## 16-5-1 Data Assembly and Collection September 2019

### 1.1 Introduction

Transportation planning and engineering requires real-world data to understand system performance, identify emerging trends, and find solutions to issues. This section discusses data assembly, collection, and preparation for use in the development of traffic models and other general capacity analyses. Other specialized studies, such as safety, transit, parking, noise, or freight, would need data beyond the scope of this section. Data requirements are highly dependent on the individual project needs and goals and may necessitate additional data beyond that discussed within this policy. Prior to gathering any data, coordinate with the regional traffic engineer to discuss the data needs for the project, identify potential data sources, and develop a data assembly/collection plan.

### 1.2 Data Assembly/Collection Plan

This section describes the typical components of a data assembly/collection plan (“data plan”). The actual data plan will vary depending on the specific needs of the project. Regardless of the precise content, the data plan *should* provide clear guidance as to how, when, and where to obtain the required data. The data plan should also include details on the schedule and budget needs necessary to compile the data elements. Preparing the data plan should occur during project scoping to avoid project delays and to allow time for acquiring existing and any new time-sensitive data.

The following provides an example outline of a data assembly/collection plan.

1. **Introduction/Background**

   Provide a brief background on the project, including a description of the project’s needs and purpose. Include a discussion on the traffic analysis tools, traffic models, and other analyses that require data for the project.

2. **Data Needs**

   Identify the data requirements necessary to develop, calibrate, and validate the traffic models and other analyses tools. See TEOpS 16-5-1.4 for guidance on selecting the appropriate data for analysis. When defining the data needs, consider not only the project objectives but also other potential uses and users of the data to optimize resources. Coordinate with WisDOT regional traffic staff to determine if there are current or upcoming projects that could also benefit from the required data.

3. **Data Locations**

   Illustrate the data needs on a list or map. Label what type of data to assemble at each location. As the data plan progresses, identify where existing data is available and its source, as well as where new data collection is necessary.

4. **Data Sources**

   List potential sources for obtaining the necessary data and identify the owner or responsible party for each data source. Data sources could include existing databases, previous studies, and new data collection efforts. The Bureau of Traffic Operations (BTO) - Traffic Analysis and Safety Unit (TASU) Data Hub provides a list of potential data sources. Coordinate with WisDOT regional traffic staff to verify other potential sources of data. Additional resources for identifying data sources include WisDOT Bureau of State Highway Programs (BSHP) and WisDOT Traffic Forecasting Section (TFS).

5. **Justification for New Data Collection**

   Identify any gaps, errors, obsolete, or other issues/concerns with existing data sources. Establish an approach for resolving the identified issues. Document and justify the need for new/additional field data collection. Follow the Transportation Planning Manual (TPM) and other available WisDOT guidelines for data collection as applicable.

6. **Methodology for Acquiring Data**

   For new data collection efforts, identify the approach for gathering the data. Include information on how to collect the data, when to collect the data (e.g., months of the year, days of the week, time periods, or time of day), who is responsible for the data collection, the duration of the counts (e.g., peak-hour, peak-period, one week, one month, etc.) and the time interval (e.g., 5 minutes, 15 minutes, 1 hour, etc.). Where appropriate, define how to determine the appropriate sample size. Refer to TEOpS 16-5-1.3 for additional guidance on the techniques for acquiring data.

7. **Data Preparation and Management Strategies**

   Establish procedures for conducting data quality assurance and control. Define protocols for archiving and storing the data files, noting that WisDOT will maintain ownership of all data collected for WisDOT projects. Refer to TEOpS 16-5-1.5 for additional information on data preparation.

8. **Schedule and Budget**

   Prepare a schedule and an itemized budget for the data assembly/collection efforts.

Submit the data plan to the WisDOT regional traffic engineer for review and approval prior to gathering any data. Involve WisDOT TFS and BTO-TASU in the review of the data plan as appropriate. Save the data plan with the project files.

### 1.3 Techniques for Acquiring Data

There are several resources available on data acquisition techniques, three of which include:

- *Manual of Transportation Engineering Studies, 2nd Edition* (1)
- *Highway Capacity Manual, 6th Edition* (HCM6) (2)
- *Traffic Monitoring Guide* (3)

As noted in the above documents, it is possible to acquire transportation data through office reviews, existing databases, and field data. Oftentimes, it is necessary to utilize a combination of all three approaches. See below for additional details on each of these data acquisition techniques.

### 1.3.1 Office Reviews

Office reviews include any means of gathering data from existing sources to determine physical system characteristics and asset locations. Example office reviews include inspecting aerial maps, as-built plans, and Photolog. Office reviews are appropriate for high-level data acquisition to become familiar with a project location, land use, and existing infrastructure. The age of existing sources can vary and may not reflect current conditions. Verify office reviews with field reviews as appropriate, especially when using the data for detailed study or design projects.

### 1.3.2 Existing Databases

WisDOT has access to or maintains existing databases of traffic count, speed, and other transportation data. Examples include: MetaManager, WisTransPortal, and WisDOT TCMap (Traffic Count Map), among others. Existing databases often contain data aggregated at a statewide level for facilities managed by WisDOT. Data for local municipalities or counties may or may not be available. Coordinate with WisDOT regional traffic staff to identify existing database sources.

Evaluate the spatial and temporal resolution of existing databases against project needs. Validate existing databases with field reviews as appropriate, especially for older or unmaintained databases.

### 1.3.3 Field Data

Field data collection refers to any manual or automatic method of obtaining data directly from the field. This may include taking video or pictures, jotting down field notes, or using portable microwave/radar or other equipment. Field data collection may require specialized equipment that entails mounting hardware to poles or locating equipment on private property. Contact WisDOT regional staff to approve data collection techniques with these requirements. It is advisable to contact property owners and local law enforcement to inform them of the data collection activities. Contact the WisDOT Traffic Data Unit (traffic.counts@dot.wi.gov) for specifications and guidance relating to the statewide count program traffic count data. Guidance for conducting turning movement counts is available on the BTO Traffic Analysis, Modeling and Data Management Program area webpage.

Complete office reviews and consult existing databases first before collecting field data. The age of existing data and effort to reconcile old and new data, however, can create challenges. For example, balancing old and new traffic volumes (see TEOpS 16-5-15 for additional details on volume balancing), or utilizing speed and count data from different days, can increase the traffic model calibration effort.

Prior to collecting new counts, coordinate with WisDOT regional traffic staff to verify there are no other sources of data available. Additional resources for identifying data sources include WisDOT BSHP and WisDOT TFS. Document and justify the need for any new traffic counts and save as part of the project files.

## 1.4 Selecting Appropriate Data for Analysis

Data needs (type, amount, etc.) vary by the facility type and study purpose. As the complexity and detail of the analyses increase, so does the need for more meticulous data. Table 1.1 shows potential data requirements for use in traffic modeling of typical weekday AM and PM peak period scenarios. Table 1.1 also identifies if the data type is a required capacity analysis input, or if the data, although not necessarily required, may have value for calibration or general deficiency analyses.

Analyses beyond the scope of Table 1.1 may require additional data. Such analyses include, but are not limited to:

- Analysis of special peak periods (e.g., weekends or special events)
- Travel time reliability analysis (See *HCM6* (2), Chapters 11 and 17 for freeways and arterials, respectively)
- Project-specific needs
- Other specialized analyses (e.g., safety, transit, parking, noise, freight, etc.)

**Table 1.1 Selecting Data for Traffic Analysis**

| Facility Type | Data Type | Notes and Potential Data Needs/Sources | Required for Capacity Analysis | Useful for Calibration or Deficiency Analysis | Additional Resources |
|---|---|---|---|---|---|
| **Signalized Intersection** | Intersection Geometry and Configuration | • Number of lanes on each approach, lane markings, and turn lane lengths<br>• Aerial maps/photography<br>• Photolog/Google Streetview<br>• Confirm with field reviews as appropriate | X | | |
| | Turning Movement Counts | • 15-minute interval counts, for all turning movements, vehicle classes, and pedestrians/bikes<br>• Weekday AM and PM peak period counts (typically 3 hours each)<br>• Other peaks and times as necessary<br>• Ensure counts reflect traffic demand and not discharge in oversaturation conditions. Supplement turning movement counts with additional counts upstream of queuing. | X | | ITE (1) |
| | Saturation Flow | • Obtain if existing conditions operate at or over capacity<br>• Use TEOpS 16-15-5.2.2.3 as estimates when field data is unavailable | | X | TEOpS 16-15<br>ITE (1)<br>HCM (2) |
| | Right-Turn on Red (RTOR) | • If applicable, observe RTOR operation in the field<br>• Use TEOpS 16-15-5.2.1.3 as estimates when field data is unavailable | | X | TEOpS 16-15 |
| | Signal Timing | • Contact WisDOT regional staff for signal plans and timing | X | | WisDOT regional staff |

