation network. A proper model boundary is one that reasonably encompasses the extents of all design alternatives being evaluated, as well as all surrounding areas which may have an effect on traffic operations at the site of the proposed alternatives. Ultimately, the intent should be to include all traffic congestion relevant to the proposed alternatives without extending the limits of the boundary beyond what is necessary. Doing so allows the model to produce more accurate and all-inclusive predictions of travel conditions within the study area while keeping the model's size manageable. The model boundary should be agreed upon by the project team, including FHWA when applicable, during project scoping. Below is guidance for typical model limits of different project types.

- **Freeways –** at least one interchange beyond construction limits –including that interchange's on and off-ramps closest to the construction at a minimum or an evaluation of the full adjacent interchanges if required and agreed upon by all stakeholders in the project scoping process
- **Ramp terminals –** one major intersection beyond construction limits and to the next interchange on freeway. In cases where next intersection is close (e.g., Outer Road), consider the functional area of the interchange.
- **Arterials –** one major intersection on either end of the project. Include minor streets at least up to next major upstream intersection or end of street, to the extent possible. 1000 feet is desirable for queue evaluation, even if space may not be physically available.

905.3.5.3.2.2.2 Global Network Parameters

Unless otherwise requested during the scoping process, all VISSIM parameters should be coded using U.S. customary units (ft and mph). The simulation resolution typically should be set to ten time steps per simulation second. Any other value should be documented in the Methods and Assumptions Memo. Best practices recommend that modelers use an aerial image as the basis for their model. Recent versions of VISSIM allow modelers to take advantage of Bing Map aerials and OpenStreetMap schematic map sources that are scalable. However, modelers using imagery from external sources should take care to scale their imagery appropriately by using VISSIM to assign a base coordinate system and sizing to their images.

It is recommended to utilize MoDOT's customized base VISSIM file for proper default initial parameter set up. This file should be used for all VISSIM projects unless approved by MoDOT and included in a Methodology and Assumptions (M&A) report.

905.3.5.3.2.2.3 Vehicle Fleet Setup

In the Traffic Analysis Toolbox, Volume III, the FHWA recommends that analysts should "attempt to obtain the vehicle fleet data (vehicle mix dimensions, and performance) from the local State DOT or air quality management agency." It is best to use data from the specific project area to define the vehicle fleet. If this is not available, however, MoDOT has developed a vehicle fleet that should be used. This vehicle fleet is already coded into MoDOT's customized base VISSIM file and can be viewed by clicking on Base Data -> Distributions -> 2D/3D Model.

The fleet coded into the model has associated 3D vehicle model files with defined lengths/widths and truck/trailer combinations for those semi-tractor trailer types. If the analyst receives warnings that certain 3D model files cannot be found when opening the base VISSIM file, then the missing files must be copied into the location on the user's hard drive shown in the warning message. 3D models provided by PTV Group (including those needed for MoDOT's default fleet) can be downloaded for free.

905.3.5.3.2.2.4 Scenario Manager

The scenario manager allows the user to develop a base model that can be used to apply one or more modifications to create various scenarios. Modifications can be turned on and off to create different combinations of scenarios. These scenarios may have different volumes or network modifications that can be directly compared to each other. This feature is available from VISSIM Version 8.0 and later. Use of the scenario manager is completely optional. Should modelers choose to use the scenario manager, this choice should be discussed during the scoping process and details regarding how the scenario manager was used should be included in the final project report.

905.3.5.3.2.2.5 Network Link Coding

VISSIM modeling begins by establishing links, then joining those links with connectors. Links are representations of roadway networks that reflect the traffic flow and geometry of each road segment. Connectors are used to join two parts of a single link or two parts of two different links. In addition to joining links, connectors also have characteristics that determine driver behavior in the model. For this reason, it's important to be aware of how many connectors are being used in a model and to eliminate unnecessary connectors or to shorten lengthy ones.

Freeway Merge, Diverge, and Weave Coding

During scoping, it should be determined if HCM methodology for analyzing freeway segments will be strictly followed. If LOS is the main MOE used, then this is recommended, and the following guidance applies:

- Typical freeway merges and diverges should be coded with a length of 1,500' from the painted gore point.
- Weaves may be coded as a single link between ramp gores as long as roadway attributes do not change. The first links coded on either end of the weave should be no longer than 500 feet.

If other MOEs (e.g., travel time, speed, etc.) are primarily used, then the above distances are not as crucial. Regardless of MOEs, the following modeling practices are recommended:

- Any parallel acceleration or deceleration lane should be coded for the full length of the parallel distance and half the length of the taper unless a different distance is needed for calibration purposes.
- No parallel distance should be coded for tapered entrances and exits. Often no conflict areas or priority rules are coded, even at a merge. The model may show vehicles overlapping each other, but they then adjust their spacing for the merge to occur. Lane taper links can be coded for visual completeness but should not be connected to links that actively carry traffic or need to be closed to all vehicle classes.
- Unless other distances are needed for calibration, connectors to off-ramps should be coded with a lane change distance (LCD) of 5280’ or with measured distances to the locations of upstream signage that indicates the upcoming off-ramp. LCD is discussed in more detail in EPG 905.3.5.3.2.3.3 Calibration Parameters.
- Mainline connectors at the end of acceleration and deceleration lanes should be coded with a lane change distance that covers the full distance of the acceleration/deceleration lane.
- Mainline connectors at the end of weaves should be coded with a lane change distance that covers the full distance of the weave.
- Grade information (especially that over two percent) should be included from field observation/measurement or external sources (traffic signal plans, roadway design plans, aerial imagery/LIDAR sources etc.).

Surface Streets and Intersections

When coding intersections, turn lanes can be coded on the same link as the through lanes or as a separate link. Either method is acceptable, but different situations may call for different methods. For example, if coding turn lanes on the same link is leading to unrealistic last-minute lane changes at the stop bar, then using a separate link may be preferred. If a turn lane is shared with a through movement, then it may be best to keep everything on one single link. In the end, the approach selected should best replicate field observed driver behaviors. This may also apply to the use of connectors representing tapers between upstream links and downstream links featuring the turn lane.

Like freeway link coding, the coding of approach grades at intersections should be done consistently through a model to account for acceleration and deceleration changes and their effect on capacity. It is recommended to include grades if they are anticipated to affect the acceleration or deceleration of the vehicles, or if they are greater than two percent.

Roundabouts

There are many ways to code a roundabout in VISSIM. Several considerations include:

- Limiting the number of links used to code the roundabout is preferred. Ideally, one circular link would be used with connectors attaching at all entry and exit points. This will help to avoid situations where connectors overlap links and mask other coding elements such that they are ignored by vehicles. Where the number of lanes varies around a roundabout, multiple links will be needed within the circle.

• Lane changing should be prohibited within the circle when coding a multi-lane modern roundabout

• Using desired speed decisions (DSD) helps keep speeds consistent within the roundabout, and reduced speed areas (RSA) ensure that vehicles are traveling the preferred speed at roundabout entry and exit locations where geometric deflections affect vehicle speeds. This approach to use both network elements at the roundabout to control the speed of the vehicles entering, exiting and within the roundabout allows flexibility to keep speeds in the roundabout vicinity consistent. DSDs and RSAs are discussed in more detail in EPG 905.3.5.3.2.2.6 Speed Control Coding and Desired Speed Distributions.

• Conflict areas or priority rules can be used to code yielding at roundabouts, but priority rules allow for greater control of yielding, particularly for multi-lane roundabouts. Additional information on conflict areas and priority rules are found in EPG 905.3.5.3.2.2.7 Control Coding.

Pedestrian and Bicycle Links

The inclusion of bicycles and pedestrians in the model should be discussed during scoping. Generally, they should be included if they have a measurable impact on operations or if they are needed for visualization purposes. The level of effort used for modeling bikes and peds should be in line with the level of impact. Larger cities may have stricter requirements for bicycle and pedestrian analysis.

905.3.5.3.2.2.6 Speed Control Coding and Desired Speed Distributions

Speed control coding dictates the speeds with which vehicles traverse different links and navigate certain movements. Desired Speed Decisions (DSD) and Reduced Speed Areas (RSA) are both controlled by Desired Speed Distributions. These distributions provide a range of potential speeds that can be assigned to individual vehicle classes during simulation. Desired Speed Distributions are particularly important parameters because they influence link capacity and achievable travel times. VISSIM produces a range of default speed distributions in a new .inpx file that “generally” could be considered to correspond to some posted facility speed limits, but for consistency, establishment of DSD’s based on the criteria described below are recommended.

Best practices recommend generating Desired Speed Distributions from existing field data for existing conditions models and for future models with the same geometry as existing conditions. For future models of arterials, using a linear distribution ranging +/- 5 mph from the posted speed limit is reasonable. For future models of freeways, using a linear distribution ranging from 3 mph below the posted speed limit to 10 mph above the speed limit is reasonable. In addition, a default distribution with using the posted speed as the 85th percentile speed in a distribution curve can also produce reasonable variation in traffic speed for any model scenario. Curve advisory speeds for loop ramps (use 25 mph as default) and for diamond ramps (35 mph) can also be applied.

Particularly for uninterrupted freeway facilities, free flow speed distributions are useful for calibration purposes to produce more realistic conditions. Speed data may be obtained by point speed data collection at/near network entry locations where flow interruptions or geometric conditions (grades/sight distance etc.) are at a minimum, or from third party big data sets (e.g., NPMRDS, INRIX, RITIS) that can produce appropriate individual speed estimates for network segments from which a distribution can be obtained. Similar data could be collected for interrupted facilities, though collection of truly free-flowing speeds may be more difficult due to traffic control devices and generally more turbulent conditions along an arterial corridor.

Desired Speed Decisions

As drivers enter the network during a simulation, they are assigned a desired speed from the Desired Speed Distribution that is associated with their vehicle class. Unless they are hindered by other vehicles or network objects, such as signal controls, drivers will travel at the desired speed they were assigned at entry in the Vehicle Compositions for each Vehicle Input. Placing a Desired Speed Decision in the network creates a place where a driver's desired speed is updated and they are reassigned a speed from the Desired Speed Distribution associated with their vehicle class. This process will be repeated each time a driver encounters a Desired Speed Decision.

When approaching a Desired Speed Decision, a driver will not accelerate or decelerate in anticipation of a change in their Desired Speed. A vehicle's speed will begin to change once it has passed through the Desired Speed Decision and not before. For this reason, it's important that modelers account for the amount of time it will take for a driver to accelerate or decelerate to their new Desired Speed.

In general, desired speed distributions from MoDOT's base VISSIM model can be selected based on the posted speed limit. During the calibration process, it may be necessary to provide different DSDs at a desired speed decision point if field data or observation indicate that, for example, trucks operate at a more conservative speed than cars along a particular link. Care should be used in applying this method to all situations, as the performance of cars and trucks may also be affected by the presence of grades.

Reduced Speed Areas

Vehicles in a VISSIM network will not automatically adjust their speed for turning movements as drivers in the real world normally do. For this reason, Reduced Speed Areas must be defined for areas where turning movements take place.

Best practices recommend that Reduced Speed Areas for right turns and U-turns use a linear distribution with a range of 7.5 mph to 15.5 mph. Similarly, best practices recommend that Reduced Speed Areas for left turns use a linear distribution with a range of 12.4 mph to 18.6 mph. Modelers should note that these distributions are coded into the base VISSIM model and represent a reasonable baseline, but they can be adjusted during the calibration process if need be. Reduced speed areas may also be placed in areas of a network where significant horizontal geometry changes occur that would impact the normal desired vehicular speed. For a more precise estimate of speeds around a curve, refer to AASHTO Green Book Table 3-13b.

In the model calibration process, if bottlenecks/congestion occurs beyond the area of a modeled network, reduced speed areas may be used at network exit points to emulate the extent and duration of the off-model congestion. Reduced speed areas have the ability on a per-lane bases to change the nature of the reduced speed and the time period for which it might be applied. While this is not a preferred way to model congestion and should not be used for congestion internal to the model, sometimes it is necessary at the edges of the model to keep the model limits reasonable and allow models to emulate field conditions to achieve model validation thresholds.

905.3.5.3.2.2.7 Control Coding

Control coding is used to replicate real-world traffic controls such as signals, stop signs, and yield conditions (conflict areas and/or priority rules). These controls should replicate real-world conditions as closely as possible. For instance, signal timing collected should be used to code signals and conflict areas and/or priority rules should be used at all intersections to dictate realistic vehicle interactions. Conflict areas are preferred when they can adequately reflect field conditions. When coding future traffic signal timing, it’s recommended that modelers use optimized signal timing. This can be done by using Synchro outputs that are then imported into VISSIM or by using another signal timing optimization software.

Signal Controller Settings

Best practices recommend the Ring Barrier Controller (RBC) method for coding traffic signals. RBC controllers can either be imported through Synchro files with optimized signal timings or can be directly coded into VISSIM using its RBC add-on module. Modelers should take care to make sure that the frequency of the RBC file matches the VISSIM time steps per second when coding signal controller settings.

Where pedestrians have a measurable impact on operations, code pedestrian signals to match corresponding through signal phase at a minimum or add pedestrian phasing specifically to RBC controller inputs. VISSIM has a separate RBC manual included with the installation for more information.

Unsignalized Intersections

Intersections which are stop controlled should be coded so that the location of stop signs is based on where drivers actually stop in the field, or if unknown, stop bar locations recorded during data collection/shown on aerial imagery. Similarly, conflict areas and priority rules should be coded at the actual locations of conflict between vehicles. Intersections which are yield controlled, like roundabouts and right turns entering a roadway, should be coded using only conflict areas and/or priority rules. Conflict areas should be applied first when coding unsignalized intersections, then priority rules can be used if real-world conditions need to be better replicated, but only one of these types of control should be active for any given conflict situation between vehicles or other modes of transportation that are modeled.

Conflict areas are automatically generated where network links and connectors overlap but are initially “inactive”. All intersections and junction areas in a network need to be assessed as to which conflict areas are needing to be activated. This is based on the likelihood of a conflict actually occurring – i.e., for a signalized intersection, no conflicting through movements should typically ever actually conflict due to the signal control of movements so these “conflict areas” do not need to be activated. Conflict areas where a through movement vehicle and right-turn movement vehicle could “overlap” due to close proximity of the links/connectors should have a “red-red” conflict area activated so vehicles will avoid entering these areas if a vehicle is stopped and present in either direction.

905.3.5.3.2.2.8 Vehicle Types/Inputs/Compositions

A vehicle type allows the formation of a group of vehicles with the same technical driving characteristics. The vehicle type data is included in emission calculations. Vissim has the following default vehicle types:

- Car
- HGV
- Bus
- Tram
- Man
- Woman
- Bike

Based on these vehicle types, it is possible to further define specialized vehicle types such as a trailer truck, articulated truck, standard bus, articulated bus.

If vehicles in a vehicle category have different speed or acceleration behavior, define each vehicle type separately.

If vehicles of one type only differ in their shape, length or width, they may be distinguished by 2D/3D model distribution or color distribution and still would be managed under the same vehicle type. For example, the “car” vehicle type represents vehicle models that differ in length but have a similar driving behavior. This is why they can be defined under a single vehicle type, using 2D/3D model distribution for different types of “car” vehicles.

Vehicle types can be grouped into vehicle classes. A vehicle class may contain any number of vehicle types. Vehicle classes provide the basis for speed data, evaluations, path selection behavior and other network objects. Per default, a vehicle class contains a vehicle type of the same name. You may assign a vehicle type to several vehicle classes. A vehicle class is, for example, used to obtain data for specific vehicle types or to recognize and distinguish them based on their color during simulation.

Vehicles with different technical driving properties must belong to different vehicle types. Group vehicle types to a vehicle class in the following cases:

- If multiple vehicle types share the same properties such as speed distribution.
- To collect aggregated data on all vehicles collectively.

Best practices recommend that vehicle inputs be coded in 15-minute demand increments. In some situations where traffic volumes are consistent over longer time periods, hour long demand increments can be used. If there are significant differences in the vehicular fleet characteristics between input locations, then the fleet mix specific to each entry location should be specified. In the case of freeway models, a global estimate of heavy vehicles in the traffic stream can be generated from project-specific classification counts / project-level traffic forecast data or a regional travel demand model if no classification count or forecast information is available. In the case of modeling of new facilities in a future scenario, forecast or regional travel demand model information would be needed to properly assess the future vehicle mix on facilities that do not exist in the base model.

All vehicle input locations to the model require information on vehicle compositions which need to be coded separately. The vehicle compositions, depending on the level of detail needed and information available for each entry link, can be modified at a global level, roadway functional class level, or individual link level, as noted above. Vehicle compositions include the vehicle class differentiation, assumed speed distributions, and relative proportions of each vehicle type.