| Facility Type | Data Type | Notes and Potential Data Needs/Sources | Required for Capacity Analysis | Useful for Calibration or Deficiency Analysis | Additional Resources |
|---|---|---|---|---|---|
| | Queue Length | • Record queue lengths on all approaches. Queue length is extremely sensitive to prevailing conditions and traffic volumes. Record queues and volumes simultaneously when possible. | | X | ITE (1) |
| | Delay | • Perform travel time runs through the intersection during peak periods to determine actual versus free-flow travel time | | X | ITE (1) |
| **Unsignalized Intersection** | Intersection Geometry and Configuration | • Number of lanes on each approach, lane markings, turn lane lengths, and control sign types (stop, yield) and locations<br>• Aerial maps/photography<br>• Photolog/Google Streetview<br>• Confirm with field reviews as appropriate | X | | |
| | Turning Movement Counts | • 15-minute interval counts, for all turning movements, vehicle classes, and pedestrians/bikes<br>• Weekday AM and PM peak period counts (typically 3 hours each)<br>• 12 to 14 hour counts if analyzing traffic signal warrants<br>• Ensure counts reflect traffic demand and not discharge in oversaturation conditions. May need to supplement turning movement counts with additional counts upstream of queuing. | X | | ITE (1) |
| | Crash History | • Required if analyzing traffic signal warrants | | X | WisTransPortal<br>WisDOT regional staff |
| | Queue Length | • Record queue length for stop or yield controlled movements. Queue length is extremely sensitive to prevailing conditions and traffic volumes. Record queues and volumes simultaneously when possible. | | X | ITE (1) |
| | Gap Acceptance | • Use Wisconsin calibrated gap parameters for roundabout analysis (FDM 11-26-20.4).<br>• Can require intensive labor effort; only conduct gap studies if traffic modelling and engineering judgement fail to produce reasonable results | | X | FDM 11-26-20.4<br>ITE (1) |
| | Sight Distance | • Verify sight distance in the field if considering geometric improvements | | X | ITE (1) |
| **Freeway** | Highway Geometry and Configuration | • Speed limit, number of lanes, auxiliary lane lengths, and merge/diverge/weave locations<br>• Aerial maps/photography<br>• Photolog/Google Streetview<br>• Confirm with field reviews as appropriate | X | | |
| | Statewide Count Program Data | • Use Automatic Traffic Recorder (ATR) counts where possible to obtain current and historical trends.<br>• WisDOT short-term counts<br>• Ensure counts are of sufficient duration to capture all congestion<br>• 15-minute interval counts are preferable | X | | WisDOT regional staff<br>WisDOT Traffic Data Unit |

| Facility Type | Data Type | Notes and Potential Data Needs/Sources | Required for Capacity Analysis | Useful for Calibration or Deficiency Analysis | Additional Resources |
|---|---|---|---|---|---|
| | Ramp Counts | • WisDOT short-term counts<br>• Volume, Speed and Occupancy (V-SPOC) data<br>• Obtain new counts when WisDOT short-term counts are unavailable or no longer reflect existing conditions<br>• 15-minute interval counts are preferable | X | | WisDOT regional staff<br>V-SPOC<br>WisTransPortal |
| | Ramp Terminal Intersection Data | • Assemble signalized and unsignalized intersection data shown above at all interchanges<br>• Data at the ramp terminals within the same interchange *should* reflect the same date/time | X | | ITE (1) |
| | Capacity | • If existing conditions are over capacity, use 15-minute volume and speed data to estimate capacity | | X | HCM (2) |
| | Spot Speeds | • V-SPOC, microwave, or radar data collection useful for determining free-flow and congested speeds | | X | ITE (1)<br>V-SPOC |
| | Travel Time | • FHWA NPMRDS or other 3rd party data providers<br>• Use travel time runs to verify 3rd party data<br>• Use GPS tracking to continuously record time/speed | | X | ITE (1) |
| | Origin-Destination | • Bluetooth or other OD study method<br>• 3rd party data provider<br>• WisDOT Travel Demand Model (TDM) | | X | TEOpS 16-5-20<br>Transportation Planning Manual (TPM) |
| **Rural Corridor** | Highway Geometry and Configuration | • Speed limit, number of lanes<br>• Aerial maps/photography<br>• Photolog/Google Streetview<br>• Confirm with field reviews as appropriate | X | | |
| | Count Data | • Counts, covering a minimum of a 24-hour period, along the corridor wherever major changes in traffic occur (before and after major intersections, corridor termini).<br>• 15-minute interval counts are preferable | X | | ITE (1) |
| | Intersection Data | • Assemble signalized and unsignalized intersection data shown above at all intersections.<br>• Aerial maps/photography<br>• Photolog/Google Streetview<br>• Confirm with field reviews as appropriate | X | | ITE (1) |
| | Driveway Locations | • Required for calculating access point density for two-lane highway HCM analysis<br>• Aerial maps/photography<br>• Photolog/Google Streetview<br>• Confirm with field reviews as appropriate | X | | WisDOT regional staff |
| | Passing Lanes and No Passing Zones | • Required for two-lane highway HCM analysis<br>• Aerial maps/photography<br>• Photolog/Google Streetview<br>• Confirm with field reviews as appropriate | X | | WisDOT regional staff |
| | Spot Speeds | • Requires microwave or radar data collection. Useful for speed limit analysis. | | X | ITE (1) |

| Facility Type | Data Type | Notes and Potential Data Needs/Sources | Required for Capacity Analysis | Useful for Calibration or Deficiency Analysis | Additional Resources |
|---|---|---|---|---|---|
| | Travel Time | • Travel time runs for end-to-end through the corridor<br>• Use GPS tracking to continuously record time/speed | | X | ITE (1) |
| **Urban Corridor** | Highway Geometry and Configuration | • Speed limit, number of lanes<br>• Aerial maps/photography<br>• Photolog/Google Streetview<br>• Confirm with field reviews as appropriate | X | | |
| | Intersection Data | • Assemble signalized and unsignalized intersection data shown above at all intersections.<br>• Aerial maps/photography<br>• Photolog/Google Streetview<br>• Confirm with field reviews as appropriate | X | | ITE (1) |
| | Count Data | • Supplement intersection counts with directional counts covering a minimum of a 24-hour period to determine daily traffic volumes. | X | | ITE (1) |
| | Transit Routes, Stops, & Parking | • Note bus routes, bus stop frequency, and parking maneuvers for use in intersection traffic analysis | X | | WisDOT regional staff |
| | Spot Speeds | • Requires microwave or radar data collection. Useful for speed limit analysis. | | X | ITE (1) |
| | Travel Time | • Travel time runs for end-to-end through the corridor<br>• Use GPS tracking to continuously record time/speed | | X | ITE (1) |
| | Origin Destination | • Useful for complex corridors where traffic patterns affect operations such as closely spaced intersections | | | TEOpS 16-5-20 |
| Additional Resources<br>(1) Manual of Transportation Engineering Studies, 2nd Edition<br>(2) Highway Capacity Manual, 6th Edition | | | | | |

## 1.5 Data Preparation

After assembling data from existing or field sources, additional data preparation steps typically include data storage, cleaning, reduction, and presentation. The following sections discuss each of these steps in more detail.

### 1.5.1 Data Storage

Store data with file and folder names consistent with conventions established for the project. If integrating the project data into existing databases, check with WisDOT regional staff and BTO-TASU to ensure the project data is in a compatible format. Regardless of file and folder convention, ensure there is a traceable record of the data to facilitate ease of use and file transfers. Include a “readme” file, map, emails, or other documentation to accompany the data.

Before processing the data, save a backup of the original unmodified/raw data in case of computer failure. Unmodified data is also useful to keep because it allows comparisons between raw and processed data when investigating data quality issues discovered during later analyses.

### 1.5.2 Cleaning the Data

Inspect the data for missing values, outliers, duplicate records, misplaced locations, or counter-intuitive trends. Document and justify the need to collect additional data to address issues.

Use descriptive statistics (average, mean, standard deviation, etc.), graphs, and maps to help visualize and spot issues with the data. Avoid filling in, or imputing, missing data unless necessary for the specific analysis. When it is necessary to impute missing data, the documentation should note where and why it was necessary. The documentation should also provide a summary of the techniques used to fill in the data gaps.

### 1.5.3 Data Reduction

Data reduction, or analysis, aims to answer questions that vary in complexity and vary from project to project. Analysis involves translating raw data into meaningful information using summaries, graphs, maps, and tables. Regardless of the data type or complexity, the analysis should be reproduceable and understandable by others to facilitate decision making and to allow for error checking.

Most data reduction processes start by converting the raw data into a format suitable for analysis. Keep the converted data separate from the raw/unmodified data to prevent data loss. Data conversion could include combining multiple files into one file, reshaping the organization of tables, or projecting spatial data to a common coordinate system. Data conversion may also be part of the cleaning process (TEOpS 16-5-1.5.2). It may be necessary to filter the dataset to extract specific records or time periods of interest for further exploration and more detailed analysis.

Documenting the data reduction should scale with the complexity of the analysis. For example, collecting and analyzing intersection turning movement counts for import into a traffic model may be a linear process of documenting the field data, inputs, and outputs of the analysis in a traffic report. More complex data analyses may be iterative and require additional documentation of methodology and assumptions. The analyst may need to try multiple statistical tests (hypothesis testing, ANOVA, etc.), or create diverse types of tables and graphs before formulating conclusions. Creating documentation throughout complex analyses can help the analyst keep track of and support resulting conclusions in addition to keeping the project organized.

### 1.5.4 Presentation of Data

Mass amounts of data can be overwhelming. Thus, it is important to present the data in such a way as to accurately communicate what the data means in an easy to understand format. Take into consideration the target audience; public documents may require simplified explanations of the technical details. Data visualization techniques like tables, graphs, maps, infographics, pictures, and videos can enhance communication by providing a clear and concise message without overwhelming the audience. Highlight key information to focus the audience’s attention on conclusions. Check with WisDOT regional staff for preferences and examples of data presentation methods, especially regarding public involvement.

## 16-5-15 Volume Balancing September 2019

### 15.1 Introduction

Traffic volume balancing is the act of reconciling discrepancies in traffic volumes between adjacent locations. Discrepancies or imbalances are often the result of having to utilize counts from various times, days, or years. Longer time differences between adjacent counts typically results in larger imbalances. Although utilizing counts from the same period may minimize these differences, limited data collection resources may preclude this as an option. Differences in data collection methods may also lead to an imbalance of traffic volumes. Depending on the calibration of the device and skill of the manual counter, manual traffic counts may be more error-prone than automatic data collection devices.

The purpose of balancing is to create a logical set of volumes that is representative of the current or forecasted year traffic demand. Balancing the traffic volumes is necessary when evaluating a “closed-system” corridor with no driveways or other access points between intersections/ramps. In a closed-system corridor, the amount of traffic leaving one location must equal the amount of traffic arriving at the next downstream junction. A balanced volume data set is typically more critical for intersection-focused analyses versus analyses that focus on the mainline, although project specific needs *may* necessitate volume balancing along a freeway-only corridor. Additionally, since microsimulation models track individual vehicle movements, most microsimulation software require a balanced volume data set. For those microsimulation models that do not require a balanced volume data set to function (e.g., SimTraffic), use of unbalanced volumes will result in vehicles randomly appearing/disappearing from the roadway network, potentially skewing the results of the analysis.

There is no single unique solution when balancing volumes. Balancing using traffic counts taken on one day would yield a different answer than counts taken on a different day. Likewise, one analyst's results from the volume balancing process will not necessarily match the results from another analyst. This policy addresses how to reconcile imbalanced traffic volumes to foster consistency in traffic analysis conducted within Wisconsin. The Bureau of Traffic Operations, Traffic Analysis and Safety Unit (BTO-TASU) has developed Excel spreadsheet tools to help perform volume balancing in a consistent manner. The volume balancing Excel tools, one-page user guides, and step-by-step job aids are available on the BTO Traffic Analysis, Modeling and Data Management Program area webpage. TEOpS 16-5-15.4.3 provides additional details on the BTO-TASU volume balancing tools.

Although an analyst *may* choose to develop their own templates for balancing volumes, BTO encourages the use of the BTO-TASU volume balancing tools. Obtain approval from the WisDOT regional traffic engineer on the volume balancing methodology prior to developing or utilizing a tool other than that provided by BTO-TASU.

### 15.2 Benefits of Volume Balancing

When implemented judiciously, volume balancing helps "clean" the traffic data. The balancing process can moderate the effects of the daily, monthly, and seasonal factors, lessen the impact of counting errors (such as counts affected by equipment problems), and temper the influence of outliers (such as counts collected on non-representative days). To a limited degree, volume balancing may also allow the analyst to fill in gaps of data with a preliminary count estimate (e.g., using last year's data as an approximation of the volume at a site where a detector has recently failed).

Volume balancing may also be beneficial for the development of origin-destination (O-D) matrices, the mechanism for providing traffic volume demand data for most microsimulation software. By avoiding oscillation between conflicting numerical targets that slows or prevents convergence, volume balancing reduces the matrix estimation effort. Refer to TEOpS 16-5-20 for additional details on the O-D matrix development process.

Volume balancing ensures that traffic demands reflect what the analyst intends to simulate (e.g., microsimulation). Balancing also helps the simulation to meet the microsimulation traffic volume validation requirements of TEOpS 16-20-8.3.1 and TEOpS 16-20-8.4.1.

### 15.3 When to Conduct Volume Balancing

Unless mitigating circumstances dictate otherwise, the analyst **shall** perform volume balancing for:

- Closed-system corridor analyses (i.e., there are no mid-block driveways or other access points for traffic to enter or exit the network) along arterials and freeways where a balanced volume data set is critical for the operational analyses (e.g., HCM freeway facility analyses) and
- Apart from SimTraffic analyses as defined below, all microsimulation analyses.

The analyst could choose to, but does not have to, perform volume balancing for:

- Analyses of an urban corridor with driveways, or
- SimTraffic analyses to evaluate signal timings and progression.

Scenarios that typically do not warrant volume balancing include:

- Analysis of a single isolated intersection or interchange, provided that the adjacent interchanges, intersections, or driveways will not impact traffic operations.
- HCM/deterministic or planning-level analysis of a long freeway corridor with isolated interchanges (e.g., K30 analysis on I-39/90).

Depending on the purpose and need of the project; the analyst *may* not include all driveways or intersections along the study corridor within the traffic model. In these instances, the analyst *should* confirm that the excluded driveway/intersection can appropriately account for any imbalance in the traffic volumes. If not, the analyst *should* consider including a "dummy" access to act as a sink/source to capture the representative imbalance and then balance the remaining volumes along the corridor.

Coordinate with the WisDOT Traffic Forecasting Section (TFS) (DOTTrafficForecasting@dot.wi.gov) to confirm whether to conduct volume balancing before or after completion of the traffic forecasts. If requesting WisDOT TFS to balance the traffic volumes, note this on the DT1601 – Project Level Traffic Forecast Request form.

If unsure about the need for volume balancing on a specific project, check with the WisDOT regional traffic engineer. If desired, the WisDOT regional traffic engineer *may* request additional support or guidance from BTO-TASU (DOTTrafficAnalysisModeling@dot.wi.gov).

## 15.4 Volume Balancing Process

The typical volume balancing process includes the following primary steps:

1. **Assemble** traffic volume data (traffic counts and forecasts). See TEOpS 16-5-15.4.1.
2. **Select** the volume data to use as a starting point for balancing (referred to as the "raw" or initial volumes). See TEOpS 16-5-15.4.2.
3. **Balance** volumes by adjusting the raw/initial volumes up or down as needed to account for imbalances and driveways. Where and how the analyst makes these adjustments typically depends on the type of facility included in the traffic model (freeway-only, intersection-only, or mixed freeway-arterial corridors). See TEOpS 16-5-15.4.3.
4. **Review** the balanced volumes for reasonableness; adjust balanced volumes as necessary. See TEOpS 16-5-15.4.4.
5. **Document** the data sources and volume balancing methodology. See TEOpS 16-5-15.4.5.

The following sections detail each step of the volume balancing process. The BTO-TASU volume balancing tools provide a mechanism to help organize, document, and perform volume balancing. Refer to TEOpS 16-5-15.4.3 for additional details on the BTO-TASU volume balancing tools.

### 15.4.1 Assemble Traffic Volumes

Obtain existing or base year (if other than current year) and forecasted traffic count data for each intersection, ramp, mainline, and major driveway within the analysis limits. If available, the analyst *should* also gather historical count information which may be helpful in assessing data quality and identifying outliers.

There are several data sources for traffic volumes with varying levels of availability and data quality. Some of these resources include manual counts and various detection methods (e.g., loop, microwave, radar, video, etc.). Sources available in Wisconsin include: WisDOT, Wisconsin Traffic Operations and Safety (TOPS) Lab (WisTransPortal), and local municipalities. The BTO-TASU Data Hub provides a list of additional data sources with a brief description of types of data available through each source, a hyperlink to the primary data source, and notes to consider when selecting a particular data source. Contact WisDOT regional traffic staff to determine whether there are other data sources available for the project study area. Additional resources for identifying data sources include WisDOT Bureau of State Highway Programs (BSHP) and WisDOT TFS.

If the required data, such as turning movement counts, is not available from existing sources, project specific data-collection efforts *may* be necessary. Document and justify the need for new/additional field data collection. Follow the Transportation Planning Manual (TPM) and other available WisDOT guidelines for data collection as applicable.

Review, verify, and document the validity of the count data prior to balancing the volumes. Coordinate with WisDOT regional traffic staff as appropriate.

#### 15.4.1.1 Forecasted Traffic Volumes

Refer to the TPM for guidance on when and how to obtain forecasts from WisDOT TFS. If there is a need to convert daily traffic forecasts into hourly volumes through use of K-factors or other means, document the conversion process and obtain approval of the hourly volumes from TFS and WisDOT regional traffic staff. If desired, the WisDOT regional traffic engineer *may* request additional support or guidance from BTO-TASU. Refer to the Traffic Forecasting webpage and Section 40.3 of the TPM for more information regarding the use of design-hourly volumes and K-factors.

#### 15.4.1.2 Data Quality

Traffic count quality may vary by location, data collection device, and data collection method. The analyst must apply judgement based on historical data, adjacent counts, and location-specific knowledge to assess traffic count quality. Permanent automatic traffic recorder (ATR) stations typically produce high quality traffic counts and often have extensive historical data that can help in assessing data quality if located within the analysis limits.

The analyst **shall** document the rationale for any suspected errors and any manual error corrections in the BTO-TASU or other equivalent volume balancing worksheet. Report any suspected errors in counts, especially those from WisDOT data sources, back to the appropriate WisDOT contact.