905.3.5.3.2.2.9 Vehicle Routing

Similar to vehicle inputs, vehicle routes should be coded in 15-minute demand increments if possible. Hour-long demand and routing increments are acceptable in cases where traffic volumes are consistent throughout the time period. There are three methods for coding vehicle routing, each of which has been briefly described below:

- **Origin-Destination Static Routing (Preferred Method):** This is the most common method of vehicle routing and applicable for most arterial and freeway networks. These routes can pass through one intersection/interchange or several, or from one end of the network to another. MoDOT's preference is to create multiple static routes from one entry point to all destination points within a network to accept O-D information generated in a spreadsheet or similar transferrable source outside the model from traffic forecast or count data that proportionally would take each O-D pair and make appropriate traffic assignments. This allows the modeler some control over appropriate and realistic routing through a network with several paths or situations where certain O-D pairs would not be used.
- **Individual Static Routes from Intersection to Intersection:** As vehicles leave one intersection, they are assigned as left turns, through movements, or right turns as they approach the next intersection. These routing assignments should be made as far upstream as possible on each link to maximize the amount of weaving and/or merging distance available to drivers. However, if intersections within a network are spaced very closely, modelers may need to route vehicles through multiple intersections to allow for adequate time for vehicles to change lanes to execute their assigned turning movement. This can be achieved using the Combine Routes feature of VISSIM.
- **Origin-Destination (O-D) Based Dynamic Traffic Assignment (DTA) Routing:** - In some cases where multiple paths are available in a grid network, or network with

paralleling route options, automated O-D routing in VISSIM can be done by using VISUM to macroscopically assign the O-D matrix to the network and then by using VISSIM's Dynamic Traffic assignment to generate the actual routes. This is a complex, iterative process that should be used in limited situations with a full knowledge of the methodology by which VISSIM integrates O-D matrix flow taken from VISUM (or other travel demand model software packages) and is modified to properly assign traffic flows to match existing traffic patterns and avoid unrealistic paths through the model network. Approval will be needed by MoDOT prior to using O-D based DTA for traffic assignment and documentation of processes and model changes necessary to achieve desired DTA goals will be necessary in the Methodology and Assumptions and Model Calibration reports.

905.3.5.3.2.2.10 Driver Behavior

Vehicle interactions in VISSIM are guided by the Wiedemann 1974 and 1999 car-following models, in addition to several proprietary lane changing models. Users can alter these lane changing models by adjusting the parameters located in driver behavior containers. These driver behavior containers are assigned to links within the network and dictate how vehicles travel and interact along the link. VISSIM provides eight default driver behavior containers each of which is briefly described below in Table 905.3.5.3.2.2.10.

Table 905.3.5.3.2.2.10, Default Driver Behavior Container

Container Name	Description/Purpose
Urban (motorized)	Based on the Wiedemann 1974 car-following model, therefore, is **recommended for use when modeling arterials.** This container is typically the default for urban streets and arterials.
Right-side rule (motorized)	Based on the Wiedemann 1999 car-following model, therefore recommended for use when modeling freeways. This container dictates that vehicles only use the left lane to pass. This practice is common in Europe, but not necessarily in the United States.
Freeway (free lane section)	Based on the Wiedemann 1999 car-following model, therefore, is **recommended for use when modeling freeways.** This container is typically the default for freeways.
Footpath (no interaction)	Used to control pedestrian movements on walkways and crosswalks because it does not monitor the interaction between entities modeled on these links.
Cycle-Track (free overtaking)	Used to control bicycle movements on cycle tracks. Based on the Wiedemann 1999 car-following model but incorporates updated parameters that mimic cyclist behavior more realistically.
AV_cautious (CoEXist)	Based on the Wiedemann 1999 car-following model. Includes updated parameters to reflect cautious behavior of an Automated Vehicle as determined by the CoEXist research project.

AV_normal (CoEXist)	Based on the Wiedemann 1999 car-following model. Includes updated parameters to reflect normal behavior of an Automated Vehicle as determined by the CoEXist research project.
AV_allknowing (CoEXist)	Based on the Wiedemann 1999 car-following model. Includes updated parameters to reflect all-knowing, or fully connected, behavior of an Automated Vehicle as determined by the CoEXist research project.

905.3.5.3.2.2.11 Coding of Other Modes

There may be a desire in some models to code other transportation modes such as pedestrians, bicycles, buses, trains, etc. When modeling transit stops (especially with buses), make sure to consider the possibility that a bus may skip the stop. If creating dwell time distributions for bus stops, note that dwell time values of zero or less will result in the bus skipping the stop if skipping is allowed. Knowing what percentage of the time the bus skips the stop may impact how the dwell time distribution is coded.

905.3.5.3.2.2.12 Using Lists in VISSIM

Within VISSIM a list can be generated for most model elements. Many parameters can be selected to be included as columns in the list. The lists can be very beneficial for making similar changes to many elements quickly. The list itself can be copied to a Microsoft Excel file, manipulated using the full functionality of Excel, and then imported back into VISSIM. Lists can also be used to organize and filter data within the model.

905.3.5.3.2.3 Error Correction, Calibration and Validation

Once base model development is complete, it is important to run the model and check the model for errors and to correct those errors. Then, possibly the most important step of the process, is calibration of the existing model. Calibration give confidence that the model is replicating real world conditions reasonably well. The calibrated model and the settings used to calibrate the model is carried forward and mimicked in the alternatives' testing. EPG 905.3.5.3.2.3 describes the process of initial model run set-up, error detection and rectification, and detailed model calibration once a model has been checked for basic coding errors.

905.3.5.3.2.3.1 Initial Simulation Runs

Determining the Seeding Period

A seeding period, the amount of time required for a network to reach equilibrium and/or saturated conditions, should be identified that is the longest of the following four criteria:

1. A minimum of 15 minutes.
2. The number of vehicles in the network levels off. Note that in a highly congested network the rate of increase may slow down, but the number of vehicles will continue to increase throughout the simulation.

3. Equal to or greater than twice the estimated free flow travel time from one end of the network to the other.
4. Vehicle queue lengths in the model at the end of the period are similar to real-world observations at that time of day.

Calculating Required Number of Simulation Runs

MoDOT's preference for the number of simulation runs to provide adequate statistical validity is to start with a recommended number of 20 runs. Depending on a model's size and complexity or for other reasons discussed and agreed upon on the project scoping process, this number may be reduced under 20 to a minimum of 10 if justified using the FHWA's guidance on calculating the required number of simulation runs that is outlined in *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software - 2019 Update to the 2004 Version*. FHWA's methodology uses a standard statistical t-test to determine the number of simulation runs required to ensure a 95th percentile confidence level with a 10% tolerance. The t-test is executed using the following equation:

$$N = \frac{Z^2 S^2}{E^2}$$

Simulation Runs Equation

Where:
N = Number of simulation runs
Z = z-score (1.96 for the 95th percentile)
S = Standard deviation of the sample
E = Tolerable error in terms of the sample mean

In this methodology, the initial sample consists of the values of a primary MOE (such as network speeds, travel times, overall delay or throughput) returned by the first N runs of the simulation. Use of generalized network-level statistics for the sample may be considered and more than one MOE statistic should be utilized in the assessment of minimum run size. The MOE producing the largest number of runs should be considered to be used as a conservative basis for determining the minimum number of calibration runs. The sample standard deviation (S) is used directly in the equation shown above, while the sample mean is used to calculate the tolerable error (E). E is calculated by multiplying the sample mean by the error tolerance, which is typically a total range of 10% which equates to +/- 5 percent from the sample mean. A different tolerance or percentile confidence interval could be used if agreed upon by the project team. If the first calculation of the number of required simulation runs (N) is less than or equal to 10, then 10 model runs is statistically acceptable. If the first calculation of N is greater than 10, modelers should run the number of simulations returned by the equation and repeat the calculation until the number of simulation runs returned by the equation is less than or equal to the number of runs used to generate the sample.

Number of Required Runs - Example

Travel speed has been chosen as the primary MOE for an analysis. After 10 initial runs, the sample of speeds has a mean of 32.5 mph and a standard deviation of 6.5 mph. Assuming a 95%

confidence level and 10% tolerance error, Z is 1.96 and E is 3.25 mph. Using the Simulation Runs Equation, N is calculated to be 15.37, or 16 runs. This tells the modeler that using only 10 simulation runs would be inadequate. Instead, the modeler should recalculate the required number of simulation runs using a sample size of 16. The modeler should then iterate through this process until the value of N they calculate is less than or equal to the size of the sample being used to calculate N.

Random Number Seeds and Intervals

Once the appropriate number of runs is determined, a consistent hierarchy should be established for the random number seeds and interval to be set for the calibration process. It is suggested that a range of numbers be consistently applied for all models of one time period both in the calibration process and for future scenario testing. An initial random seed number can be set and then an interval of 10 or greater can be established for the total number of runs required. This can be kept constant for a different time period or a new initial number and range for that time period can be established, which again would be kept constant for future scenarios of that time period. For example, in Table 905.3.5.3.2.3.1:

Table 905.3.5.3.2.3.1, Example of Random Seeds and Increments

Model	Initial Random Seed	Increment	Run								
			2	3	4	5	6	7	8	9	10
AM Peak	12	10	22	32	42	52	62	72	82	92	102
PM Peak	23	11	34	45	56	67	78	89	100	111	122

905.3.5.3.2.3.2 Error Correction Process

Modelers should note that MoDOT has made a reviewer’s checklist available for those reviewing VISSIM base models. The best practices outlined in EPG 905.3.5.3.2.3.2 should be used in conjunction with the reviewer’s checklist to carry out the error checking and debugging processes. Ideally this review will be done by a modeler who didn’t have a hand in the majority of the coding process but is well versed in the development and use of the VISSIM software, along with EPG 905.3.

Input Review/Verification

After network coding has been completed, the review process should begin with a check of all network inputs. Any deviations from what was previously documented in the project TIA Methods and Assumptions Report or Data Collection Summary should be noted in the Calibration Report. Refer to MoDOT’s VISSIM Reviewer’s Checklist for a full list of inputs that should be checked.

Animation Checking

Watching the animation shown in the VISSIM interface while a simulation is running is an effective and necessary way to quickly spot errors. The reviewer should observe the animation for the full seeding period and simulation time, paying special attention to points of congestion to verify that driver behavior is realistic. If the reviewer notices unrealistic behavior, the following issues may be to blame:

Data coding errors: The reviewer should check for minor data coding errors that might be causing the model to produce an inaccurate representation of travel behavior.
Route assignment errors: If the unrealistic behavior the model produces involves an excessive number of vehicles traveling to the end of a link and not attempting a lane change to continue the route, enter a turn lane, or some similar situation, the reviewer should check for errors in route assignment, as the route the vehicles may be assigned to may be incomplete or missing a valid sequence of links and connectors
Error in expectations: Before continuing, review vehicle behavior at the location and time period in question to ensure that the reviewer has an accurate understanding of actual driver behavior in the field. Further inspection of field conditions may reveal causes for unusual vehicle behavior. If this is the case, the causes should be coded into the model to ensure the model replicates realistic behavior.

Discrepancies between model results and field conditions may also arise because of unique events that occur in the field that have not been accounted for when coding the model. Some of these unique events include the following:

- Irregular vehicle operations (e.g., drivers using shoulders as turning or travel lanes, etc.)
- Previously unidentified points of ingress or egress
- Complex driver behavior, such as the interactions in a two-way left turn lane (TWLTL)
- Average travel speeds that exceed posted or legal speeds (the average speed measured in the field should be used in the calibration process)
- Turn bays that cannot be fully utilized because they are blocked by through traffic
- Localized problems that can result in a system-wide impact – oversaturated intersections where vehicles block critical movements eventually locking up an entire network
- Stopped vehicles in flowing traffic
- Frequent lane changes or lane changes in unrealistic locations
- Vehicles turning at inappropriate times or locations
- Vehicles requiring long or accepting short, risky gaps
- Signal timing and coordination errors
- Large number of vehicles routed on minor streets.

Review VISSIM Error Log/Files

At the end of every simulation run, VISSIM provides an error log that provides the user with the time and location of model errors. The location is specified by the line number in the input file or with the link number, and the time is specified by the time step in the simulation. Modelers should review each entry in the error file to ensure that the errors aren’t impacting the model’s results. There are three types of error messages that represent potentially significant issues:

- An entry link that did not generate all vehicles (congestion spillback off the network)
- A vehicle left its route because the distance between the routing decision and the first connector on its path was too short
- A vehicle was removed from the network because it had reached the maximum lane change waiting time (time before diffusion).

These errors are usually associated with areas of congestion in the model. Modelers should take care to make sure that these areas are associated with areas of congestion in the field and not caused by coding errors. In general, adjustments to lane change behaviors, driver behavior changes applied to select critical links, or geometric changes through adjusting distances of links, connectors and junction points may fix these issues.

In large model networks with extended periods and/or locations subject to oversaturated conditions, it may not be feasible to correct every single instance of vehicles being removed from the network because of diffusion. In the model calibration report, some mention of this occurrence should be made and a report of the overall percentage of vehicles in the network being removed due to diffusion (less than 0.5 percent would be a good general rule of thumb).

Common Coding Errors

If the source of a modeling error still cannot be found after reviewing the model's inputs and the error files VISSIM provides, modelers may find it useful to consult the below list of common coding errors. Otherwise, this list may be useful for modelers to consult before they begin coding to make themselves aware of common pitfalls.

- **Signal timing/signal head coding:** Coding signal timing and signal heads can be difficult because signal timing is usually coded in an *.RBC file, then referenced into a *.inpx file. Before referencing the signal timing code into VISSIM, there is not a good way to visualize what's been coded. To help alleviate this issue, VISSIM includes a test function that gives users the chance to watch signal heads change color in the network according to the referenced RBC file. Although this is a helpful tool when reviewing signal coding, it is sometimes more effective to watch the signals operate in the simulation and use the Evaluation->Window->Signal Times Table feature. Modelers should take care to review RBC files that are imported from older versions of VISSIM or from Synchro to ensure the transfer of signal timing parameter data is consistent.
- **Vehicles driving over red signal heads:** This may occur if a connecter has been coded over a signal head that is coded on a link. In this case, the simulated vehicles will be considered as being on the connector rather than the link and therefore will not respond to the status of the signal head.
- **Ensure adequate Conflict Areas are coded:** Modelers should take care to observe whether simulated vehicles are colliding where links overlap. If this occurs, the affected area will likely require an additional Conflict Area or Priority Rules so that vehicles yield to each other appropriately.
- **Check that Lane Change Distances are coded correctly:** Using a Lane Change Distance which is too short is a common issue, especially when coding freeways. This error usually results in the formation of long, unrealistic queues at decision points in the

network (e.g., an off-ramp on a freeway). EPG 905.3.5.3.2.2.12 Using Lists in VISSIM includes a discussion of how to use lists to easily modify the lane change distances of many connectors at once.

• **Check that Desired Speed Decisions have been coded correctly:** Because Desired Speed Decisions dictate the speed at which vehicles travel within the network, forgetting to code speed decisions or coding them incorrectly will result in simulated vehicles moving at significantly different speeds on the same facility. Modelers can set graphic parameters to color-code vehicles by speed to help look for these abnormalities during animation review and should address speed decisions accordingly.

• **Check that Reduced Speed Areas are coded at all intersections for U-turn, right-turn and left-turn connectors:** Use of Reduced Speed Areas ensures that turning vehicles travel at a reasonable speed as they turn.

• **Check that correct vehicle types are coded on correct facilities:** Modelers should note whether the mix of vehicles on a facility is appropriate during the animation review process. For instance, while VISSIM can simulate pedestrians on a freeway, this would likely never be done intentionally. Vehicle mix issues can also be less obvious. In particular, the percentage of truck traffic in a vehicle mix should be carefully evaluated during the review process to ensure it aligns with typical conditions. Color-coding vehicles by vehicle type and/or reviewing model outputs by vehicle type can help with this check.

• **Ensure entry links are sufficiently long for downstream routing decisions and to contain queues:** If entry links are not coded with sufficient length, vehicles will not have the space they need to make necessary lane changes when entering the network. If a model produces significant congestion at the beginning of a network, entry links upstream may need to be made longer. Where possible, links should be long enough to allow all vehicles to enter the network and prevent warnings that vehicles are remaining unserved into the network at the input locations. Additional link modifications may be necessary to load traffic into the actual study area network where entry links are not part of the area where link evaluations are made. In cases of short minor street/driveway entry links, similar adjustments can be made, with a possibility in all cases of creating links that are invisible (to still allow accurate visualization of the model and replication of actual field conditions).

905.3.5.3.2.3.3 Calibration Parameters

Calibration parameters are the parameters modelers adjust to finely tune a VISSIM model to real world conditions. EPG 905.3.5.3.2.3.3 provides brief descriptions of how to apply commonly used calibration parameters.