If there are potential errors in the data, depending on the project-specific needs, obtaining new counts may be more effective compared to adjusting questionable counts before or during balancing. Prior to collecting new counts, coordinate with WisDOT regional traffic staff to verify there are no other sources of data available. Additional resources for identifying data sources include WisDOT BSHP and WisDOT TFS. Follow the TPM and other available WisDOT guidelines for data collection as applicable.

#### 15.4.1.3 Volume Balancing Between Multiple Projects

Occasionally, the study limits of one project will intersect or overlap with the limits of another project. Theoretically, the same location in multiple projects *should* have the same volume for the same analysis period. However, differing study limits, facility types, and study-specific priorities (e.g., if one project prioritizes the freeway facility while the other project prioritizes the arterial corridor) may result in variations in volumes at the same location. The project study teams *should* seek to minimize differing volumes for the same location and analysis period. Document and identify reasons for and potential consequences of any volume differences. Obtain approval from WisDOT regional traffic staff prior to utilizing the resulting traffic volumes in any analysis.

Throughout the volume balancing process, the overlapping project teams *should* coordinate and share volume and forecast information with each other and the WisDOT regional traffic staff. This will ensure consistency and avoid duplicating efforts. Involve BTO-TASU and WisDOT TFS in these coordination efforts as appropriate.

### 15.4.2 Select Raw/Initial Volumes

To start the volume balancing process, the analyst must select a single traffic volume for each study location. If multiple existing or historical counts are available for the same location, choose the count that is representative of the scenario under investigation. Selected counts may or may not be the most recent count depending on data quality factors as described in TEOpS 16-5-15.4.1.2. Document, in the BTO-TASU or other equivalent volume balancing worksheet, the data source and count date and identify whether the raw/initial volume accounts for seasonal, daily, and axle factor adjustments (typically incorporated into mainline counts but not raw turning movement counts). If balancing forecasted volumes, use the forecasted hourly volumes as described in TEOpS 16-5-15.4.1.1 as a starting point for the balancing process. Record the details of any additional adjustments made to the raw/initial or forecasted volumes before starting the balancing process. Note any other unique information regarding the traffic volumes within the BTO-TASU or other equivalent volume balancing worksheet and save as part of the project files.

### 15.4.3 Balance Volumes

Traffic volume balancing can be a highly iterative, time consuming, and judgement-oriented process because there are an infinite number of solutions to achieve balanced volumes. The BTO-TASU volume balancing tools provide a mechanism to help organize, document, and perform volume balancing. There is one tool for balancing along freeway-only corridors and one tool available for balancing intersection volumes along an arterial corridor. These tools provide a template for manual balancing and provide automatic balancing methods to help the iterative process. The analyst **shall** review and, if necessary, adjust the results from the automated balancing methods to ensure the balanced volumes are logical.

Projects *may* need to develop their own templates for balancing volumes beyond the tools provided by BTO-TASU. Any volume balancing templates **shall** provide an organized means for reviewing:

- Raw/initial input volumes (existing, base-year or forecast volumes)
- Comparisons between raw/initial and balanced volumes
- Methodology for balancing volumes
- Notes regarding count errors, manual adjustments, and large discrepancies between raw/initial and balanced volumes.

Obtain approval from the WisDOT regional traffic engineer on the volume balancing methodology prior to developing or utilizing a tool other than that provided by BTO-TASU. Consult with WisDOT TFS as appropriate. If unsure about whether the tools available for volume balancing will work for a particular project, the WisDOT regional traffic engineer *may* contact BTO-TASU (DOTTrafficAnalysisModeling@dot.wi.gov) for additional support or guidance.

### 15.4.3.1 Volume Balancing Calculation Methods

Volume balancing *should* seek to minimize the difference between raw/initial and balanced volumes. Proportioning (pro-rata) methodologies and goal-seeking optimization routines are common calculation methodologies to obtain balanced volumes[1,2,3]. To account for any data quality concerns and to capture location-specific knowledge, the volume balancing process will also typically involve manual adjustments. The BTO-TASU volume balancing tools provide templates to help implement these methodologies.

The goals of the project and the type of facility in the traffic model (freeway-only, intersection-only, or mixed freeway-arterial corridors) *may* require the prioritization of critical locations over others during the volume balancing process. Prioritized locations *should* have minimal difference between the raw/initial and balanced volumes and *may* result in larger differences at lower priority locations. The following sections (TEOpS 16-5-15.4.3.2.2 – 4.3.2.5) discuss balancing priorities for different facility types.

### 15.4.3.2 Balancing Freeway-Only Corridors

Freeway analysis typically focuses on the freeway mainline, merge, diverge, and weaving traffic operations. Volume balancing for freeway-only corridors *should* prioritize mainline and ramp locations before any ramp-terminal intersection or arterials in the study limits.

Analysts will often use ATR locations on the freeway mainline as “anchor” points, meaning they consider the raw/initial volumes as fixed values. To eliminate any imbalance along the corridor, the analyst will adjust the ramp volumes between the anchor points and will hold the volumes at the anchors constant. The analyst *should* ensure that any location used as an anchor has high-quality volume data representative of the scenario under investigation. Even if anchor points are high quality, the analyst *may* consider allowing some flexibility (e.g., allow ± 20 vehicles/hour/lane difference between the raw/initial and balanced volumes) at the anchor location if it helps minimize differences between raw/initial and balanced volumes at other critical locations. Confirm the allowable flexibility at anchor points with WisDOT regional traffic staff. Involve WisDOT TFS as appropriate. If desired, the WisDOT regional traffic engineer *may* request additional support or guidance from BTO-TASU.

If the analyst suspects that the differences between the raw/initial and balanced volumes at ramp-terminal intersections may trigger operational issues affecting the mainline freeway, they *should*:

- If possible, manually adjust the balanced volumes at the ramp-terminal to reduce the differences between the raw/initial and balanced volume; or
- Conduct separate sensitivity analysis with higher demand intersection volumes to investigate operational concerns.

Coordinate the need for manual adjustments or sensitivity analysis with WisDOT regional traffic staff. Involve WisDOT TFS as appropriate. If desired, the WisDOT regional traffic engineer *may* request additional support or guidance from BTO-TASU. Document any manual adjustments or sensitivity analysis within the BTO-TASU or other equivalent volume balancing worksheet and save as part of the project files.

### 15.4.3.3 Balancing Intersection-Only Corridors

Intersection-focused analyses *should* prioritize high-volume capacity-critical intersections and allow more flexibility at lower-volume locations with reserve capacity. The purpose of the analysis may provide additional priorities for balancing. For example, a study focused on signal timing and coordination *may* allow more flexibility in changing mainline volumes that have fixed phase lengths to avoid overestimating side road timing needs.

The volume balancing process will typically resolve any imbalances between intersections by proportioning adjustments amongst all contributing turning movements, and not necessarily take into consideration any prioritization of which locations or turning movements are most important. Thus, if utilizing the BTO-TASU volume balancing tools or other automated balancing tool, the analyst *may* need to manually refine outputs to reflect any project-specific prioritization. Note any project-specific prioritization needs or other unique considerations within the BTO-TASU or other equivalent volume balancing worksheet and save as part of the project files.

The analyst *should* also consider driveways when balancing intersection corridors. Refer to TEOpS 16-5-15.4.3.2.5 for additional details on volume balancing at driveways.

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[1] Federal Highway Administration, *Traffic Monitoring Guide*. 2016 (3)

[2] Shaw, J. Automated Optimal Balancing of Traffic Volume Data for Large Access-Controlled Highway Networks and Freeway-to-Freeway Interchanges. Proceedings from the TRB 2014 Annual Meeting. (5)

[3] Ren, J. & Rahman, A, Automatically Balancing Intersection Volumes in a Highway Network. 12th TRB Transportation Planning Applications Conference. 2009. (6)

### 15.4.3.4 Balancing Mixed Freeway-Arterial Corridors

Traffic models that contain both freeway and arterial intersections are the most complex case for volume balancing, and require simultaneous consideration of freeway-only and intersection-only priorities (see TEOpS 16-5-15.4.3.2 and TEOpS 16-5-15.4.3.3, respectively). The analyst *should* prioritize capacity-critical freeway, mainline, and intersection locations first and allow more flexibility at lower-volume locations with reserve capacity. The analyst can accomplish this by utilizing the weighting factors to influence the automated balancing in the BTO-TASU freeway volume balancing tool or by manually adjusting outputs. Note any project-specific prioritization needs or other unique considerations within the BTO-TASU or other equivalent volume balancing worksheet and save as part of the project files.

Balancing the freeway and arterials simultaneously *may* or *may not* be feasible from a calculation standpoint. If not, balancing *may* require iterating between balancing the freeway and arterial separately and using the results of one iteration to inform the next.

### 15.4.3.5 Volume Balancing at Driveways

Driveways are any mid-block locations where traffic can enter or exit the network and are typically access points to businesses or intersections excluded from the traffic model. The analyst **shall** review any volume imbalance between intersections to ensure that the driveways could realistically capture the magnitude of the imbalance. Land use, development type, and directionality of the imbalance *may* help determine if the imbalance is reasonable.

- If a driveway imbalance appears unreasonably high, volume balancing *should* minimize the imbalance to a reasonable percentage. For example, the analyst *may* adjust the imbalance to be within 10% of the adjacent intersection volumes.
- If a driveway imbalance appears unreasonably low, the analyst *should* use caution when adjusting the imbalance, as it *may* be possible for the incoming and outgoing traffic at the driveway to yield no net change in volume. The analyst *should* also consider the directionality of the traffic (i.e., origin and destination) when assessing reasonableness.

Microsimulation *may* require special treatment of driveways depending on if the simulation is closed-system (such as Vissim) or open-system (such as SimTraffic).

Vissim uses a closed-system of roadway links where traffic can only enter or exit at the network edges, which assumes balanced input volumes. The analyst must account for driveways in the network by the following methods:

- Explicitly model all high-volume driveways which affect operations of adjacent junctures as separate intersections.
- Combine multiple low-volume driveways into one or more “dummy” intersections.
- Omit driveways with negligible effects on traffic operations from the traffic volume and eliminate all volume imbalances. This method is acceptable only if the balanced volumes and traffic operations at intersections near the omitted driveways are representative of field or benchmark conditions.

SimTraffic uses an open-system network where simulated vehicles instantly appear or disappear mid-block when there are imbalanced input volumes. Depending on the project-specific needs, this *may* or *may not* be acceptable. With an open-system network, it *may* be necessary to include major driveways as explicit intersections to replicate field or benchmark conditions.

The analyst *should* direct any questions regarding how to accommodate driveways to the WisDOT regional traffic engineer. If desired, the WisDOT regional traffic engineer *may* contact BTO-TASU (DOTTrafficAnalysisModeling@dot.wi.gov) for additional support or guidance. Note any project-specific needs or other unique considerations within the BTO-TASU or other equivalent volume balancing worksheet and save as part of the project files.

### 15.4.4 Review

To ensure that the results are logical and representative of the analysis scenario, it is critical to carefully review the results of the volume balancing process, especially if using automated balancing tools. Diagnostic checks to help the review *should* include:

- Comparison between raw/initial and balanced counts using the WisDOT root normalized squared error (RNSE)[4] metric (See TEOpS 16-20-8.4.1).
    - RNSE less than 3.0 are typically acceptable,
    - RNSE 3.0 to 4.9 *may* be acceptable,
    - RNSE 5.0 or greater require further investigation. Avoid RNSE values equal to or greater than 5.0, unless lowering the difference negatively affects higher priority locations. Document and explain the reason for high RNSE values.
- Review of any remaining imbalances in the balanced volumes to ensure they appropriately reflect driveways.

Diagnostic checks of balanced volumes sometimes reveal errors in the raw/initial traffic count data. If this occurs, the balancing process *may* restart using corrected raw/initial values as inputs or remain as-is if the balanced volumes are reasonable. In either case, document the error in the raw/initial count.

Final review of balanced volumes typically occurs during the modeling peer review process described in TEOpS 16-25 and Section 10 of the TPM. WisDOT regional traffic staff will typically lead the volume balancing review process, with assistance from WisDOT TFS, WisDOT BTO-TASU and an independent consultant as deemed appropriate. Refer to the Volume Balancing Checklist available on the BTO Traffic Analysis, Modeling and Data Management Program area webpage for criteria to consider while reviewing the balanced volumes. Document and save the results of the volume balancing review with the project files. Direct questions regarding review of volume balancing to BTO-TASU (DOTTrafficAnalysisModeling@dot.wi.gov).

### 15.4.5 Document

Document the volume balancing methodology including a summary of the raw/initial and balanced traffic volumes, data sources, and count dates. Note any count errors and manual adjustments. Explain any large discrepancies between raw/initial and balanced volumes. Describe any sensitivity analysis and potential impacts to the operational analyses. Provide a summary of the volume balancing peer review. If utilizing the BTO-TASU volume balancing tools, it *may* be sufficient to provide this documentation within the Excel template. Use of alternate volume balancing methodologies or tools, or complex volume balancing scenarios *may* require a technical memorandum to properly document the process. Consult with the WisDOT regional traffic engineer to confirm the required level of documentation (i.e., confirm the need for a technical memorandum). Save the completed volume balancing tools and associated documentation with the project files.

Obtain approval from the WisDOT regional traffic engineer on the volume balancing methodology and documentation prior to proceeding with the traffic analysis. Involve WisDOT TFS and BTO-TASU in the review of the volume balancing documentation as appropriate, noting that volume balancing of forecasted traffic volumes for use in microsimulation models will require WisDOT TFS approval. Refer to TEOpS 16-25 and Section 10 of the TPM for additional details on when to involve WisDOT TFS and BTO-TASU in the review process.

## 16-5-20 Origin-Destination Matrix Development September 2019

### 20.1 Basic Principles

This policy focuses on the use of origin-destination (O-D) matrices in microsimulation models. Refer to the TPM for additional details on working with O-D matrices in travel demand models (TDMs).

An O-D matrix is a table that displays the number of trips (i.e., traffic demand) traveling from each origin (row) to each destination (column) in the study area. The O-D matrix provides a mechanism to illustrate the travel demand patterns across small and large transportation networks in a single table. An analyst will often use O-D matrices to load traffic demand data into a microsimulation model. Figure 20.1 provides an example of an O-D matrix.

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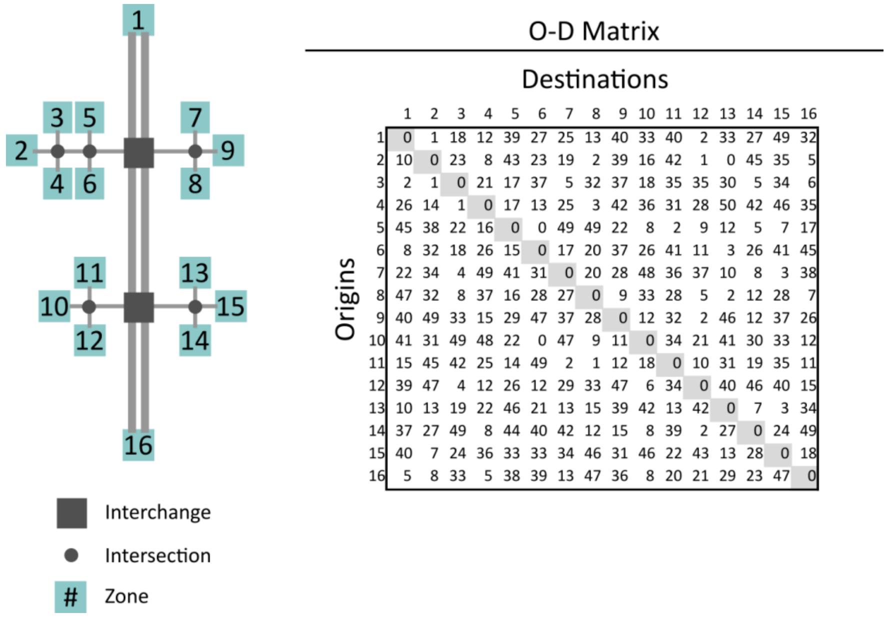
[4] $RNSE = \sqrt{\frac{(Vb-Vr)^2}{Vr}}$ Where Vb = Balanced Volume and Vr = Raw Volume

O-D matrices can be challenging to develop in terms of time and amount of data. The following provides information to help the analyst choose appropriate O-D estimation or data collection methods and data requirements when working with microsimulation models. Document the O-D development methodologies and assumptions, typically within the Traffic Forecasting Methodology Report, and submit to WisDOT regional traffic staff and WisDOT TFS for review and approval. WisDOT TFS will summarize their comments on the development of the O-D matrices within DT2340. Involve BTO-TASU in the review as appropriate (see TEOpS 16-25).