Lane Change Distance Parameters

There are several link connector parameters related to how lane changes are made within a network that can be adjusted to calibrate a model. The first is lane change distance (LCD), which dictates how early a vehicle in the model will begin to make a lane change before reaching a decision point, such as a turning movement or exiting a freeway. The default value for this parameter in VISSIM is 656.2 feet (200 meters), however, this distance is generally too short to be considered realistic in congested arterials and most freeway networks. To make sure that vehicles make lane changes at the proper times on freeways and arterials, the default LCD may need to be lengthened and initial model development suggestions are found in EPG 905.3.5.3.2.2.5 Network Link Coding. Additional calibration for lane change distances may need to include lengthening LCDs beyond initial suggestions at major freeway system interchanges or actually reducing LCDs in some diverge situations where field observations indicate, due to congested conditions, that vehicles make late lane changes or do not react until the very end of a freeway lane drop.

LCD can be modified on a "per lane" basis, so the distance entered will be added to its singular lane distance for each freeway or arterial lane that is adjacent to the connector "exit" lane. The resulting effect is that vehicles in lanes furthest from the connector will begin lane positioning further upstream than lanes adjacent to the connector. Care should be taken to observe the effects on traffic lane-changing movements upstream of a critical network weaving or diverge area if the "per lane" option is used versus a singular value for LCD that would apply to all lanes upstream.

Emergency stop distance (ESD) is a second parameter that may require adjustment to match conditions on arterials and freeways more realistically. Increasing the ESD would help to ensure that the vehicles in the model are stopping to wait for a lane change before reaching the decision point. This can occur at a diverging off-ramp downstream of congested weaving section. Separating the ESD for the two weaving maneuvers by 100 feet (or possibly more) reduces the potentially unrealistic vehicle behavior that two vehicles would make emergency stops at the same location to force their intended maneuvers. While altering LCD and ESD can help during calibration, modelers should consider how lengthening these distances may have network-wide impacts and refine their parameter adjustments accordingly. For example, an LCD that is too long can have unintended consequences of vehicles positioning for a decision too far upstream, resulting in poor lane utilization. An ESD that is too long could cause vehicles to stop in the middle of the network for seemingly no reason.

Speed Distributions

As discussed in EPG 905.3.5.3.2.2.6 Speed Control Coding and Desired Speed Distributions, where field speed data is not available, speed decisions are coded into a model according to posted speeds and reduced speed areas are coded where drivers would reasonably travel at lower speeds (i.e., significant curves, turning movements, etc.). Both speed decisions and reduced speed areas are defined by speed distributions.

Best practice dictates that speed distributions portraying posted speed limits be generated so that 85% of vehicles travel at or above the posted speed limit and the maximum speed of any vehicles in the network is 10 mph above the speed limit. However, modelers may see a need to stray from these best practices slightly during calibration. It is generally acknowledged that drivers will exceed posted speed limits in free-flow conditions.

Driving Behavior

In VISSIM, driver behavior is dictated by car following models and lane change models. During initial model development or later on for calibration purposes, parameters within these models can be adjusted to more accurately reflect real-world driver behavior in the area being modeled. The following guidance provides brief descriptions of these models and the parameters they contain which may be modified.

1. Car Following Models

There are two car following models available in VISSIM: the Wiedemann 99 Model and the Wiedemann 74 Model. Best practices recommend that the Wiedemann 99 Model be used for freeway traffic and the Wiedemann 74 Model be used for arterial/urban traffic. Both models have a parameter for Number of Observed Vehicles that could be increased to up to ten to better account for the interaction with many surrounding vehicles.

There are 10 parameters in the Wiedemann 99 Model, and three of the most influential parameters are defined below. These definitions are followed by Table 905.3.5.3.2.3.3.1 which specifies recommended starting default values and suggested ranges for all 10 parameters.

CC0 (standstill distance): rear-bumper to front-bumper distance between stopped cars

CC1 (headway time): distance (in seconds) a following driver wishes to keep between their vehicle and the vehicle in front of them

CC2 (following variation): a measure of how much more distance than the desired safety distance before the driver intentionally moves closer to the vehicle in front of them.

Table 905.3.5.3.2.3.3.1, Recommended Wiedemann 99 Car Following Parameters

Parameter		Default	Unit	Suggested Range		Capacity Effect
				Basic Segment	Merge/Diverge & Weaving	
CC0	Standstill distance	4.92	ft	4.5 – 5.5	> 4.92	Higher value = lower capacity
CC1	Headway time	0.90	s	0.70 – 3.00	0.90 – 3.00	Higher value = lower capacity
CC2	"Following" variation	13.12	ft	6.56 – 22.97	13.12 – 39.37	Higher value = lower capacity
CC3	Threshold for entering "following"	-8		Use default		
CC4	Negative "following" threshold	-0.35		Use default		
CC5	Positive "following" threshold	0.35		Use default		
CC6	Speed dependency of oscillation	11.44		Use default		
CC7	Oscillation acceleration	0.82	ft/s^2	Use default		

CC8	Standstill acceleration	11.48	ft/s^2	Use default	
CC9	Acceleration at 50 mph	4.92	ft/s^2	Use default	

When using the Wiedemann 74 Model for analysis of arterial and/or urban traffic conditions, there are three parameters to consider: average standstill distance, additive part of safety distance, and multiple part of safety distance. Average standstill corresponds to the CC0 parameter used in the Wiedemann 99 Model and can be subject to calibration as shown in the table above, while the other two parameters dictate the target desired safety distance which has a direct impact on the ultimate saturation flow rate of the network. In general, using MoDOT's base VISSIM model's default parameters is adequate most of the time for undersaturated conditions as it was developed to emulate typical driver behaviors observed in Missouri. If conditions are known to be oversaturated in the calibration of existing models, it is likely that additional driver behaviors may need to be created to address areas of a freeway/arterial network that experience congestion. If these parameters need to be adjusted during calibration, modelers should note that increasing the additive part of safety distance and the multiple part of safety distance increases the desired safety distance which in turn reduces the saturation flow rate. This is highlighted in Figure 905.3.5.3.2.3.3.2 which is taken from Section 5.8.4.1 of the PTV Group VISSIM User's Manual. The figure is representative for a particular set of vehicular attributes but generally shows the intended effects of varying the multiplicative (x-axis values) part of safety distance if it is coded as the additive part of safety distance value + 1.

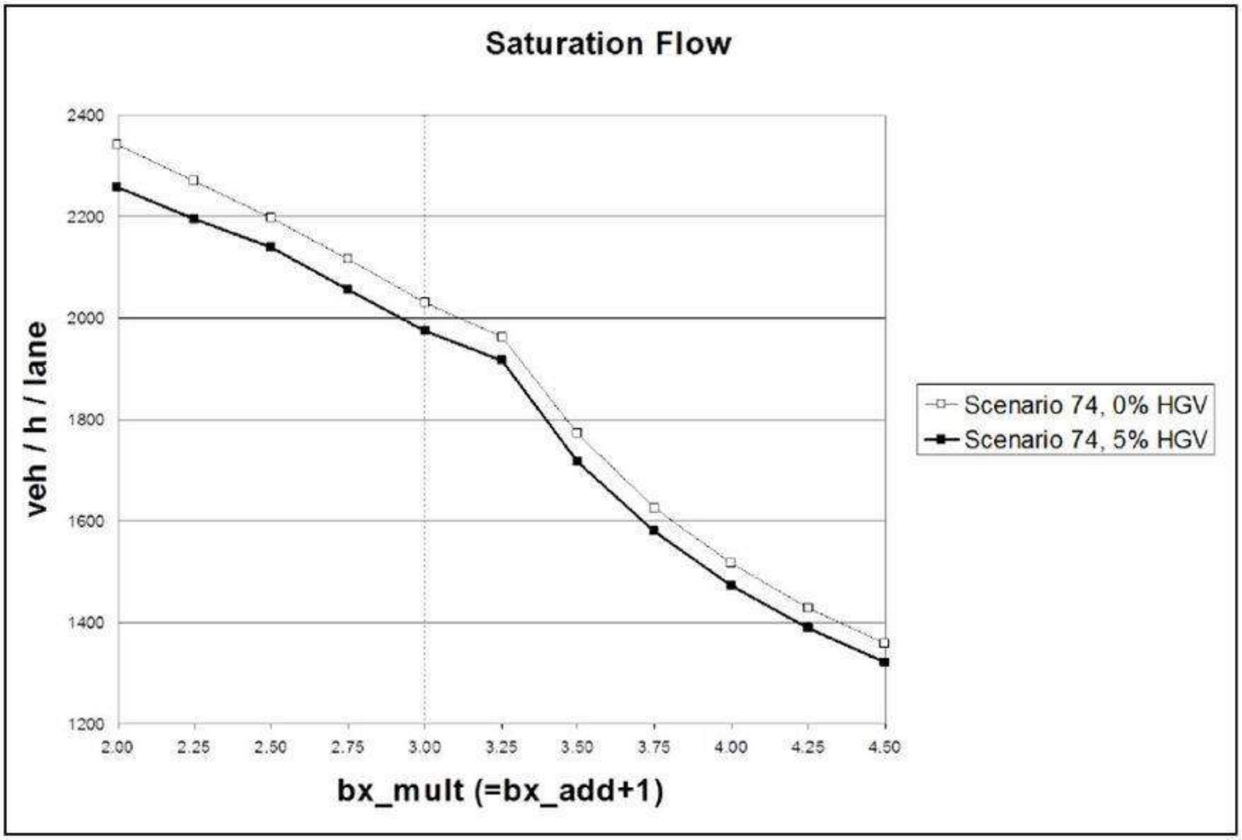


Figure 905.3.5.3.2.3.3.2, Effect of Changes to Wiedemann 74 Model Parameters on Saturation Flow

2. Lane Change Models

The parameters used for lane change models are the same for both freeway and arterial analysis. Similar to driver behavior model parameters, VISSIM's default parameter values for lane change models are a good starting point in most situations. However, these parameters can also be carefully adjusted during the calibration process to help reflect real-world conditions more accurately. See Table 905.3.5.3.2.3.3.3 for a list of VISSIM's default parameter values and suggested parameter ranges, according to MoDOT Preferences. It is important to note that the lane change model parameters are related to vehicular movements within the traffic stream in their aggressiveness and desire to change lanes to pass vehicles, merge with vehicles and laterally adjust their position. They are not the same as the lane change distance (LCD) adjustments described previously.

Table 905.3.5.3.2.3.3.3, Lane Change Parameters

Defaults					
General Behavior Necessary Lane Change (route)	**Free Lane Selection Own**	**Unit**	**Trailing Vehicle**	**Unit**	**Typically Adjusted?**
Maximum deceleration:	-13.12	ft/s^2	-9.84	ft/s^2	Yes
-1 ft/s2 per distance:	200	ft	200	ft	No
Accepted deceleration:	-3.28	ft/s^2	-1.64	ft/s^2	No
Waiting time before diffusion:			60	s	Yes
Min. headway (front/rear):			1.64	ft	No
To slower lane if collision time above:			0	s	No
Safety distance reduction factor:			0.6		Yes
Maximum deceleration for cooperative braking:			-9.84	ft/s^2	Yes
Overtake reduced speed areas:			*Box Unchecked*		No
Advanced Merging:			*Box Checked*		Yes
Cooperative Lane Change:			*Box Unchecked*		Yes
Rear Correction of Lateral Position:			*Box Unchecked*		No
Suggested Ranges					
General Behavior Necessary Lane Change (route)	**Free Lane Selection Own**	**Unit**	**Trailing Vehicle**	**Unit**	**Driver Behavior Effect**
Maximum deceleration:	-15 to -12	ft/s^2	-12 to -8	ft/s^2	Higher Absolute Value = More Aggressive

-1 ft/s^2 per distance:	150 to 250	ft	150 to 250	ft	Lower Value = More Aggressive
Accepted deceleration:	-2.5 to -4.0	ft/s^2	-1.5 to 2.5	ft/s^2	Higher Absolute Value = More Aggressive
Waiting time before diffusion:			30-60	s	Longer Duration = More Potential Unrealistic Congestion
Min. headway (front/rear):			1.5 to 2.0	ft	Lower Value = More Capacity
To slower lane if collision time above:			0 to 0.5	s	Lower Value = More Capacity
Safety distance reduction factor:			0.25 to 1.00		Lower Value = More Aggressive
Maximum deceleration for cooperative braking:			-8 to -15	ft/s^2	Higher Absolute Value = More Aggressive
Overtake reduced speed areas:			*Leave box unchecked*		If Checked – Capacity Increases
Advanced Merging:			*Can Adjust*		
Cooperative Lane Change:			*Can Adjust*		
Rear Correction of Lateral Position:			*Leave Box Unchecked*		

Conflict Areas and Priority Rules

The conflict area input dialog box is shown in Figure 905.3.5.3.2.3.3.4. In conflict areas, altering the safety distance factor (SDF) can be effective during calibration as it dictates merging behavior. The factor is multiplied by the normal desired safety distance between vehicles to determine the minimum safe distance a yielding vehicle must maintain. A smaller SDF allows for more aggressive merging behavior, while a larger SDF ensures more conservative merging behavior. Modelers should pay special attention to adjusting the SDF at merging conflict areas, such as right-turn-on-red or channelized turning movements. These adjustments may not have a large effect on throughput, but they can be used to impact delay and queueing. Overall, the degree to which adjusting SDFs affects a network depends on general network conditions like congestion levels and how the volumes of major movements compare to the volumes of minor movements at conflict areas. The default SDF for a conflict area is 1.5. A reasonable range for this value is between 1.0 and 2.0. Changes to this value in the calibration process are generally similar to adjustments made to safety distances in the Wiedemann 74 model and highlighted previously in Figure 905.3.5.3.2.3.3.2.

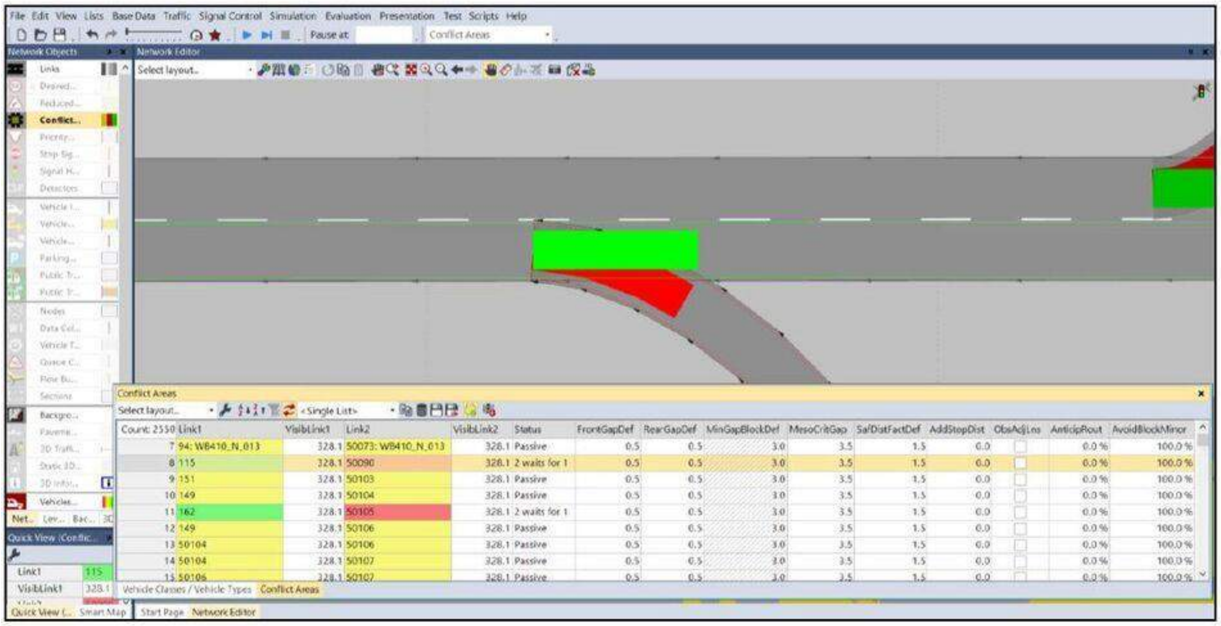


Figure 905.3.5.3.2.3.3.4, Conflict Area Dialog Box

Other input values that can be adjusted to provide better realism in vehicular stopping and gap acceptance behavior is to adjust the Front Gap, Rear Gap and Additional Stop Distance parameters.

- Both the Front Gap and Rear Gap are set to 0.5 second defaults. Increasing the gap time will cause more cautious reactions for minor and major street vehicles in the defined conflict area for crossing or merging conflicts.
- Increasing the Additional Stop Distance from 0 feet to a higher value will cause a minor street vehicle to yield further away from the defined conflict area and thus increase the caution in behaviors at the conflict area, reducing capacity for the minor street movement.