**Figure 20.1 Example Zone Map and O-D Matrix**



O-D Matrix

Destinations

Origins

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 18 | 12 | 39 | 27 | 25 | 13 | 40 | 33 | 40 | 2 | 33 | 27 | 49 | 32 |
| 2 | 10 | 0 | 23 | 8 | 43 | 23 | 19 | 2 | 39 | 16 | 42 | 1 | 0 | 45 | 35 | 5 |
| 3 | 2 | 1 | 0 | 21 | 17 | 37 | 5 | 32 | 37 | 18 | 35 | 35 | 30 | 5 | 34 | 6 |
| 4 | 26 | 14 | 1 | 0 | 17 | 13 | 25 | 3 | 42 | 36 | 31 | 28 | 50 | 42 | 46 | 35 |
| 5 | 45 | 38 | 22 | 16 | 0 | 0 | 49 | 49 | 22 | 8 | 2 | 9 | 12 | 5 | 7 | 17 |
| 6 | 8 | 32 | 18 | 26 | 15 | 0 | 17 | 20 | 37 | 26 | 41 | 11 | 3 | 26 | 41 | 45 |
| 7 | 22 | 34 | 4 | 49 | 41 | 31 | 0 | 20 | 28 | 48 | 36 | 37 | 10 | 8 | 3 | 38 |
| 8 | 47 | 32 | 8 | 37 | 16 | 28 | 27 | 0 | 9 | 33 | 28 | 5 | 2 | 12 | 28 | 7 |
| 9 | 40 | 49 | 33 | 15 | 29 | 47 | 37 | 28 | 0 | 12 | 32 | 2 | 46 | 12 | 37 | 26 |
| 10 | 41 | 31 | 49 | 48 | 22 | 0 | 47 | 9 | 11 | 0 | 34 | 21 | 41 | 30 | 33 | 12 |
| 11 | 15 | 45 | 42 | 25 | 14 | 49 | 2 | 1 | 12 | 18 | 0 | 10 | 31 | 19 | 35 | 11 |
| 12 | 39 | 47 | 4 | 12 | 26 | 12 | 29 | 33 | 47 | 6 | 34 | 0 | 40 | 46 | 40 | 15 |
| 13 | 10 | 13 | 19 | 22 | 46 | 21 | 13 | 15 | 39 | 42 | 13 | 42 | 0 | 7 | 3 | 34 |
| 14 | 37 | 27 | 49 | 8 | 44 | 40 | 42 | 12 | 15 | 8 | 39 | 2 | 27 | 0 | 24 | 49 |
| 15 | 40 | 7 | 24 | 36 | 33 | 33 | 34 | 46 | 31 | 46 | 22 | 43 | 13 | 28 | 0 | 18 |
| 16 | 5 | 8 | 33 | 5 | 38 | 39 | 13 | 47 | 36 | 8 | 20 | 21 | 29 | 23 | 47 | 0 |

## 20.2 Defining Zones

One of the first steps in building an O-D based microsimulation model is to establish a set of zones which represent the locations where traffic enters and exits the model. Zones can be origins or destinations of traffic. The schematic in Figure 20.1 illustrates an example zone map where the numbers represent the zones at the edges of the network.

Figure 20.1 also shows an example O-D matrix which corresponds to the zone map in the schematic. The values in each cell of the matrix represent the number of one-way trips between each O-D pair for a given time period. If a model is comprised entirely of two-way links, each zone will function as both an origin and a destination. In the O-D matrix, zeros reflect intrazonal trips (the shaded diagonal line in Figure 20.1), impossible trip pairs, or just the absence of trips between the zones. Depending on the zone structure, it *may* be possible for a trip to start and end at the same zone, specifically for U-turns or alternative intersection designs[5]. For the traffic model to properly capture these trips, it *may* be necessary to modify the zone structure by splitting zones into separate origin and destination zones or by adding “dummy” zones.

Consistent zone numbering helps organize O-D matrices. For example, an analyst might start with Zone 1 at one end of the model and continue numbering to the other end as shown in Figure 20.1. If the modeling objectives include analyzing the impacts of future development, it *may* be appropriate to reserve one or more “dummy” zone numbers to facilitate adding the development traffic to the design year model.

Prior to developing the O-D matrices, the analyst *should* meet with WisDOT regional traffic staff to confirm the proposed zone structure. It *may* be advantageous to involve WisDOT TFS and BTO-TASU in these meetings, especially if they will be involved in the review of the traffic model (see TEOpS 16-25).

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[5] Alternative intersections reroute one or more turning movements (typically left-turns) away from the center of the primary intersection to a secondary junction and then back through the primary intersection. Examples of alternative intersections include, but are not limited to, restricted crossing U-Turn (RCUT), median U-Turn (MUT) and displaced left turn (DLT).

## 20.3 Sources of O-D Data

There are multiple techniques, within two main classifications (field measurement or synthesis), available for collecting or estimating O-D data. The basis of the O-D data for the simulation modeling (not including the TDM) typically comes from three main sources:

- TDM data
- Field measured O-D data
- O-D synthesis using traffic count data

Depending on the level of detail and confidence required to accomplish the goal of the simulation analysis, the analyst *may* utilize one or more sources to develop the O-D matrix. Refer to TEOpS 16-5-20.4 for additional details on what O-D sources *may* be appropriate for modeling.

### 20.3.1 TDM O-D Data

In Wisconsin, the Metropolitan Planning Organizations (MPOs) and most Regional Planning Commissions (RPCs) coordinate with WisDOT TFS to develop and maintain TDMs which aid in the development of long-range transportation plans. WisDOT TFS also maintains a statewide TDM. Contact WisDOT TFS to determine the latest version of TDMs for project data. Complete the DT1599 (Agreement for and Restrictions on use of WisDOT Travel Demand Models) form and submit to WisDOT TFS (DOTTrafficForecasting@dot.wi.gov) to request a copy of the TDM or subarea model extraction and the associated O-D trip tables. Refer to the TPM for additional details on the TDMs in Wisconsin.

If there is an existing TDM that covers the area of interest, the associated O-D information from a subarea model extraction can be a good starting point for the O-D matrix for the microsimulation models. However, since the microsimulation models typically have more detail than TDMs, in terms of the transportation network and zones, and often require more discrete analysis periods, the conversion from the TDM is not without effort. The additional effort *may* be attributable to the following:

- To utilize the TDM subarea O-D data in the more detailed simulation models, the analyst must first make sure that they align the origin and destination data between the two models. This *may* require the analyst to group the zones within the more detailed model to reflect the TDM zone structure.
- Although peak hour or peak period data *may* be available from the TDM, in some of the TDMs, the output is only representative of 24-hour traffic flows. Further, the TDM output *may* only represent traffic patterns from the nearest decennial census year. Thus, to develop accurate peak hour or peak period O-D matrices from regional TDM data, the analyst *may* need to apply factors to the O-D data to represent the desired conditions (e.g., AM and PM peak hours of the existing conditions).
- TDM O-D data typically reflect regional travel patterns and *may not* be able to accurately capture turning movements at the intersection level. If the project goals require detailed intersection level analysis, prior to utilizing the TDM O-D data, it *may* be necessary to gather field counts to validate and modify the volume targets. Before collecting new field counts, coordinate with WisDOT regional traffic staff to verify there are no other sources of the necessary data available. Additional resources for identifying data sources include WisDOT BSHP and WisDOT TFS.  Follow the TPM and other available WisDOT guidelines for data collection as applicable.

### 20.3.2 Field Measured O-D Data

O-D data collection methods have historically been labor and time intensive, but modern technologies and data sources have reduced the effort involved. The benefits of having additional data from the field (e.g., better understanding of travel patterns in the study area, a more legally defensible and accurate model), often out-weigh the additional time and effort spent collecting the O-D information necessary for development of microsimulation models. With that said, before conducting any new O-D field surveys, coordinate with WisDOT regional staff and WisDOT TFS to verify there are no existing sources of relevant O-D data available. Refer to Section 60 of the TPM for additional information on O-D travel surveys as they pertain to TDMs.

Historical techniques for collecting O-D data have included: roadside interviews, mail-back (postcard) surveys, telephone surveys, and license plate matching. These techniques often have limited sample sizes and can be invasive or disruptive to traffic. License plate matching using video data collection can still be a useful technique, but requires extensive data collection equipment, data reduction, and has privacy concerns because it *may* be possible to trace the license plates to a database of vehicle owners.

Modern techniques for collecting O-D data include:

- **Wireless Data Readers:** Analyst can utilize Bluetooth devices to determine vehicle O-D patterns. Bluetooth is a short-range wireless communication protocol for connecting consumer electronics such as headsets, mobile phones, laptop computers, global positioning systems (GPS), and car communication systems. Every device equipped with Bluetooth has a number called the Media Access Control (MAC) address. Bluetooth devices exchange MAC addresses to initiate communication with each other. Unless the user has manually disabled "discovery mode", the Bluetooth device transmits its MAC address periodically to search for new connections. For traffic monitoring purposes, it is not necessary to establish communication with the Bluetooth device—it is sufficient to monitor the signals from passing vehicles, record the MAC addresses they transmit, and re-identify the devices when they cross another zone boundary. In principle, this is like the license plate matching technique, but it avoids some of the privacy concerns since there is no master database of MAC addresses. The number of discoverable vehicles by Bluetooth, sometimes referred to as the "penetration rate," can vary depending on location and time of day, so it is necessary to scale up (i.e., post-process) the raw Bluetooth O-D matrix to reflect actual traffic volumes. With Bluetooth surveys, it is important to note that most, if not all, commercial trucks have GPS devices in discovery mode, while it is unknown if passenger vehicles have GPS, potentially leading to an overrepresentation of heavy vehicles. Additionally, the Bluetooth penetration rate is relatively low (typically less than 10%). The sample size *should* consider the penetration rate and potential overrepresentation of heavy vehicles to ensure that the Bluetooth O-D data sufficiently captures the travel patterns of those utilizing the roadway system.
- **Aerial Observation:** Airplanes, helicopters, drones, or even hot air balloons can observe and photograph traffic to collect O-D data. The images can be post-processed, via manual methods or computer algorithms, to track vehicle paths through the study area to measure O-D data. License plates are typically not visible in the photos, avoiding privacy concerns.
- **Third Party Probe Data Providers:** Third party companies like Streetlight, Teralytics, and others use "probe" data from GPS and cell phones to develop O-D matrices. The companies process, anonymize, and report the data in project-specific O-D zones. Purchased O-D data *may* have higher penetration rates than Bluetooth O-D data because of the multiple sources of probe data collected by third parties. Like, Bluetooth O-D data, third party probe data *may* provide an overrepresentation of heavy vehicles. The analyst *should* consider this potential overrepresentation when determining the sample size.

Forward the results of any O-D data collection efforts to WisDOT TFS (DOTTrafficForecasting@dot.wi.gov) for their reference and potential use within the TDM.

### 20.3.3 O-D Synthesis Using Traffic Count Data

Although there is a link between traffic volumes and O-D traffic demand, measuring traffic volumes in the field is often easier than measuring O-D demand data. Potential reasons for this include, but are not limited to, the following:

- Observations and data collection at spot/isolated locations (e.g., turning movement volumes at a single intersection or traffic flows on a basic freeway segment) can provide traffic volume data. However, congestion upstream or downstream of the count site *may* be metering traffic such that the spot location volume *may not* reflect the "true" demand. To capture "true" demand, it *may* be necessary to collect additional field data at the upstream or downstream locations, which *may* or *may not* be within the project study area.
- Multiple combinations of travel patterns can yield the same traffic volume at a spot location. Thus, to measure O-D data in the field, it is often necessary to track a vehicle from the point it first enters the roadway network to the point it exits the network.

Document, typically within the Traffic Forecasting Methodology Report, and save the results of any O-D synthesis efforts with the project files.

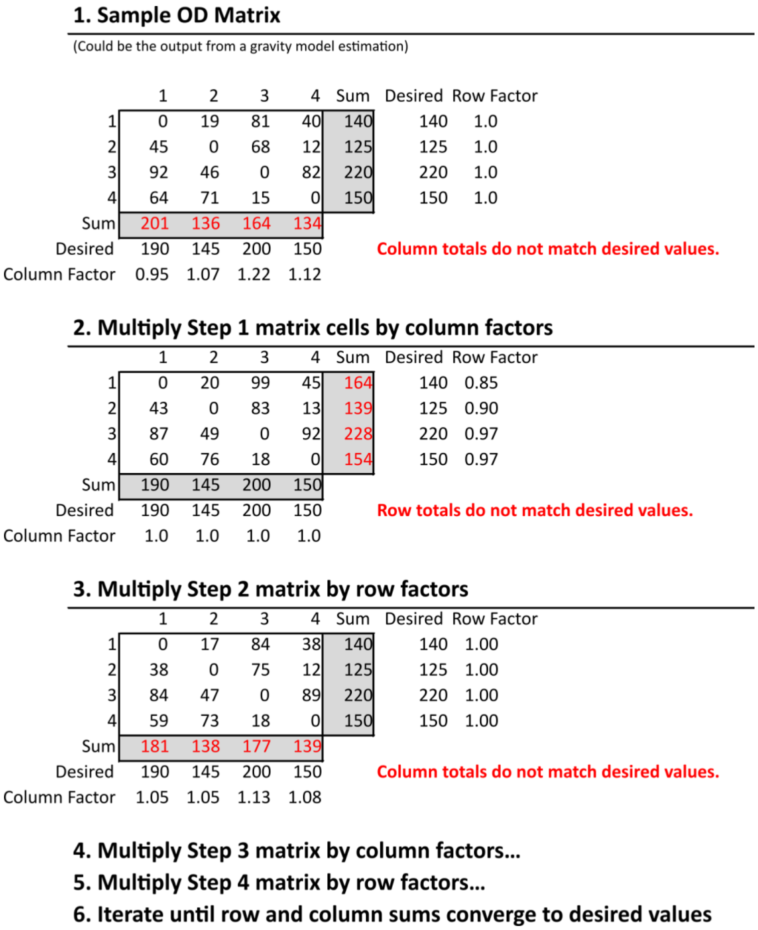
#### 20.3.3.1 Manual Estimation Techniques

It *may* be possible to utilize manual estimation techniques to develop an O-D matrix from traffic counts. Analysts will typically use manual techniques for small O-D matrices or when TDM data is not available but *may* also choose to utilize manual techniques when obtaining O-D field data is time or cost prohibitive or when they wish to refine a previously developed O-D matrix. Typical manual techniques include gravity model estimation, by-hand estimation (such as using turning movement percentages or local traffic knowledge), or software designed for O-D estimation.

The gravity model is an algorithm used in transportation planning to measure the amount of traffic between activity centers. The model assumes the number of trips between two zones is directly proportional to the number of trip attractions in the destination zone and inversely proportional to a function of travel time between the two zones. In other words, the number of trips destined for a particular zone is dependent on the zones relative attractiveness and the length or difficulty of making the trip. The amount and type of land use in each zone determines this relative attractiveness based on the amount of travel people are willing to make for different trip purposes. Drivers usually take the shortest, fastest route and, as congestion makes one route less desirable, drivers will use other routes.

Employing the gravity model to create an O-D table will rarely lead to row and column totals that sum correctly so it is necessary to factor the cells within a matrix using biproportional matrix balancing (also known as the Fratar or Furness procedure). The Furness procedure factors the rows and columns by multiplying a row or column by the ratio of the desired to actual values. Figure 20.2 illustrates an example of the Furness procedure. After several iterations, the matrix *may* converge as the ratio of desired to actual values approaches one. If it does not converge, the analyst *should* perform enough iterations to result in a tolerable error. Additionally, the analyst could average the last row and column iterations to help improve the O-D estimation.

**Figure 20.2 Example Biproportional Matrix Balancing (Fratar or Furness Procedure)**



**1. Sample OD Matrix**

(Could be the output from a gravity model estimation)

| | 1 | 2 | 3 | 4 | Sum | Desired | Row Factor |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 19 | 81 | 40 | 140 | 140 | 1.0 |
| 2 | 45 | 0 | 68 | 12 | 125 | 125 | 1.0 |
| 3 | 92 | 46 | 0 | 82 | 220 | 220 | 1.0 |
| 4 | 64 | 71 | 15 | 0 | 150 | 150 | 1.0 |
| Sum | 201 | 136 | 164 | 134 | | | |
| Desired | 190 | 145 | 200 | 150 | | | |
| Column Factor | 0.95 | 1.07 | 1.22 | 1.12 | | | |

**Column totals do not match desired values.**

**2. Multiply Step 1 matrix cells by column factors**

| | 1 | 2 | 3 | 4 | Sum | Desired | Row Factor |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 20 | 99 | 45 | 164 | 140 | 0.85 |
| 2 | 43 | 0 | 83 | 13 | 139 | 125 | 0.90 |
| 3 | 87 | 49 | 0 | 92 | 228 | 220 | 0.97 |
| 4 | 60 | 76 | 18 | 0 | 154 | 150 | 0.97 |
| Sum | 190 | 145 | 200 | 150 | | | |
| Desired | 190 | 145 | 200 | 150 | | | |
| Column Factor | 1.0 | 1.0 | 1.0 | 1.0 | | | |

**Row totals do not match desired values.**

**3. Multiply Step 2 matrix by row factors**

| | 1 | 2 | 3 | 4 | Sum | Desired | Row Factor |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 17 | 84 | 38 | 140 | 140 | 1.00 |
| 2 | 38 | 0 | 75 | 12 | 125 | 125 | 1.00 |
| 3 | 84 | 47 | 0 | 89 | 220 | 220 | 1.00 |
| 4 | 59 | 73 | 18 | 0 | 150 | 150 | 1.00 |
| Sum | 181 | 138 | 177 | 139 | | | |
| Desired | 190 | 145 | 200 | 150 | | | |
| Column Factor | 1.05 | 1.05 | 1.13 | 1.08 | | | |

**Column totals do not match desired values.**

**4. Multiply Step 3 matrix by column factors…**

**5. Multiply Step 4 matrix by row factors…**

**6. Iterate until row and column sums converge to desired values**

#### 20.3.3.2 O-D Estimation Software

Another way for an analyst to synthesize an O-D matrix from traffic counts is through utilization of specialized O-D estimation software. Often the estimation software is part of a larger software suite, such as Cube Analyst (part of the Cube TDM software) or VISUM (part of PTV's suite of tools). O-D estimation software often requires several iterations and fine-tuning of algorithm parameters to produce an O-D matrix. The analyst *should* read and understand the parameters used by each software method. As true for any estimation methodology, it is critical to carefully check the resulting O-D matrix for reasonableness.

## 20.4 O-D Data Requirements

Model size and complexity are the primary factors in determining the O-D data requirements. The number of zones in the network determines the model size. Model complexity is more subjective. Factors that tend to influence the complexity of the model include weaving areas, closely-spaced intersections, and other locations where O-D patterns affect traffic operations. The number of zones in the model also increases complexity by requiring exponentially more data. For example, a model with 5 zones has 5x5=25 O-D pairs, while a model with 50 zones has 50x50=2500 O-D pairs. As the model increases in size and complexity, so does the need for more accurate sources of O-D data. Additionally, the larger and more complex the model, the more time and resources are necessary to develop the O-D matrix.

To allow for the discussion of O-D estimation data requirements, this policy divides model size and complexity into three categories:

- **Small** – Models with fewer than 20 zones
- **Medium** – Models with 20 to 50 zones
- **Large** – Models with more than 50 zones

Small models typically have less than 20 zones. O-D matrices for models of this size typically require limited or no field-measured O-D data. The analyst *should* gather traffic counts for the project area. Additionally, with some knowledge of local traffic patterns, the analyst often can develop the O-D by hand. If existing data sources cannot provide the information, at critical locations affected by O-D patterns, consider collecting field O-D data or performing sensitivity analysis.