Similar to Figure 905.3.5.3.2.3.3.4, Figure 905.3.5.3.2.3.3.5 shows the basic set up for calibration of priority rules. Three factors in the conflict marker input dialog are important in the calibration process. The gap time, clearance, and max speed inputs can be adjusted to match vehicle yielding and gap acceptance to field observed conditions. Increasing the gap time (default of 3 seconds) will lower the yielding vehicle's aggressiveness in accepting gaps in the conflicting traffic stream. Increasing the clearance distance (default 16.4 feet) has a similar effect in keeping that defined area free of observed vehicles before the yielding vehicle accepts a gap. The maximum speed parameter is initially set at a high-speed default, meaning all observed vehicles will be considered in the yielding vehicle's observation of gap and clearance. Lowering the maximum speed value below field travel speeds means that conflicting vehicles may not be considered by the yielding vehicle.

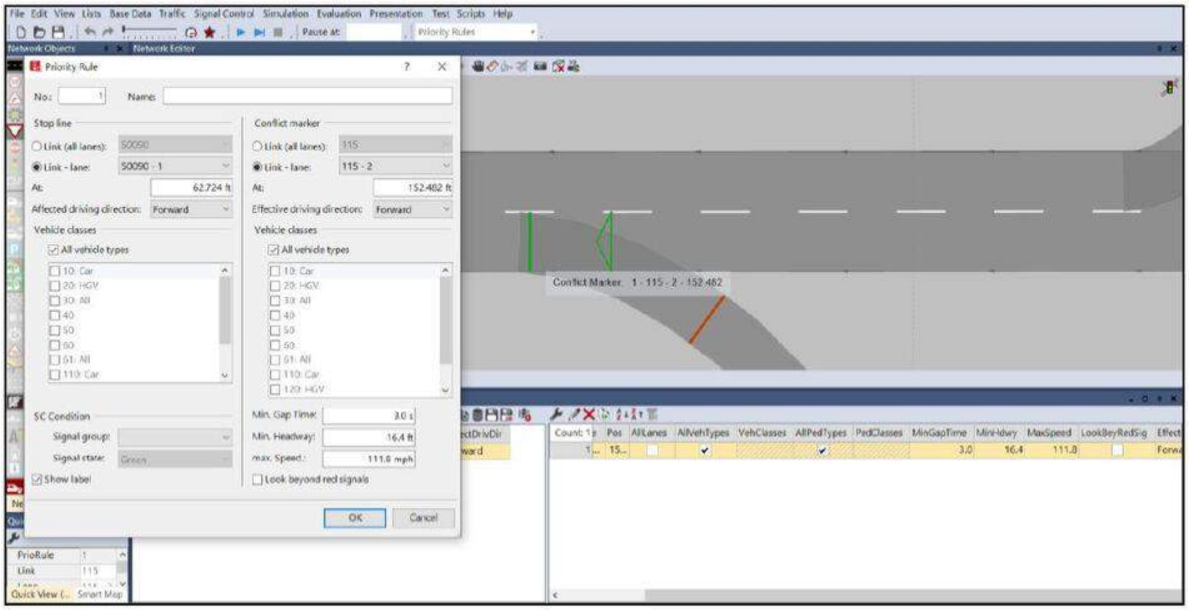


Figure 905.3.5.3.2.3.3.5, Priority Rule Dialog Box

In using priority rules, it is important to code the stop line and conflict marker locations correctly and to include conflict markers for all affected traffic streams that vehicles at the stop line need to yield to – including additional lanes on a link crossing the link with the stop line. Priority rules are effective in specialized situations, such as roundabouts, “Do Not Block The Box” intersections, and situations where conflict areas are not producing accurate depictions of yielding behavior.

905.3.5.3.2.3.4 Calibration Targets/Model Validation

Calibration is a way of fine tuning a model to better replicate field conditions by iteratively adjusting several calibration parameters. A model is deemed to be sufficiently calibrated once it achieves calibration targets that are based on observed field conditions and agreed upon at the outset of a project, a process known as model validation. A few examples of such calibration targets are discussed in EPG 905.3.5.3.2.3.4 Calibration Targets/Model Validation.

Visual Inspection

Visual comparisons between a simulation and real-world traffic conditions go a long way in proving a model’s reasonableness. These inspections are important to conduct throughout the modeling process, not just during calibration. Modelers should be sure to consider multiple sources that capture real-world traffic conditions, such as observations made during data collection, photos and videos of the study area, and 3rd party congestion data.

Because these inspections are more qualitative than quantitative, modelers should use their best judgement when determining where the simulation reflects real-world traffic conditions accurately and where the simulation may require calibration. These sorts of determinations should be documented, to the extent possible, in the Calibration Report. Quantitative proof of calibration will come with the analysis of other calibration targets.

Volume and Origin-Destination

After visual inspection, showing that simulation output volumes closely match field volumes is an important step in proving that a model is calibrated. A common way of comparing a model's estimate of volume to field counts is to compute the GEH Statistic.

The GEH Statistic is computed as follows:

$$GEH = \sqrt{\frac{(E-V)^2}{(E+V)/2}}$$

Where:
E = Model estimated volume
V = Field Count

Refer to the FHWA *Traffic Analysis Toolbox*, *Volume III*, Section 5.6 for more information on computing the GEH Statistic.

With regards to calibration acceptance targets for link flows and GEH statistics, *Traffic Analysis Toolbox* recommends the criteria shown below in Table 905.3.5.3.2.3.4. These criteria are particularly suited for freeway modeling in comparing mainline and ramp flow volumes, and also are applicable for arterial corridor volume comparisons on entry/exit links. Caution may need to be applied to use of these criteria for lower volume facilities or driveways and for application directly to intersection turning movements for arterial corridor studies. *Traffic Analysis Toolbox* was updated in 2019 but is not yet widely used. The study team may elect to use the newer targets in lieu of those presented here.

Table 905.3.5.3.2.3.4, Calibration Targets for Link Flows and GEH Statistics

Criteria and Measures	Calibration Acceptance Targets
Individual Link Flows	
Within 15%, for 700 veh/h < Flow < 2700 veh/h	> 85% of cases
Within 100 veh/h, for Flow < 700 veh/h	> 85% of cases
Within 400 veh/h, for Flow > 2700 veh/h	> 85% of cases
Sum of All Link Flows	Within 5% of sum of all link counts
GEH Statistic <5 for Individual Link Flows	> 85% of cases
GEH Statistic for Sum of All Link Flows	GEH < 4 for sum of all link counts
Source: FHWA Traffic Analysis Toolbox, Volume III, Section 5.6 (Table 4)	

Spot Speed

While calibrating the number of vehicles within the network is necessary, so is calibrating the behavior of the drivers of those vehicles. Assessing driver speed (both range and average) is usually the first step in this process and is particularly important for freeway segments. Sometimes a visual check of link speeds is satisfactory, however, some projects may require a direct comparison of spot speeds for calibration.

Key calibration locations can be near model entry points where spot speeds are useful in defining/refining assumed speed profiles for traffic streams or for bottleneck/congestion locations to help in determining appropriate throughput in these areas. Spots speed verification/calibration is not needed comprehensively throughout the freeway model but is typically appropriate on select freeway mainline segments. Locations may be governed by location of existing ITS devices that may aid in the collection of spot speed data and should be discussed for inclusion in the project scoping process.

For more detailed analyses where spot speeds are widely available throughout the model, it's considered best practice for model speeds to be within +5/-5 mph of real-world spot speed data on at least 85% of all freeway links and in certain key locations where real-world speeds are available. If more precise requirements for speed calibration are deemed necessary for a project, these requirements should be outlined in a Methods and Assumptions Report at the outset of the project.

Travel Time

With regards to travel time, the FHWA *Traffic Analysis Toolbox, Volume III,* Section 5.6 recommends that journey times within a modeled network ought to be within 15% (or 1 minute maximum, if higher) of real-world travel time runs for greater than 85% of cases. The intent is not to compare many short (one mile or less) travel time segments, but to choose longer travel times through the network that are meaningful to the project's purpose and need. If more precise travel time calibration is deemed necessary for a project, these requirements should be outlined in a Methods and Assumptions Report at the outset of a project. It is also important to note that the standards and thresholds for spot speeds described in Spot Speed are not directly applicable to the thresholds defined for segment travel times. Both should be used in the calibration and validation process for models.

Queuing

A qualitative comparison of modeled queue lengths and queue lengths observed in the field is necessary to ensure intersections are operating properly within the model. Excessive queueing, or alternatively a lack of queueing, can be a symptom of coding errors in intersection control or vehicles demand. If the model still does not model queues accurately after coding inputs have been checked, then adjusting some calibration parameters may be required to address the issue.

In general, a qualitative comparison is sufficient when calibrating queues. However, depending on the project there may be a desire for a more detailed queue calibration at specific locations. In this case, a quantitative comparison should be detailed in a Methods and Assumptions Report and include field collected information on queue lengths, queue duration and visual comparisons to queues from collected pictures/video to model animations.

Lane Utilization

The need to calibrate lane utilization varies between projects. If collecting lane utilization data were deemed necessary during the scoping process, then lane utilization information should be extracted from the model at the same locations where data were collected in the field.

Transit Travel times

Like vehicular travel times, transit travel times can be calibrated to meet current transit schedules and field collected data, particularly if transit operations are a primary focus of a project process. Transit bus speed distributions and stop durations (including skipping probability) can be modified to reflect field data and model validation can be achieved through comparisons between field/model travel times for segments or time points along a transit route that is continuous in the VISSIM model. Model/field differences within 15 percent can generally considered to be acceptable unless more stringent criteria are discussed and agreed upon in the M&A process.

905.3.5.3.2.3.5 Calibration Report

MoDOT will require a calibration report to be submitted in conjunction with most microsimulation projects. A calibration report serves as proof that a microsimulation model has been adjusted to replicate the real-world traffic conditions within the study area. A calibration report also summarizes how the model’s ability to replicate these real-world conditions has been thoroughly validated using observed counts and measurements.

All calibration reports submitted to MoDOT should be made using MoDOT’s Calibration Report Template. Topics of discussion outlined in the template and required in all calibration reports include the following:

- Simulation study area, analysis years, and analysis peak periods
- Relevant data collection and preparation
- Base model development, including model assumptions
- Calibration procedure, including process of calibration parameter selection
- Calibration criteria and targets
- Summary of simulation runs and resulting parameter refinement
- Validation results

For smaller microsimulation projects, a formal calibration report may not be required. However, the modeler may still be required to outline their calibration processes in the technical documentation they prepare for the project. If a project doesn’t require significant calibration, and therefore doesn’t merit a calibration report, the modeler should also explain this in their technical documentation.

905.3.5.3.2.4 Results and Presentation

905.3.5.3.2.4.1 Output Results

VISSIM output can be divided into two categories: output which is recommended for most projects and output which may be needed for select projects. Consultants should work with MoDOT and other stakeholders to determine what VISSIM outputs are most relevant to each unique analysis and expected to be included in a final report.

Recommended for Most Projects

MoDOT considers it best practice for modelers to include the following data in their final reports for most projects:

Node Evaluation

Nodes are a very efficient way to collect performance data at intersections in an orderly output, although there might be some limitations in their ability to correctly capture all queues/delays if intersections are closely spaced. Obtaining node evaluation data requires placing “nodes” throughout a network at important locations. These locations should be previously defined in a Methods and Assumptions Report and usually include study intersections, ramp terminals, and other significant points. Modelers should use the node evaluation feature in VISSIM to report the MOEs for each movement at every node and then aggregate the results for each node. MOEs to report for each node may include the following: node number, movement, number of vehicles, average delay, queue lengths, and stops.

Travel Time

Travel times in VISSIM are collected by creating travel time collection (TTC) segments. Upon evaluating TTC segments, VISSIM reports the average time it takes for the vehicles in the model to travel a given segment during a time interval specified by the user. TTC segments should be coded to match the segments used during data collection to conduct travel time runs in the field. Doing so allows for direct comparison of VISSIM output to real-world measurements. However, TTC segments must be coded carefully if there are several paths in the network vehicles could use to travel between the start and end of the segment. If there are multiple paths between the start and end of a segment, VISSIM will report the average time for vehicles using all available paths. It is also important to note the number of vehicles using each TTC in the model and to ensure an adequate sample size. If few vehicles are using a given TTC, it may be beneficial to break the TTC into smaller segments to increase the same sizes.

Network Performance Evaluation

Network performance evaluation helps to provide a general idea of how well a network is operating that can be useful for making very high-level comparisons of design alternatives, including alternatives that move access points. This evaluation produces standard MOEs including vehicle miles traveled (VMT), vehicle hours traveled (VHT), vehicle delay and stops, as well as the number of vehicles that were not able to enter the network or have to wait outside the network and the latent delay time of those vehicles. Exhibit 35 shows an example of formatted output from network evaluation data that can be easily compared to highlight advantages/disadvantages of impacts of design alternatives on the modeled study area.

	Metric	Average Vehicular Delay	Average Number of Stops	Average Speed	Average Stopped Delay	Total Distance Traveled (VMT)	Total Travel Time (VHT)	Total Delay	Total Number of Stops	Total Stopped Delay	Vehicles Arrived	Latent Total Delay	Latent Demand
	Unit	seconds/ vehicle	stops/ vehicle	miles/ hour	seconds/ vehicle	miles	hours	hours	stops	hours	vehicles	hours	vehicles
AM Peak Hour	Base Year	105	9.2	14.7	29	2,949	202	117	36,574	32	3,684	30	125
	Future No-Build	223	19.8	8.8	69	2,870	327	244	77,846	75	3,586	866	2,072
	Alternative 1	129	8.5	12.0	53	3,978	335	200	47,594	82	5,156	110	397
	Alternative 2	65	1.2	19.2	50	***4,344***	226	108	7,355	84	5,768	1	2
	Alternative 3	37	1.2	23.5	21	4,380	187	62	6,980	***35***	5,809	1	1
PM Peak Hour	Base Year	132	11.5	13.0	33	2,898	224	140	43,830	35	3,519	113	352
	Future No-Build	220	19.6	9.0	61	2,861	316	234	75,305	65	3,490	973	2,251
	Alternative 1	103	7.8	13.8	33	3,839	279	148	40,405	48	4,831	382	911
	Alternative 2	61	1.2	20.0	47	***4,481***	224	104	7,464	79	5,870	1	0
	Alternative 3	49	1.5	21.5	30	4,500	210	82	8,872	51	5,854	1	1
		Averaged Performance MOE Statistics				Aggregated Performance MOE Statistics					Throughput MOE Statistics		

BOLD/ITALIC = Highest MOE Improvement Over 2040 No-Build Conditions

Figure 905.3.5.3.2.4.1.1, Network Evaluation Formatted Output Table

Link Evaluations

Link evaluation is most commonly used when *Highway Capacity Manual 2016* (HCM6) Level of Service (LOS) is needed for freeway analysis. When using link evaluation, the following MOEs should be reported on a link-by-link basis:

- Volume (Throughput)
- Speed (spot mean speed and/or space mean speed)
- Data collection intervals
- Link Evaluation Segment length
- Density

The default link evaluation segment length is short (32.8 feet, or 10 meters), so it may be beneficial to change this value for all links to a large value (99,999 feet, for example). Then links can be split to generate the desired link evaluation lengths.

Modelers should note that density calculated by VISSIM is a measured density, which does not align with the Highway Capacity Manual (HCM) definition of density. In order to obtain the HCM equivalent density, users must post-process the measured volumes and speeds reported by VISSIM. The HCM equivalent density can then be used to assign an HCM LOS letter grade. See HCM Equivalent LOS in EPG 905.3.5.3.2.4.2 Post Processing.

However, modelers should also remember that the ultimate goal of an analysis is most commonly to compare the performance of design alternatives in a design year. For this reason, using the density reported by VISSIM is typically acceptable and determining the HCM density equivalent (used to assign LOS) is often unnecessary. In this case, a "simulation LOS" can be reported using VISSIM-generated density and applying the HCM LOS thresholds.

Note on Volume to Capacity Ratio

Unlike deterministic software programs, VISSIM does not report volume to capacity (v/c) ratios. This is because both volume and capacity are highly variable in microsimulation. Although it is possible to calculate capacity at any given time, capacity is not constant. The capacity during one time period of the run may not be equal to the capacity during any other time period. Microsimulation also does not provide demand volumes. Rather, the model reports congestion and queuing, which are direct effects of a network being at capacity.

Instead of supplying v/c ratios, VISSIM produces the following information that conveys the relationship between traffic supply and demand:

- Volume, speed, and density at given locations
- Congestion duration at variable traffic volume flow levels
- System-wide effect of congestion and queueing.

Speed Contour Plots

Statistics produced by link evaluation or data collection points may be used to create speed contour plots which are useful in demonstrating the intensity and duration of congestion. The link-by-link statistics gathered during initial link evaluation can be used to generate contour plots, or modelers may choose to rerun the link evaluation with smaller segments (can use 100-foot segment lengths) to improve the resolution of the plot.

Figure 905.3.5.3.2.4.1.2 shows an example of a speed contour plot where the x-axis shows the horizontal distance along a corridor and the y-axis shows temporal time distribution through a peak period. Individual cell locations are color coded to match speed range results.

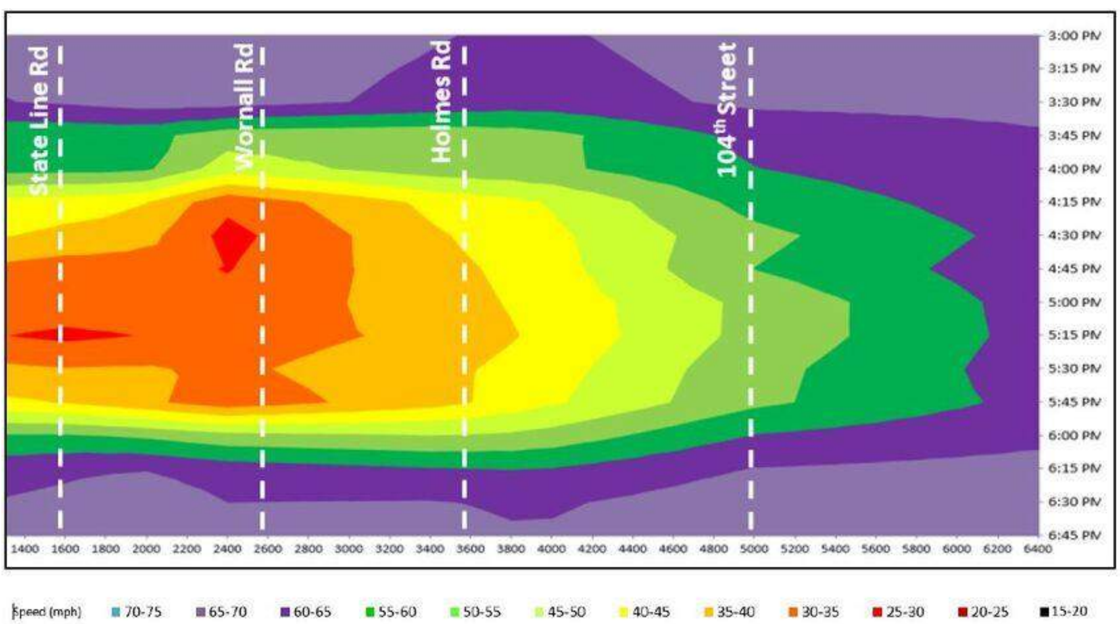


Figure 905.3.5.3.2.4.1.2, Example of a Speed Contour Plot

Other Output for Select Projects

MoDOT considers including the following information in a final report to be needed only for select projects, as agreed-upon during scoping. Modelers should review this list and include any topics which are relevant to the analysis at hand.

Queue Counters

Queue counters can be coded into VISSIM to measure queue lengths starting at the downstream position of the counter until the furthest upstream vehicle has entered queue conditions. Queue counters report average queue length, maximum queue length, and average number of stops for the defined time intervals. Queue lengths may extend as far as the next queue counter or as long as the maximum queue length specified by the user. According to the VISSIM User Manual, "If the queue backs up onto multiple different approaches the queue counter will record information for all of them and report the longest as the maximum queue length." For this reason, modelers must place queue counters on all side streets to ensure the reported queue length is an accurate measurement of the queue on the actual roadway in question.

Queue counters can be coded under Evaluation/Configuration, as shown in Figure 905.3.5.3.2.4.1.3.

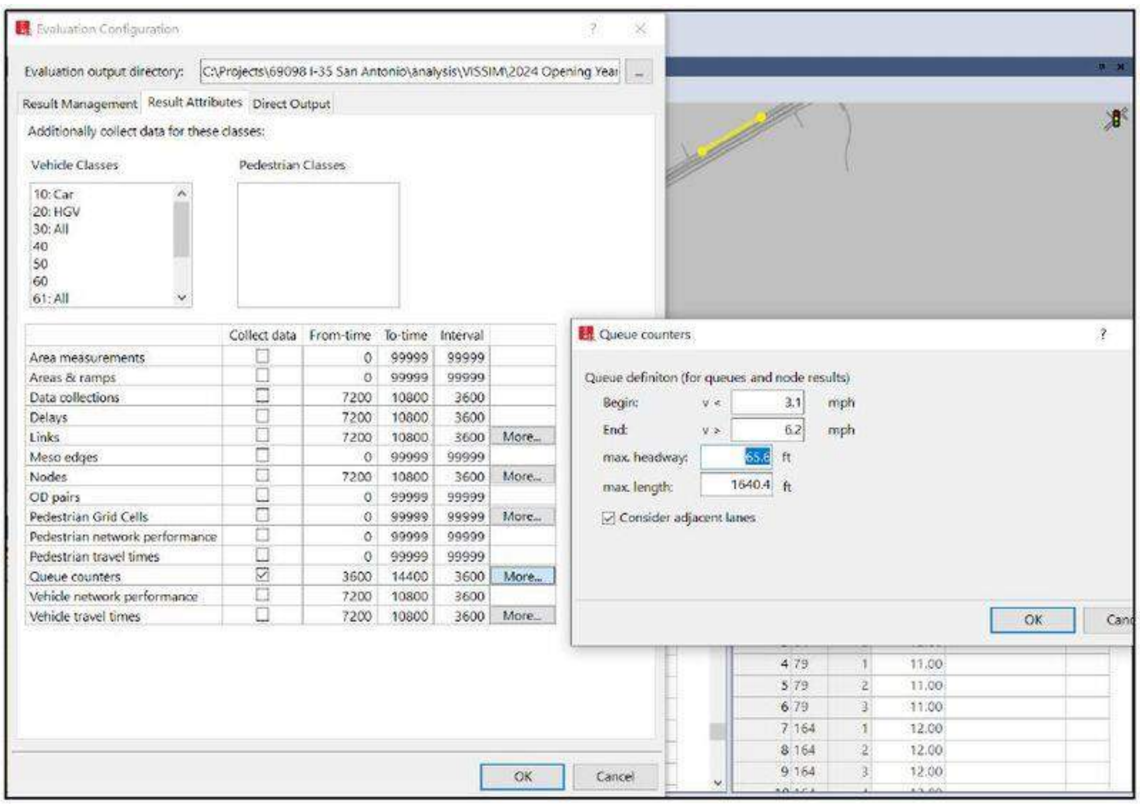


Figure 905.3.5.3.2.4.1.3, Queue Counter Evaluation Dialog Boxes

If a project requires calculating average and 95th percentile queue lengths, modelers should record queuing information in 120-second intervals. The data set from the queue counters over the multiple simulation runs must be compiled and the list of all maximum queues for each movement must be averaged together to get the “average of the max.” The standard deviation from this data set must also be calculated. With these two values the 95th percentile queue can be calculated using the formula (same calculation as used in the SimTraffic microsimulation software package):

95th percentile queue = average of the max queues + 1.65 * standard deviation

It is MoDOT’s preference that maximum queue values be directly extracted from the VISSIM node or queue counter functions. If the project needs to use 95th percentile queue information, that will need agreement and justification during the project scoping process.

Additionally, custom aggregation percentiles for queues (or any other defined MOE statistic) can be specified in the Result Management tab of the Evaluation->Configuration window within VISSIM. The percentile calculations do not use the estimation formula as shown above for 95th percentile queues and again, will need to be justified for use during the project scoping process in lieu of reporting maximum queue values.

Data Collection Points (DCPs)

Placement of DCPs should reflect the locations where field data were actually collected. If the model is being calibrated with archived speed or data volume, DCPs should be placed as closely to the original data collection locations as possible.

After coding and naming all DCPs, modelers must create data collection measurements (DCMs) to extract vehicular counts and spot speeds at DCPs. These DCMs can be coded individually to capture lane by lane data or grouped to show full roadway cross-sectional data. Data extracted from DCMs can be useful in creating speed comparison tables to compare field measurements with model outputs.

Emissions

Through node evaluation, VISSIM is able to report emissions output for CO, NOx, VOC, and inputs needed for the EPA’s Motor Vehicles Emissions Simulator. If a project requires EPA compliant emissions, VISSIM does have the capability to interface with external emissions models. If emissions are being used simply to compare alternatives, VISSIM’s emissions reports are sufficient.

Lane Changes

Lane change output is used most often when comparing design alternatives for weaving sections. VISSIM’s lane change output provides a record of each lane change maneuver with a time stamp, as well as the origin and destination lanes of the maneuver. This information can help to compare alternatives, where alternatives that produce fewer lane changes are likely preferable. However, users should make note that VISSIM does not allow for filtering by link number before recording. Finding the records of lane changes made in the segment in question requires post-processing filtering, which can be time consuming and costly.

Managed Lanes

If a project requires use of VISSIM's managed lane add on module to account for HOV or other managed lanes, modelers can use the managed lane output option to report more detailed information about the network's performance. Additional details include the following:

- Average speed on managed lanes
- Average speed on general purpose lanes
- Travel time savings for managed lanes routes
- Tolls collected in the managed lanes by vehicle class

Delay Segments

Delay segments in VISSIM can be used for several purposes, including the following:

- Collecting intersection MOEs at locations with unusual geometry
- Measuring delays for a movement through multiple intersections
- Measuring the delay along a specific path along a network
- An alternative to node evaluation for networks with a unique street system

When using this option, the user defines the start and end of the delay segment and assigns it a number. To do this, the user must first define travel time segments for each movement and then combine them as delay segments. Although this process is labor intensive at first, it allows for the user to have complete control over how delay segments are defined.

Green Time Distribution

The green time distribution option may be useful if there are signalized intersections in the VISSIM model where the signal timing changes from cycle to cycle. The signal timing may change due to actuation or because of transit signal priority or railroad preemption. The option reports the average green and red times for each signal phase and a summary table of each value of green and red times recorded.

Vehicle Record

VISSIM's vehicle record option can be used to report vehicle performance characteristics, such as position, instantaneous speed and acceleration, desired speed, and lane, in the network for every time step. This option is most normally used to collect data that will be exported to a third-party software program for visualization purposes.

Public Transport Waiting Time

VISSIM's public transport waiting time option aggregates the amount of time a transit vehicle stops for any reason other than a designated transit stop or a stop sign coded with a dwell time. This wait time is largely a sum of the time spend at traffic signals or waiting in congestion.

905.3.5.3.2.4.2 Post Processing

VISSIM data requires some post-processing to arrive at a truly accurate representation of a model's predictions. Because randomization is inherent to the microsimulation process, modelers should average the results from several runs using different random number seeds to develop the most correct interpretation of the model.

Post-processing methods may vary from modeler to modeler; however, spreadsheets are commonly used because VISSIM data is usually output as a delimited text file. Modelers should take care to outline their post-processing procedures, and any spreadsheets they plan to use for post-processing, in a Methods and Assumptions report. Modelers should also note that standard deviation for all data should be reported when possible and that the random number seeds used to produce runs should be recorded and reported to ensure that their results can be replicated later.

Post-processing is also sometimes carried out using VISSIM's built-in Data Analyzer feature. The Data Analyzer can generate reports from Node Evaluation and Travel times data, however, doing so requires a significant amount of time to collect the data and run the data analyzer. This saves modelers from having to sort through raw data themselves, but modelers are still expected to review their raw data to determine standard deviation and identify outliers if they choose to use this method.

HCM Equivalent LOS

During scoping, it should be determined if HCM methodology for analyzing freeway segments will be strictly followed. If LOS is the main MOE used, then this is recommended, and the following guidance applies:

- For typical freeway merges and diverges, density should be calculated for every 15-minute period using the average density (weighted by lane-length) of the acceleration/deceleration lane(s) and the two adjacent freeway through lanes for a length of 1,500' from the painted gore point. For example, if a merge includes a 1,000' acceleration lane, then the average density output by VISSIM for the acceleration lane and each of the two adjacent through lanes should be multiplied by 1,000' and added together. This should then be added to the average density of each of the two outer through lanes downstream of the acceleration lane multiplied by 500'. The overall total should be divided by the total lane-length of the merge segment (in this case 3x1,000' + 2x500' = 4,000').
- Weave density should be calculated for every 15-minute period using the average density (weighted by lane-length) of the weave area (between the painted ramp gores) and each of the two 500' segments on either side of the weave area. For example, for a three-lane freeway with a 3,000' weave area (with a single auxiliary lane) the average density for the weave area would be multiplied by 3,000' times four lanes and added to the density of the segments on either side multiplied by 500' times three lanes. The

overall total should be divided by the total lane-length of the weave segment (in this case 4x3,000' + 2x3x500' = 15,000').

The resulting density can then be assigned an "equivalent LOS" based on HCM thresholds. Without this post-processing, LOS can still be assigned using HCM thresholds, but should be reported as "simulation LOS."

905.3.5.3.2.4.3 Visualization of Simulation Results

In addition to post-processing using spreadsheet tools or VISSIM's Data Analyzer, modelers may choose to explore some of VISSIM's options for visual displays and interpretations of simulation data. Several of these advanced options are listed and briefly described here:

Output plots: VISSIM can generate relatively simple plots for several output parameters, including but not limited to, Node outputs, Link segment outputs, Vehicle Travel Time results, and Queue results. VISSIM can output these plots as line graphs or bar charts based on how the user would like to illustrate the given data.

Network heat maps: VISSIM also has the capability to generate heat maps that represent link performance measures such as average speed, density, and volume. These maps convey how performance measures vary spatially within a network, making them a powerful visual aid. These heat maps can be generated using VISSIM's pre-defined color schemes, or with a color-scheme of the user's choosing.

Ancillary performance visualization: Similar to heat maps, VISSIM can generate ancillary performance visualizations as an alternative way of conveying network performance measures. These performance measures include but are not limited to VISSIM calculated LOS, queue lengths, and throughput volumes. Ancillary performance visualizations can be helpful when generating final reports, but also as a relatively fast way to evaluate the reasonableness of a model's output.

905.3.5.3.2.4.4 Video Presentation

In addition to static visual presentations, video presentations can also be a powerful way to illustrate and validate model performance. VISSIM offers several different types of video presentation, each of which are defined and briefly below:

2D Vehicle Animations: Two-dimensional animation is shown within the VISSIM user interface during simulation runs and is very useful for model debugging and validation. However, this method is not as effective as other methods when communicating results and outputs.

Real-Time Network Performance Results: Similar to the way performance metrics can be included in visual presentations of models, figures illustrating speed, volume, density, queue length, intersection performance, and other metrics can be included in model animations. Showing real-time performance results can be especially useful in showing the build-up and break-down of congestion during peak periods. Still visual presentations can be used in a report to communicate performance metrics at specific times, while animations can be used to show how performance metrics change over time.

3D Animation: Although not as commonly used as two-dimensional animations, three-dimensional animations can provide realistic illustrations of transportation networks that are especially useful when presenting to non-technical audiences. Using VISSIM’s 3D mode, modelers can create animations by recording a simulation from fixed camera viewpoints and sequences in a storyboard. Users also have the option of using a standard aerial background for their animations, or they can choose to incorporate other background elements from Google Sketchup’s online warehouse or custom made in Google Sketchup. Further editing can also be done using an external video-editing software. Modelers should note that while three-dimensional animations can be effective aids when presenting results, generating these animations is often resource intensive. The need for three-dimensional animations should be discussed with MoDOT and other stakeholders before proceeding.

905.3.5.4 Other Software

There may be situations where the contextual needs of the project make it necessary to use one or more analysis tools that are not addressed in EPG 905.3 Transportation Impact Analysis. In these circumstances, please discuss the situation with MoDOT and local planning partners as early as possible while scoping the project. Once it is collaboratively agreed upon what analysis software should be used, the analyst should document the selected software and the key reasons for selecting the software in the MoDOT TIA Methods and Assumptions Report.

Congestion Mitigation and Air Quality (CMAQ) Emissions

CMAQ provides flexible funding that may be used to reimburse eligible project sponsors for projects or programs that will contribute to attainment of the National Ambient Air Quality Standards (NAAQS). The East West Gateway Council of Governments (COG) includes the metropolitan St. Louis area, which is the only metropolitan area in Missouri subject to the CMAQ application process.

The East West Gateway COG application states that the project sponsors may be asked to estimate emissions reductions data. The emissions data is generated from the EPA’s Motor Vehicle Emission Simulator (MOVES) model, not from other modeling sources. For more information about this process, refer to the East West Gateway COG 2020 CMAQ Project Development Workbook.

905.3.5.5 Model Templates

Generic project file templates are available to non-MoDOT users upon request from the Highway Safety and Traffic Division. These file templates are a reference for users, which accompany the guidance in EPG 905.3 Transportation Impact Analysis.

- HCS

- SIDRA
- Synchro/SimTraffic
- VISSIM

905.3.5.6 Review Checklists

In addition to base model templates, project scoping and software analysis tool checklists are available. These checklists are intended to guide MoDOT project reviewers as they review the scoping and software analysis completed for a project.

- Project Scoping (TIA Scoping Reviewer’s Checklist)
- HCS
- SIDRA
- Synchro/SimTraffic
- VISSIM

905.3.6 Safety Analysis

905.3.6.1 Existing Safety Analysis

905.3.6.1.1 Purpose

A complete safety study includes two parts: Analysis of crash history, and estimation of crash future. EPG 905.3.6.1 Existing Safety Analysis is about crash history and EPG 905.3.6.2 Safety Modeling is about crash future.

TIAs provide essential information for a wide range of project types and are required for projects under the jurisdiction of MoDOT. The following guidance is intended to serve as a resource for practicing MoDOT Project Managers and consultants when completing or reviewing TIAs on various types of projects that include an existing safety analysis component. These guidelines are consistent with MoDOT's traffic safety standards of practice.

905.3.6.1.2 Introduction

TIAs are required for several different types of projects. These project types include, but are not limited to, the following:

- Planning study

- Traffic analysis study
- Environmental study
- Access Justification Report (AJR)
- Proposed development.

Safety analysis consists of locating crashes at a particular location based on predetermined criteria and should be a component of these studies when crash data is available. Analysis of safety data is conducted in a similar manner for each of these studies, however, there are differences in the purpose depending on the work product being completed.

For example, a safety analysis for a planning level study should be done at a higher level of analysis (as the project study limits tend to be broader) while a review of crash history is focused more on overall trends that may or may not be known at the time of the project. Identifying these patterns early during the planning phase allows time for additional considerations to be made and implemented on time. This differs from a work product, such as a traffic analysis study, which typically occurs later in the project's life when the scope and limits have become more defined. The safety information is similar in format, but the intent and purpose should be catered to the work product.

TIAs typically have a threshold of 100 new trips or identified safety issues in the area to trigger a safety study. However, MoDOT will make the determination on the need for a safety study if it is in question.

905.3.6.1.3 Parameters

The following are a list of parameters to be determined prior to completing crash analysis.

Analysis Type

The type of crash analysis can differ based on the project type. There are three types of crash analyses: sections, intersections, and networks. Depending on the project, one or more types of analyses may be needed.

- **Section analyses** are the preferred analysis type to be used for studies where the main concern is mainline crashes along a specific section of roadway. Examples include an interstate corridor or a rural secondary road.
  Section analyses require a begin and end point and include crashes along a corridor between these limits, including intersection related crashes, unless there is a project specific reason to exclude them. Example study limits for a section analysis are shown in Figure 905.3.6.1.3.1.

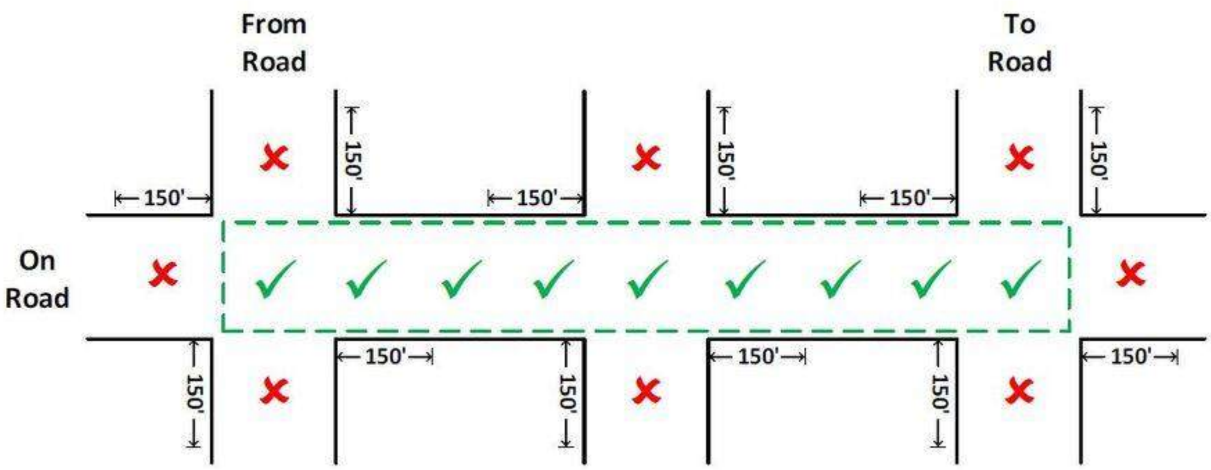


Figure 905.3.6.1.3.1, Section Analysis Study Limits

• **Intersection analyses** are the preferred analysis type to be used for studies where crashes at a specific intersection are the primary concern. Examples include a downtown intersection or a rural driveway access.

Intersection analyses include crashes within 150 feet of an intersection along all approaches. This distance should be extended from the edge of pavement of the cross-street for each approach. They should be used if project considerations are expected to impact these types of crashes. Example study limits for an intersection analysis are shown in Figure 905.3.6.1.3.2. It should be noted that the recommended study limits of 150 feet may be extended at the analyzer's discretion to capture impacts at any nearby driveway accesses that fall just outside the standard limits.

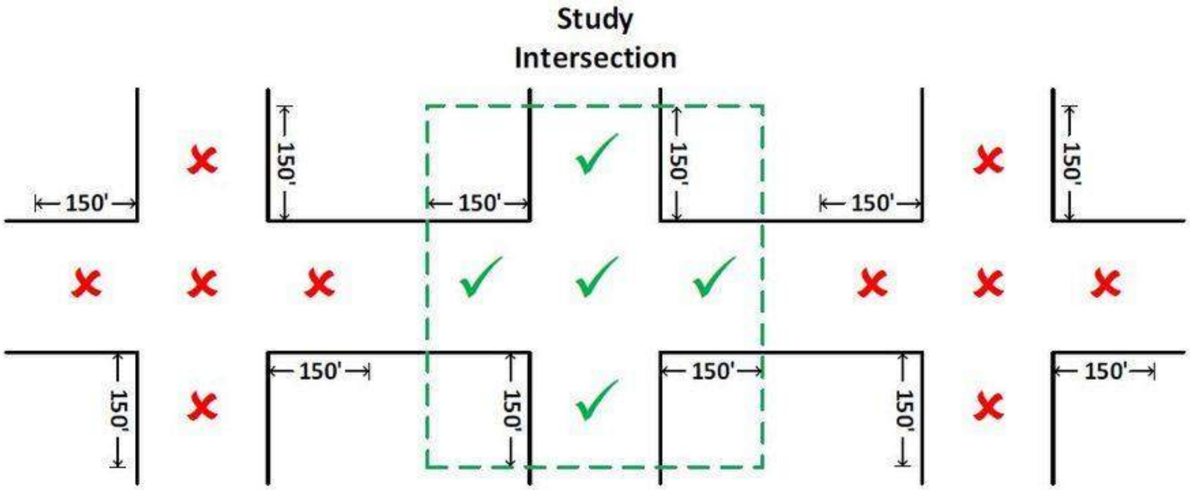


Figure 905.3.6.1.3.2, Intersection Analysis Study Limits

Both analysis types should be used on the same project if project considerations are expected to impact both section and intersection crash types. Such as widening a downtown corridor while implementing traffic signal upgrades should have an impact on both section and intersection type crashes and therefore should be analyzed as such.

• **Network analyses** are a combination of section analyses, often with one or more intersection analyses, too. For example, closing at-grade crossings while adding a new interchange will likely cause traffic to reroute through a network of sections and intersections, which need to consider not just the proposed changes in features, but also the changes in traffic patterns and volumes.

Location

It should be noted that the location reported for a crash may need to be reviewed, if possible. Most notably, crashes might be reported at the “intersection” of a minor route and a freeway, but review of the crash report is needed to determine if the crash was on the freeway level or on the minor route level, or might have happened near one of the ramp terminals instead of at the crossing of the two routes.

Likewise, crashes at a short feature might need a review of the crash reports to see if the reported location is where the crash started or ended, and how that location applies to the location being studied. For instance, crashes reported at a curve might actually be related to an issue prior to the curve. The smaller the data set (less than 30 crashes) the more significant such location issues tend to be.

Please contact the Traffic Management System (TMS) Help Desk at (573) 526-8055 or (573) 522-8464 to report incorrect crash reports.

Time Period

Typically, a study period of the most recently available five (5) full years of crash history data is standard for all crash analyses. Since there is typically a lag in crash data becoming available, please provide the most recent full years of complete data. Coordinate with the study team to determine the timeframe of complete crash data currently available.

There may be exceptions to the five-year timeframe if significant changes have occurred at the location within this period. One exception would be for analyses focused on pedestrian/bicycle crashes or railroad crossing crashes, which are typically analyzed based on the most recently available ten (10) years of crash history data due to their infrequent crash occurrences. Other exceptions that come at the discretion of the analyzer are typically any other instances of infrequent crash occurrences, such as when analyzing data along corridors that carry less than 1,500 vehicles per day.

Study Limits

As stated, section analyses require a begin and end point that should include all affected sections and intersections. At a minimum, include the entire footprint of the project area and extend study limits as needed. Proposed projects should incorporate, within reason, all intersections and access points that are expected to experience a change in crashes, traffic patterns, or traffic volumes as a result of the project. This may require extending the study limits to ensure all impacted approaches, ramps, driveways, etc. are captured.

For instance, studies involving interstate, freeway, and expressway facilities should begin and end the crash analysis at least a half mile from the center of the beginning and ending interchanges, or at least 1,500 feet from the farthest-outside ramp gores, whichever is greater. This will ensure that all crashes related to the merge and diverge areas of those interchanges will be included, however, the analyzer may extend the study limits even farther to ensure all impacts are captured, such as when dealing with vertical grade issues. Example study limits for an interstate section analysis are shown in Figure 905.3.6.1.3.3.

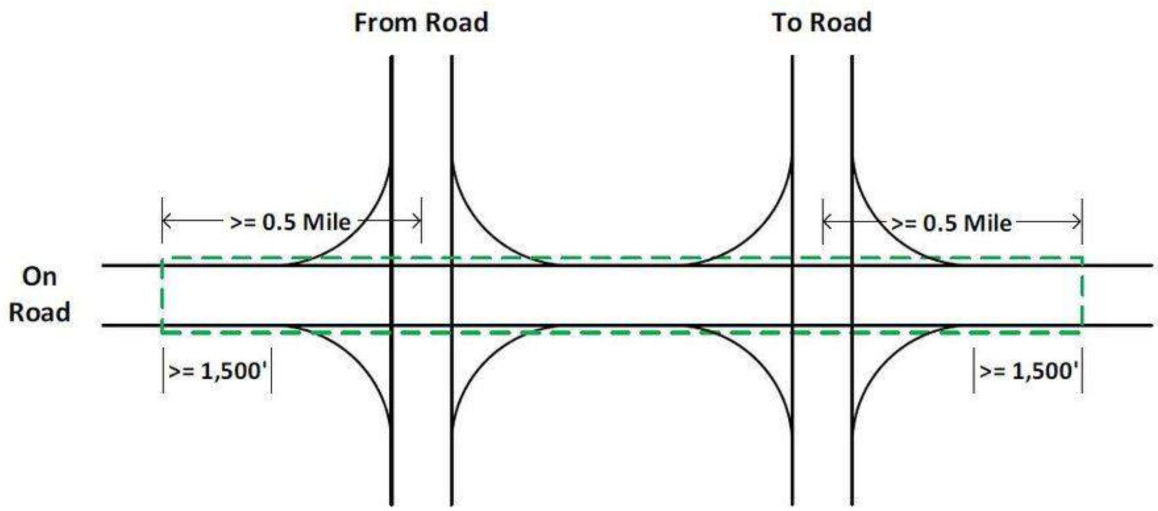


Figure 905.3.6.1.3.3, Interstate Section Analysis Study Limits

Additional Resources

There are additional resources that can be used to assist in conducting existing safety analyses, such as the MoDOT Crash Statistics Map. This map allows users to get a visual representation of crashes and their locations across the state. It also allows users to pull historical crash data and filter that information based on various crash and roadway attributes, such as crash type or curve radius. Data can also be filtered by more specific criteria, such as crashes involving older drivers or pedestrians. Results can be exported to either Excel or PDF for use. Individual crash reports may also be available via the mapping tool. The retrieval and use of crash reports by external users will be determined by MoDOT.

Statewide average crash rate information is also a useful resource when performing a safety analysis. The most recently available statewide average crash rates can be obtained through MoDOT and are helpful in comparison of the crash rates of the study location with the statewide average crash rates of locations having a similar cross-section.

905.3.6.1.4 Analysis

The following are a list of calculations and analysis techniques to be used after completing crash analysis.

Segmentation

Section crash analyses can be segmented as needed; however, it should be done in a manner that ensures the data remains statistically valid when comparing to statewide average crash rates. Due to statewide average crash rates consisting of many miles of continuous corridors, segmenting the data too much may create sample sizes that are too small and lessen the validity of the comparison of the crash rates to the statewide average.

Examples of proper places to segment a section analysis include locations where cross-sections drastically change between corridor intersections (e.g., change in number of lanes) or if multiple project phase limits exist within the study limits. Segmentation may also be done on interstate or highway facilities at each interchange. As shown in Corridor Crash Rate, segmentation of the crashes might be made to match segmentation of the AADT data, to facilitate calculations of crash rates. Segments should be broken along the corridor at the center of each overpass that has an interchange with the corridor. Note that segments less than a mile in length may show unusually high rates.

As a note, segment lengths do not need to be equal, as crash rates will be adjusted accordingly based on length. Example study limits for a segmented interstate section analysis are shown in Figure 905.3.6.1.4. Analyzers may extend the limits on cross streets as they see fit to ensure that all crashes are being considered.

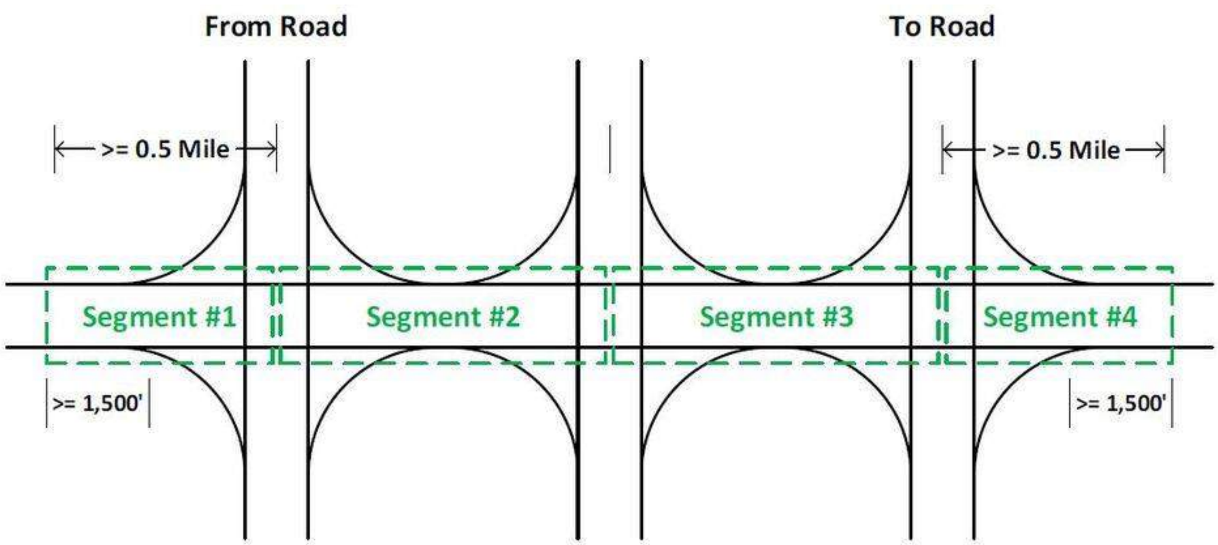


Figure 905.3.6.1.4, Segmented Interstate Section Analysis Study Limits

Corridor Crash Rate

Crash rates are calculated using a combination of crash frequency and vehicle exposure. They are expressed in either crashes per 100 million vehicle miles traveled (HMVMT) for section analyses or in crashes per 100 million entering vehicles (HMEV) for intersection analyses.

Calculate the corridor crash rate as follows:

$$Crash\ Rate = \frac{Number\ of\ Crashes}{Exposure}$$

Where:

$$Exposure = AADT * \frac{365\ Days}{Year} * \frac{Number\ of\ Years}{1} * \frac{Segnment\ Length\ (miles)}{1}$$

Critical Crash Rate

Statewide average crash rates should be used for comparison to the corridor crash rate when available. The statewide average rate used for comparison is up to the analyzer's discretion and should be one that best represents the characteristics of the study corridor. For example, occasionally US routes will function more similarly to a state or secondary road than to an interstate facility.

When appropriate and after discussing with the project team, it may be necessary to convert statewide average crash rates to critical crash rates using the Critical Crash Rate Formula, below, to remove the elements of chance and randomness. This method statistically adjusts the crash rate using the exposure from the study corridor to determine whether the corridor crash rate for a segment is significantly higher than the rate of other locations with similar characteristics based on Poisson's distribution. Poisson's distribution is defined as a discrete probability function that describes the number of events that may occur in a given time period given the average number of times that such an event would typically occur over that time. Since crashes are rare events the probability of their occurrence can be approximated based on this distribution.

Corridor crash rates equal to or greater than the critical crash rate may be considered significantly higher than average and not due to chance or randomness.

Calculate the critical crash rate as follows:

$$Critical\ Crash\ Rate = Statewide\ Average\ Rate + K * \sqrt{\frac{Statewide\ Average\ Rate}{Exposure}} + \frac{1}{2 * Exposure}$$

Where:

$$K = probability\ factor = 1.645\ (95\%\ confidence\ level)$$

$$Exposure = AADT * \frac{365\ Days}{Year} * \frac{Number\ of\ Years}{1} * \frac{Segnment\ Length\ (miles)}{1}$$

Crash Statistics

Results from the crash analyses should be summarized in a report format and include the following basic statistics:

- Study limits
- Segment length
- Annual average daily traffic
- Total number of crashes

- Crash rates and comparison to statewide average crash rates
- Summary of crash types (e.g., rear ends, sideswipes, etc.) and percentages
- Summary of crash severity and percentages

MoDOT Injury Severity Classification	KABCO Injury Severity Classification
Fatal Injury	K
Serious Injury	A
Minor Injury	B & C
No Injury Apparent	O

- Summary map of all crashes in the study area
- Summary of locations with patterns of crashes that may need to be addressed.

Crash Patterns

As stated above, the crash analysis should be reviewed to determine if specific crash patterns exist and outlined in the traffic analysis report. Crash reports should be reviewed as needed to determine location and accuracy of information. For instance, crashes may have occurred on a side street but coded as having occurred on the mainline. Other locations may have fewer crashes, so a more thorough review of the crash reports is feasible and provides the analyst with a better understanding of the crash issues.

Patterns can include, but are not limited to the following:

- Time of day
- Day of week
- Light conditions (Day or Night)
- Weather conditions (Wet)
- Pavement condition (Wet)
- Pedestrian/Bicycle crashes
- Vehicle mix (e.g., high percentage of truck crashes).

Crash patterns should be reviewed further at specific types of locations that are more likely to have them, while also factoring in the proposed improvements and whether they would address the crashes For example, horizontal curves may have lane departure crash patterns due to substandard superelevation, inadequate paved and/or grass shoulders, and/or issues with stopping sight distance and/or passing sight distance. Vertical curves may have lane departure, rear end, and/or sideswipe crash patterns due to inadequate stopping or passing sight distance issues. Intersections may have angle, left turn-different roadway, left-turn-same roadway, rear end, or other crash patterns. These patterns tend to differ based on the configuration of the intersection and whether it is signalized or unsignalized.

The level of in-depth analysis is dependent on each situation. For example, a project near a school may require a more detailed review of time of day crash patterns, while a project in a downtown area may require a more detailed review of pedestrian/bicycle crashes. At the same time, freeway sections may require a review of wet weather or wet pavement related crashes. Certain types of projects or locations may dictate more detailed reviews of crash patterns. These reviews typically require examination of the individual crash reports completed by the police (either state highway patrol or local police officers). Engineering judgment and comparison of the various data points on the crash report are needed when reviewing the crash reports to ensure the crash is accurately represented (especially crash location). Data points on the crash reports to compare include the location and reference roads, crash narrative, and diagram.

Summary of Results

The safety analysis component of the report should include an introduction with background information to include the project description, project limits, crash analysis method and crash analysis time period determined from the guidance outlined above. A comprehensive summary of the crash statistics collected and analyzed should be produced for this section, including number of crashes and crash rates of the study area and their comparison to the statewide and critical crash rates. Lastly, the summary of results should include descriptions of notable crash patterns in the study area and additional information, if pertinent. Pie charts, figures, tables and heat maps are also helpful tools to depict the crash information to stakeholders.

An evaluation of the results of the crash analysis should be completed, including an interpretation of the results and what may be contributing factors to the observed crash patterns. Understanding why crashes are occurring can help in the project scoping process and can help determine purpose and need for a project. Traffic safety countermeasures should be proposed to address the crash patterns. The *Highway Safety Manual* provides comprehensive countermeasure selection guidance for the various crash pattern types for particular locations, including along roadway segments, signalized and unsignalized intersections, and bicyclist and pedestrian related issues.

905.3.6.2 Safety Modeling

905.3.6.2.1 Purpose

A complete safety study includes two parts: Analysis of crash history, and estimation of crash future. EPG 905.3.6.1 Existing Safety Analysis is about crash history, while EPG 905.3.6.2 Safety Modeling is about crash future.

Historical crash data is not always readily available for Transportation Impact Analyses and may not apply to future conditions, especially for new construction projects; therefore a method of analysis that does not solely rely on historical data is necessary in order to quantify impacts to safety. The following guidance is intended to serve as a resource for practicing MoDOT Project Managers and consultants when completing or reviewing Transportation Impact Analyses on various types of projects that require a predictive (future) safety analysis component. These guidelines are consistent with MoDOT’s traffic safety standards of practice.

905.3.6.2.2 Introduction

As a component of the TIA, a future crash analysis is performed to evaluate the impacts that proposed geometric changes to the existing roadway and a change in traffic volumes will have on the overall safety performance of the corridor. Several modeling platforms that estimate the safety performance of design alternatives include:

- MoDOT Crash Prediction Tool, for rural 2-lane routes.
- Highway Safety Manual (HSM) Spreadsheets, for urban arterials, rural 2-lanes, or rural multi-lanes.
- Enhanced Interchange Safety Analysis Tool (ISATe), for freeways and interchanges.
- Interactive Highway Safety Design Model (IHSDM), for many types of routes.

These safety analysis tools utilize Part C of the *Highway Safety Manual* (HSM) to estimate the number of crashes based on the geometric characteristics and traffic volume of the facility.

Predictive versus Expected

The HSM is based on estimating crashes as "predicted" or "expected".

- Predicted Crashes – Predicted crashes are based on the geometry, volume, and national pattern of crashes and are calculated within these safety tools utilizing standard Safety Performance Functions (SPFs)
- Expected Crashes – Expected crashes are determined by adjusting the predicted crashes to include local crash history as a way to determine more accurately the modeled number of crashes.

MoDOT prefers that expected crashes be determined where existing crash data is available and where the geometry is similar to that of existing (e.g., adding rumble strips to a highway as opposed to rebuilding a cloverleaf interchange as a fully directional interchange). This provides more robust results that conform more closely to real world conditions. A methodology for determining future expected crashes is discussed in EPG 905.3.6.2.7 Analysis Approach.

Model Option Overview

Although these modeling platforms are all based off Part C of the HSM and will yield similar results, the method in which the analysis is conducted as well as the level of detail in the results differs. There are several modeling tools based on Part C of the HSM, including:

- MoDOT Crash Prediction Tool
    - Analyzes rural two-lane highways only
    - Used for network screening and project analysis
    - Utilizes TMS Data
    - Automates crash analysis
    - Provides both predicted and expected crashes
    - Provides the Level of Service for Safety (LOSS)

- HSM Spreadsheets
  - o Various spreadsheets have been developed by various sources, currently including analysis for rural two-lane and multi lane highways and urban/suburban arterials
  - o Provide high-level overviews of the expected and predicted number of crashes within a study corridor
  - o Require fewest number of input variables
  - o Require the user to determine segmentation and other inputs based on HSM guidance
  - o Do not analyze interchanges
  - o Good for corridors with few intersections

Additional Information about Calibration Factors

MoDOT has a list of calibration factors that should be utilized with these various modeling tools. The calibration factors are designed to provide predicted and expected crashes that more closely correspond to real world conditions in Missouri.

MoDOT's research documents

Calibration info from MoDOT SharePoint library

Summary spreadsheet

- ISATe
  - o A version of the HSM Spreadsheet for freeways.
  - o Allows for the analysis of freeway and speed change lanes (i.e., acceleration, deceleration, and weave lanes) as well as ramps and ramp terminals
  - o Requires greater number of input variables than the HSM Spreadsheets
  - o Requires the user to determine segmentation and other inputs based on HSM guidance
  - o Can be used for any type of freeway corridor, though more complex suburban and urban freeway corridor may be more suited to model using IHSDM
  - o Can be used in conjunction with other HSM Spreadsheets if a local connecting road system needs to be analyzed as well
- IHSDM
  - o Fully integrated modeling software that allows for modeling most types of facilities as an interconnected network. There are instances where the HSM Part C does not apply to a real-world situation and cannot be modeled. Please refer to the HSM Part C.
  - o Requires highest number of input variables
  - o Determines segmentation automatically

MoDOT has a list of calibration factors that should be utilized with these various modeling tools. The calibration factors are designed to provide predicted and expected crashes that more closely correspond to real world conditions in Missouri.

Tool Versioning

Various sources have developed each of these tools, though they all utilize the HSM to conduct their analysis. It is important to determine through consultation with MoDOT the appropriate tool and tool version for a specific project. The same version of the approved tool should be used throughout the entire course of the project unless instructed to utilize another version by MoDOT.

905.3.6.2.3 MoDOT Crash Prediction Tool

The Crash Prediction Tool developed by MoDOT is available for internal MoDOT use only. It allows for the analysis of rural two-lane highways only and provides the potential for safety improvements within a corridor. It automates the analysis utilizing the HSM for the selected corridors to determine predicted and expected crashes.

905.3.6.2.4 Highway Safety Manual (HSM) Spreadsheets

Following the guidelines presented in the HSM Part C, a method for estimating expected average crash frequencies at individual sites, the National Cooperative Highway Research Program (NCHRP) developed a collection of spreadsheet tools to assist with evaluating a variety of roadway types. HSM spreadsheets are available for the following roadway types (the chapter of the HSM devoted to each spreadsheet is noted as well):

- Rural Two-Lane Roads (HSM Chapter 10)
- Rural Multilane Highways (HSM Chapter 11)
- Urban and Suburban Arterials (HSM Chapter 12).

Utilization of the HSM Spreadsheets requires segmentation of the corridor manually. The corridor should be divided into individual sites consisting of homogenous segments and intersections. These segments should be no less than 0.10 miles to minimize calculation efforts and not affect the results. Roadway segments begin and end at the center of intersections or where the homogenous roadway segment changes.

905.3.6.2.5 Enhanced Interchange Safety Analysis Tool (ISATe)

ISATe (HSM Chapters 18 and 19) is a specialized spreadsheet analysis tool that was developed to analyze freeways, ramps and ramp terminals.

Segmentation of the corridor utilizing ISATe requires the user to manually divide up the corridor for entry into the spreadsheet. Each segment should be homogeneous with respect to traffic volume, geometric design features and traffic control features. Changes in any of the following characteristics require a new homogeneous segment to begin within the model.

- Number of through lanes changes.
- Lane wide changes by more than 0.5 ft.
- Inside or Outside shoulder width changes by more than 1ft.
- Median width changes by more than 10 ft.
- Ramp presence.
- Clear zone changes by more than 5 feet.

The presence of a horizontal curve on its own does not define a segment boundary; one of the above characteristics must change. The same general guidelines apply to Collector/Distributor Roads within ISATe. For detailed explanations of the segmentation process, refer to the *ISATe User Manual* included with the spreadsheet model.

905.3.6.2.6 Interactive Highway Safety Design Model (IHSDM)

IHSDM is a safety modeling software developed by the Federal Highway Administration (FHWA), with the capabilities of evaluating freeways and arterials in both urban and rural areas. Using the HSM spreadsheets as the core function of the modeling software, IHSDM automates the segmentation process and provides a visual representation of what is being modeled, based upon user defined inputs. The user also has the option to import a Land XML file containing the horizontal and vertical alignment information for every roadway, which can greatly speed up the development and accuracy of the modeling output.

905.3.6.2.7 Analysis Approach

MoDOT preferred methodology is to determine the future expected crashes and compare those to the existing expected crashes utilizing the appropriate modeling tool. This comparison allows for local crash characteristics to be taken into consideration when determining the effectiveness of proposed improvements. To determine the future expected crashes, the ratio of expected to predicted crashes under the existing condition should be determined. This ratio can be utilized along with the future predicted crashes to extrapolate the future expected crashes. Professional judgment is needed to determine if one ratio is used for the entire project, or if subparts of the project have and use separate ratios. The following formula determines the future expected crashes.

$$Future\ Expected = Future\ Predicted * \left(\frac{Existing\ Expected}{Existing\ Predicted}\right)$$

A typical modeling scenario would be:

- Model existing predicted crashes
- Model existing expected crashes by inputting existing crash information into the analysis tool
- Determine the ratio of existing expected to existing predicted crashes
- Model the proposed improvements to determine the future predicted crashes
- Utilize the formula to determine the future expected crashes and compare to the existing expected crashes.

905.3.6.2.8 Crash Modification Factors (CMF)

Crash modification factors (CMF) are values used to determine the predicted reduction in crashes from implementing a chosen countermeasure(s). They can play an important role in a traffic safety benefit-cost analysis to determine the anticipated benefits of a countermeasure. A

CMF value of less than 1 reflects a predicted reduction in crashes while a CMF value of greater than 1 reflects a predicted increase. The use of CMFs is consistent with the information contained in the HSM.

As referenced in MoDOT S-HAL: Safety Handbook for Locals, one of the most accepted methods of assessing safety at a location is through the analysis of existing crash patterns to include frequency and severity. This information is obtained through the crash analysis summaries, crash reports provided by law enforcement, and collision diagrams. Analysis of this information allows the examiner to determine appropriate countermeasures, or safety treatments intended to mitigate crash patterns.

One or more countermeasures may be proposed in order to alleviate the existing crash patterns at the location. Countermeasure selections should be vetted through a project core team. This will allow MoDOT to better maintain countermeasure selection and track historical performance. Once possible countermeasures are selected, the responsible party should determine the appropriate CMFs to apply to the analysis.

CMF Selection

Contact the MoDOT project core team and central office MoDOT staff for the approved CMF list. If MoDOT does not currently have the appropriate CMF on their approved list, they may recommend the use of the FHWA funded CMF Clearinghouse. This site provides an online searchable database to find applicable countermeasures and the published CMFs established for each. As with countermeasure selection, CMF selection should be vetted through the project core team prior to using.

Each countermeasure within the site is assigned a star quality rating (1 to 5), with 5 representing the best rating, to indicate the confidence in the results of the study that produced the CMF. The rating is based on several factors, including design of study, sample size, data source, standard error, and potential biases. The clearinghouse also assigns star quality ratings for CMFs provided in the HSM.

Due to the extensive size of the CMF Clearinghouse database, a search for CMFs will often return many results even when using the filtered search feature therefore users will often need to decide which is the best CMF to use.

MoDOT guidance is to select the CMF with the best quality rating for conditions as similar to the project area as possible.

1. **Star quality rating** – The star quality rating indicates the quality of the CMF. As noted previously, the ratings range from 1 to 5, with 5 being the highest quality rating. The rating is based on five categories to include the design of the research, study sample size, standard error, potential bias, and data source. The star quality rating can be used to determine the most appropriate CMF to use if all major factors are similar.
2. **Score details** – The clearinghouse assigns scores of excellent, fair, or poor for each of the rating categories. Details of the scores can be found within the star rating on many of

the CMFs. This information is very helpful when comparing the results of two or more comparable CMFs.

3. **Similarity in locality of data used –** Information related to the specific geographic region that the CMF was developed is provided for the user. It is preferable to use data based on similar topography, weather, and other factors if possible.

4. **Traffic volume range –** A range of traffic volumes used in the CMF development is provided for the user to select the most applicable CMF. It is at the analyst discretion whether to allow for going out of range if no other CMF is applicable.

5. **Age of data** – All studies for CMFs provide a date range for the study performed. The CMF that uses the more recent date range is preferred if all other factors are similar.

6. **Original study report –** The clearinghouse provides a link to the study report if it's available. This is often helpful to the user to gain insight on the study background.

CMFs are useful tools in the estimation of predicted impacts to crash reductions and/or increases. CMFs can be in different forms, such as crash type, crash severity, total crashes, etc. Due to the variability in location characteristics, driver behavior and other factors, actual reductions in crashes will vary. The standard error listed for each CMF is helpful in determining the anticipated effectiveness of a countermeasure.

When selecting the CMF(s), consider this guidance from the CMF Clearinghouse:

- CMFs that most accurately reflect the characteristics of the location being investigated are the most appropriate.
- More than one CMF may be applicable.
- Use the CMF with the highest star rating, making sure that it is applicable to the proposed countermeasure and study location.
- If all factors above are equal, then the more conservative value should be selected.
- If there is no applicable CMF, contact the project core team for further guidance.

CMF Application

Once CMFs are determined, they are multiplied by the appropriate crash information (numbers of crashes, severity, types, etc.) as indicated by the CMF. Many CMFs will apply to all crashes, but some CMFs specifically apply to a particular crash type (e.g., rear ends) or crash severity (e.g., fatal and serious injury crashes). For predictive analysis, which is the recommended approach, the CMFs are multiplied by the predicted crash information to estimate the predicted number of crashes as a result of the improvement. This can then be converted to expected crashes using HSM methodology as outlined in EPG 905.3.6.2.7 Analysis Approach. If predictive crash analysis is not possible, the CMFs are multiplied by the crash information as revealed in the crash history at the location. While not the preferred approach, this calculation provides a sense of the anticipated numbers of crashes as a result of the proposed countermeasure(s).

It is generally preferable to use a single CMF; however, it is also common for traffic professionals to recommend multiple countermeasures to address a crash pattern at a location. In order to accurately capture impacts for these types of situations multiple CMFs will need to be combined.

$$CMF_{Total} = CMF_1 * CMF_2$$

While multiplication of CMFs is an acceptable practice, it is undetermined if implementation of more than one countermeasure at a location will provide the full effect of crash reductions compared to countermeasures implemented individually. This overestimation of crash reductions grows more uncertain with the addition of more countermeasures at a given location. As a result, judgment should be applied when multiple countermeasures are proposed and MoDOT recommends capping the number of CMFs that are used to a maximum of three.

905.3.6.2.9 Other Analysis Methods

While HSM is the preferred method for safety analysis and should be used when applicable, there are scenarios that exist where exposure or geometric design thresholds may not allow for analysis through traditional HSM tools. Other methods of alternative safety analysis may include the measurement of exposure by counting the number of conflict points or number of weaving maneuvers, using other surrogate safety data, or calculating a crash rate based on the existing crash history and applying it to future traffic volumes.

905.3.6.2.10 Surrogate Safety Assessment Model (SSAM)

Another alternative predictive safety analysis tool that may be used on arterials is the Surrogate Safety Assessment Model (SSAM). The SSAM is a software application that automatically identifies, classifies, and evaluates traffic conflicts in the vehicle trajectory data output from microscopic traffic simulation models, such as VISSIM. Traffic conflicts are defined as an observable situation in which two or more road users approach each other in time and space to such an extent that there is risk of collision if their movements remain unchanged. The trajectory input data for the SSAM are generated by traffic simulation software in a format that is specifically designed for its use. The SSAM can also aid analysts in design with built-in statistical analysis features for conflict frequency and severity measures that can be used for comparing alternatives.

SSAM provides an option for assessing the safety of traffic facilities using popular microsimulation software. This approach eliminates the need to wait for a significant amount of crashes to occur, allows assessments of hypothetical designs and traffic control, and is applicable to facilities where HSM may not be applicable due to geometric design or volume thresholds. This technique is only expected to grow in use as simulation models and video technology continue to improve.

905.3.6.2.11 Systemic Safety Analysis

Site-specific analysis is the basis for identifying potential safety improvement projects for many traditional network screening techniques. These techniques often use historical crash data and crash severity to base decisions. Crashes occurring on rural roads account for a high percentage of severe injury crashes, however, the density of these crashes is typically low and does not lend well to identifying crash issues or locations of concern using a site-specific analysis process. These concerns are not only limited to crashes occurring on rural roads, as similar situations can exist in urban areas. Examples include crashes involving vulnerable road users, such as pedestrians, bicyclists, or motorcyclists.

Systemic Approach to Safety

A systemic approach to safety involves widely implemented improvements (e.g., median cable barriers) to a transportation system based on identified high-risk scenarios that correlate with specific crash patterns. This approach addresses crash types that contribute to a high portion of severe injury crashes across a network rather than focusing on specific locations with a pattern of severe injury crashes. This approach provides a more comprehensive method for safety planning as it considers both crash history and crash potential in decision-making.

The systemic approach is data-driven and could potentially suggest safety improvement projects that are not typically identified through the traditional site-specific analysis approach. The intent of this approach is not to replace the traditional site analysis, but to supplement it, and provide a proactive approach to preventing severe crashes. Both site-specific analysis and systemic approaches are necessary for an effective and comprehensive safety management program.

As a result, MoDOT has deployed a systemic approach to their safety planning and management efforts and currently has guidance for:

- Chevrons,
- Shoulder and rumble strips, and
- Median cable guardrail.

Project teams are responsible for reviewing to see if the project area has any locations that a systemic improvement would be applicable. Additional guidance will be incorporated as it is developed for other systematic improvements.

Systemic Safety Planning

Systemic safety planning is the process of evaluating an entire system against a defined set of criteria to identify locations for safety improvements to reduce the frequency and potential for severe injury crashes.

The systemic approach to safety planning can be summarized in the following steps:

- Identify issue based on systemwide data, such as rural lane departure crashes, urban pedestrian crashes, or rural unsignalized intersection crashes. These crashes are often spread across the network with few or no locations experiencing an abnormally high cluster of crashes during a typical analysis period.

- Identify characteristics frequently present in severe injury crashes. These characteristics, also known as risk factors, can be used to identify locations with potential for severe injury crashes despite not currently having a significant crash history.
- Prioritize locations across a network. The concept is to evaluate an entire system for roadway characteristics identified as risk factors. The result will be an inferred prioritization indicating that some parts of the system are better candidates for safety improvement than others.
- Focus on deploying low-cost countermeasures to address risk factors contributing to crashes on a majority of roads. Addressing low density crash types that contribute to a large aggregate number across the entire system will drive decision-making toward low-cost solutions that are widely deployed across the system to affect a large number of locations.

905.3.6.3 Applications of Safety Analysis

905.3.6.3.1 Benefit-Cost Analysis (BCA)

Benefit-cost analyses compare the present value of total project benefits to total project cost and are used to determine if safety improvements are economically feasible, or if the potential benefits are greater than the anticipated costs. A value greater than 1 means that the anticipated benefits of the project outweigh the anticipated costs. They also provide information on which traffic safety countermeasure(s) would provide the greatest benefit when factoring in cost, or if an improvement at one location would be more beneficial than an improvement (whether the same or different) at another location.

Benefits

The benefits of a traffic safety project are determined by calculating the total reduction in crashes and should be represented by HSM expected values when possible. This value can be calculated by using one of the various tools (HSM Spreadsheets, ISATe, IHSDM, etc.) stated in EPG 905.3.2.1.2 Safety Analysis Tools.

MoDOT calculates safety benefits based on a reduction of crashes. These crashes are multiplied by a dollars per crash value, based on periodic FHWA determined values and adapted to Missouri's Consumer Price Index. Contact the MoDOT project core team for the appropriate values to use for the study. The resulting benefit is in dollars saved due to crashes reduced. It should be noted that a negative number is possible and represents an expected increase in crashes.

Crashes reduced due to proposed safety improvements should be calculated for the service life of the improvement using the tools and methods outlined in this article, such as HSM Spreadsheets. Other tools such as ISATe or IHSDM can also be used to calculate annual benefits by estimating future crash performance with and without the countermeasure(s); however, they should be calculated for the present year of the countermeasure's service life to be accurately compared with the cost analysis in Costs. MoDOT practice is to calculate the total benefits of all crashes reduced, but also to consider the total benefits of only the fatal and serious injury crashes reduced.

$$Total\ Benefits = \sum Countermeasure\ Crashes\ Reduced * Associated\ Crash\ Costs$$

Costs

Every traffic safety project has a variety of associated costs. MoDOT guidance is that safety costs represent the Highway Safety Improvement Program (HSIP) programmed amount for safety improvement construction. As a general guideline, right of way costs are only included if nearly all of the project is for safety improvements, such as those programmed with a primary category of safety. Also, typically engineering, design, construction inspection, and other incidental costs are not included, even for projects that are entirely safety improvements. Routine maintenance is typically not included if minor, however, if significant maintenance is required on an annual basis, such as for cable guardrail, then it should be included. All costs should be represented in present year dollars and if a project needs to account for future costs, such as significant maintenance, they should be converted into present year dollars.

All construction costs only associated with the safety improvement should be included in the cost analysis. If shoulders and rumble strips are being added during a resurfacing job, costs associated with the resurfacing should not be counted.

If future costs are required to be included, such as significant maintenance, it is necessary to convert them to make an accurate comparison. It is recommended to convert everything back to present year costs in order to compare to the total benefits, which are represented in present year dollars.

Service Life

The service life of a proposed improvement refers to its anticipated useful life. For example, a bridge would be expected to have a much longer service life than a warning sign. Service life information is used in the benefit-cost analysis to factor the expected useful life of the proposed countermeasure and should be collected on all items associated with the construction of the safety improvement.

The CMF Clearinghouse, as well as MoDOT's pre-approved list of CMFs, provides a comprehensive listing of available service life information for commonly used traffic safety countermeasures. The information is provided by several states and organized consistently with the 15 countermeasure categories currently listed in the clearinghouse. Three additional categories of Resurfacing, Structures, and Other are also available. Links to tables for each category are shown, and each state's service life information is listed if it is available.

As stated previously, it is common for safety projects to include multiple countermeasures, which may have differing service lives. MoDOT guidance is to incorporate service life into the estimation of crash reductions by calculating the expected crash reduction for the entire initial life of the improvement. For example, a bridge project that also includes warning signs would estimate the crashes reduced by the bridge improvement over the life of the bridge, as well as the crashes reduced by the signs over the life of the signs. This results in the total number of estimated crashes to be reduced in the project area across the initial life cycle of each improvement. This method of analyzing crash reductions for only the initial service life of each improvement and not accounting for replacement of countermeasures with lesser service life cycles is preferred due to cost calculations generally only accounting for initial construction costs for each countermeasure. Accounting for replacement of countermeasures with lesser service life cycles also requires the life cycles of all countermeasures involved to have a common denominator otherwise determining the number of replacements to account for becomes more challenging. Therefore, it is recommended to calculate the value of the expected crash reduction for the entire initial life of the improvements compared to the total initial costs of the improvements plus any significant maintenance as stated above.

Benefit-Cost Ratio

After quantifying the total benefits and costs for the project, the benefit-cost ratio can then be calculated as follows:

$$Benefit\ to\ Cost\ Ratio = \frac{Total\ Benefits}{Total\ Cost}$$

A benefit-cost value of greater than one (1) means that the anticipated benefits of the project outweigh the costs. The ratio can be used as a comparison tool for countermeasure selection; however, it is ultimately up to professional judgment to determine the best possible countermeasure for the project rather than selecting the option that results in the highest value. MoDOT practice is to calculate two B/C ratios. One B/C ratio incorporates the total safety benefits using all crashes. The other B/C ratio is referred to as a Priority B/C that only focuses on fatal and serious injury crashes. The use of the Priority B/C analysis allows MoDOT to focus and prioritize safety projects that will maximize lives saved over a project that reduces property damage only type crashes. Other factors, such as the required time to implement and total cost, should also be factored into the decision. While the B/C must equal at least one in order to be eligible for safety funds, the intent of safety projects is to save the most lives and reduce the most serious injuries.

Documentation

The calculation of benefit-cost ratio should be well documented and cataloged for future reference. The number of anticipated lives saved, and serious injuries reduced should also be documented. This will be helpful not only for projecting cost and benefit of future projects, but also for evaluating benefit-cost analysis of past projects. Suggested items to include in this documentation are project information, such as study location, date, and proposed countermeasure(s), as well as information used in the benefit-cost analysis, such as project costs, service life, CMF(s) used and corresponding reference numbers if applicable, crash costs, and crashes saved. It is also important to include the required information for HSIP reporting, such as categories, AADT, and speed.

It is also recommended to document any special circumstances that may have had significant impacts to either costs or benefits. For example, a special circumstance that may be worth noting that would have an impact on benefits are locations that deploy an interim countermeasure. Significant impacts to costs should be accounted for as these are typically calculated on a location-specific basis.

905.3.6.3.2 Design Exceptions

MoDOT policy requires adherence to established engineering standards regarding geometric design and related design features. However, instances can occur during the design phase of the project when it is not reasonable for a design element to meet the established criteria. In these cases, design exceptions may be required. Design exceptions are completed to document the reasoning why it is not feasible to meet established MoDOT engineering policy for given design elements. The documentation consists of the engineering-based decisions used to justify an approach that would not meet the established standards. Contact the project core team to determine if design exceptions are needed for the study section.

Safety Analysis Documentation

MoDOT requires that any design exception request, related to safety, have a comparison of expected crashes if meeting design standards, with expected crashes with the proposed design exception. Refer to EPG 905.3.6.2 Safety Modeling for additional information. The HSM provides tools to complete the comparative analysis. This information is included in the submitted documentation to support the recommended exception to engineering policy. Safety related design elements include design speed, lane widths, alignments, clearances, etc. When it is undetermined that a roadway feature is safety-related, it is recommended to presume it is safety-related and provide the necessary safety analysis documentation.

Exception requests require full analysis, crash history and crash prediction. Engineering judgment should be applied to determine the appropriate type of analysis. The HSM does not distinguish between sections and intersections. However, the analysis should differentiate based on roadway types (e.g., interstates versus rural two-lane roadways). There may be some instances where an HSM analysis would not be applicable, such as a low volume or low exposure roadway of less than 400 vehicles per day. In these cases, a comparison of crash rates for the section of roadway to the statewide crash rate would be more appropriate. Please contact the MoDOT project team to determine if this alternative safety analysis is the recommended approach.

A review of the results of the safety analysis should be completed by a qualified practitioner to determine if crashes are reduced or if they increase if the design standard is not met. The costs can then be calculated to compare the costs of construction versus the cost of crashes. This information allows the project team to quantify the crash risk with the alternatives, so this risk can be weighed with other project constraints, such as cost, environmental impacts, right of way, etc.

Mitigation

To lessen the negative safety impact of a design exception, mitigating treatments may be recommended and implemented. For example, if it is not feasible to realign a horizontal curve to a 55-mph design speed due to design constraints, appropriate curve warning signs with advisory speed plaques and chevrons may be recommended. Mitigating treatments relating to warning signs or other traffic engineering features are often investigated by a traffic engineer or other qualified practitioner who is well-versed in traffic safety.

Conclusions

While design exceptions are necessary when certain design criteria cannot be reasonably met, they can also be viewed as allocating resources in a more sensible manner. Documentation of the design exception request, including the safety analysis, is essential for the appropriate staff to make an informed decision.

905.3.7 Sample Report Templates

905.3.7.1 Methods and Assumptions Report Template

A TIA Methods and Assumptions Report serves as a record of the decisions and agreements made by the advisory team at the outset of a project. This is a template that is meant to aid consultants and other parties submitting work to MoDOT in their consistent scoping and review of TIAs.

905.3.7.2 Calibration Report Template

A Calibration Report is meant to serve as proof that a microsimulation model has been adjusted to better replicate real world conditions and its ability to replicate real world conditions has been thoroughly validated using observed counts and measurements. This template is meant to aid consultants and other parties submitting work to MoDOT in their production of Calibration Reports.

905.3.7.3 TIS Report Template

A Traffic Impact Study (TIS) Report is meant to summarize the procedure and findings of traffic impact studies and to recommend adjustments to the transportation network that will be needed to handle the traffic generated by the construction of new developments. This template is meant to aid consultants and other parties submitting work to MoDOT in their production of TIS Reports.

905.3.7.4 Traffic Safety and Operations Report Template

The purpose of a Traffic Safety and Operations (TS&O) Report is to analyze the current performance of a roadway, the future performance of the roadway without improvements, and the future performance of the roadway after improvements have been made. If there are several design alternatives being considered, the TS&O study will analyze the performance of each alternative under future conditions and use the results of this analysis to recommend the most attractive design alternative. This template is meant to aid consultants and other parties submitting work to MoDOT in their production of TS&O reports.