Medium sized models have about 20 to 50 zones. Although the number of zone pairs increases substantially for models of this size, knowledge of regional trip patterns and basic trip distribution methods can result in acceptable O-D matrices without the need to use a special O-D estimation tool. Consider using the gravity model, or estimation software, to estimate the number of trips between known attractions. A TDM subarea extraction *may* also help in developing O-D matrices. It *may* be necessary to collect field data at critical locations affected by O-D patterns.

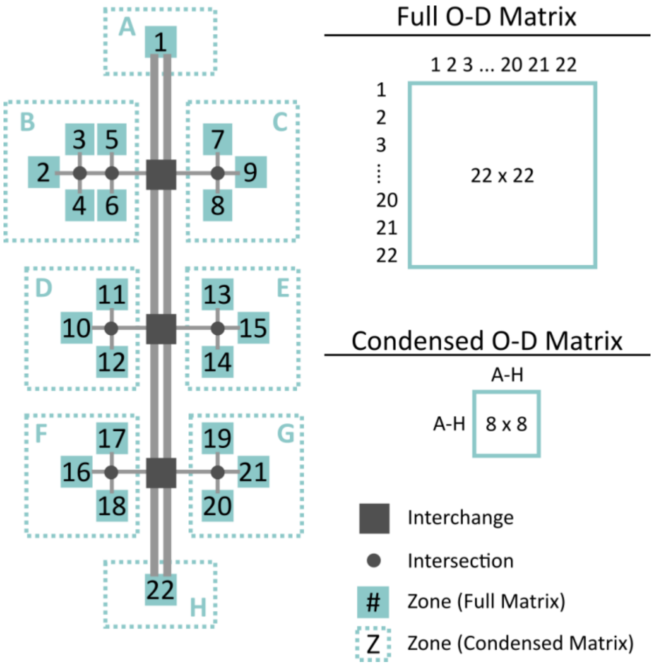
Large models tend to have more than 50 zones. Because of the number of O-D pairs, the analyst will need to employ multiple O-D estimation methods, and it will require considerable time and effort to deal with the amount of data. Use of a TDM subarea extraction will most likely be necessary for development of an O-D matrix. It *may* require the use of field data and hand-estimation to refine the matrix.

Regardless of the model size, before conducting any new O-D field surveys, coordinate with WisDOT regional staff and WisDOT TFS to verify there are no existing sources of relevant O-D data available.

Grouping zones to develop a condensed O-D matrix can be an effective technique for reducing data requirements, especially for large models or when working with TDM data. For example, a freeway focused model that includes arterial intersections could have its zones condensed to have one zone to represent each ramp terminal as shown in Figure 20.3. Figure 20.3 condenses the full 22x22 O-D matrix into an 8x8 O-D matrix. The condensed O-D matrix would require less detailed information, similar to what is available from most TDMs, and could reduce the level of effort for field data collection. Once the analyst has the condensed O-D matrix, they can expand it to the full zone structure using turning movement counts or local knowledge. Condensing and expanding O-D matrices allows broader patterns to be well-represented with less data requirements.

Prior to finalizing the details of the model and O-D matrices, the analyst *should* meet with WisDOT regional traffic staff to verify the O-D data requirements and needs. It *may* be advantageous to involve WisDOT TFS and BTO-TASU in these meetings, especially if they will be involved in the review of the traffic model (see TEOpS 16-25). Document any decisions pertaining to the O-D data requirements, typically within the Traffic Forecasting Methodology Report, and save with the project files.

Figure 20.3 Example Zone Grouping



## 20.5 Future Year O-D Estimation

Analysis of future year scenarios in microsimulation models require a future year O-D matrix. Typical techniques for developing future year O-D matrices include:

- Global scale factor
- Local scale factors
- Travel Demand Model

Of these methods, the TDM method is the most comprehensive method for integrating with traffic forecasts. Document the selected O-D estimation technique, typically within the Traffic Forecasting Methodology Report, and save with the project files.

The global scale factor method assumes all zones within the O-D matrix change by the same uniform amount. Typically, an analyst will limit the use of a global scale factor for future scenarios to sensitivity analysis testing, or for a simplified approximation to more rigorous forecasting. A global scale factor can be useful for interpolating or extrapolating a forecast to a different analysis year or helping to estimate how much spare capacity a facility *may* have.

The local scale factor method has the analyst apply changes to select O-D pairs to investigate the effects of a specific change in demand. For example, in a Traffic Impact Analysis (TIA), the analyst could change specific O-D pairs to reflect the expected development. An analyst can also use local scale factors to refine results from either the global scale factor or TDM methods for creating a future year O-D matrix.

Developing a future year microsimulation O-D matrix using TDM subarea extraction O-D matrices involves many steps as shown in Attachment 20.1 – O-D Process Flow Chart, and often requires many iterations to produce an acceptable future year O-D matrix for more detailed simulation analyses. The process starts with calculating the change in traffic between the TDM base and future year O-D matrices. As discussed in the *National Cooperative Highway Research Program (NCHRP) Report 255: Highway Traffic Data for Urbanized Area Project Planning and Design* (4), there are two methods available for computing the change in traffic from the TDM:

- **Absolute change** – Takes the difference between the future year and base year TDM O-D matrices. For example: if one O-D pair has 100 trips in the base year and 200 trips in the future year, the change is +100 trips. The change in traffic would be negative if the future year trips were lower than base year trips.
- **Relative change** – Takes the ratio of the future year to base year TDM O-D matrices. Using the same example above, the relative change would be 200 trips future / 100 trips base = 2.0.

The process continues by applying the results from both methods to the base microsimulation O-D matrix. Consider an example where the same O-D pair in the example above has 80 trips in a microscopic simulation O-D matrix. The future year could have 180 trips (80 trips + 100 trips) using the absolute change method. The future year could also have 160 trips (80 trips * 2.0) using the relative change method. Since both the absolute change and relative change methods often yield reasonable results, the analyst will typically average the results of the two methods (170 trips) as a starting point.

In some cases, the absolute or relative change methods *may* yield extreme results, typically for TDM O-D pairs that have a very small number of trips. For example: consider an O-D pair that changes from 1 trip in the base year to 10 trips in the future year. This is a 10-times increase using the relative method, but only a 9-trip increase using the absolute method. Even after averaging, the future simulation O-D matrix *may* yield unreasonably high traffic volumes because of the large multiplicative increase from the relative change method. The analyst *may* consider using only the absolute method for this O-D pair instead.

## 20.6 Review

The analyst **shall** review the O-D matrices, specifically any future O-D matrices, for reasonableness. Performing validation tests on the microsimulation model (see TEOpS 16-20-8) and reviewing traffic growth or land use can help in determining reasonableness. This could include verifying that the change in traffic at the origin and destination zones reflect that shown in the traffic forecasts or TDM. Additionally, the relative change between the existing and future O-D matrices *should* mirror the trends from the traffic forecasts.

Another check *may* include looking for O-D pairs that show fewer trips in the future year than the base year. A no-build scenario (assuming the status quo for population, land use, and transportation trends), would typically assume zero O-D growth at a minimum (no negative growth) to demonstrate that demand in the future would at least be equal to what exists today. Future decreases in O-D *may* be appropriate if there is a definitive cause, typically in an alternative scenario analysis such as a route closure, new transportation mode, or alternative land use or population scenario. Reviewing minimum and maximum growth in the future O-D matrix within the context of the scenario assumptions can help in determining reasonableness.

The WisDOT regional staff and WisDOT TFS **shall** conduct a peer review of the O-D matrices developed for microsimulation models in accordance with the procedures outlined in TEOpS 16-25. The region will involve BTO-TASU in the peer review process as appropriate. The DT2291 and DT2340 forms provide a means to document the peer review. Save the DT2291, DT2340, and all other notes on the peer review of the O-D matrices with the project files.

## 20.7 Document

Document the O-D development methodologies and assumptions, typically within the Traffic Forecasting Methodology Report. Explain the rationale for the zone structure, including the numbering scheme and use of any “dummy” zones. Provide graphics and tables to illustrate the zone map schematic. Describe what the O-D data represents (e.g., day, month, year, analysis period, etc.) making sure to note the source(s) of the O-D data. Provide justification for the use of any new O-D data collection efforts.

Outline the techniques used to develop the O-D matrices (field-measured, synthesis, manual estimation, O-D estimation software, etc.) and describe any project-specific needs and other unique considerations taken into consideration.

Submit a copy of the Traffic Forecasting Methodology Report and any other documentation associated with the O-D development to WisDOT regional traffic staff and WisDOT TFS for review and approval. The region will involve BTO-TASU in the review as appropriate.

Save all the final O-D matrices and any associated documentation with the project files.

## LIST OF ATTACHMENTS

| | |
|---|---|
| Attachment 20.1 | O-D Process Flow Chart |

## 16-5-70 References September 2019

1. **Institute of Transportation Engineerings.** *Manual of Transportation Engineering Studies, 2nd Edition.* ITE, 2010. ISBN-13: 978-1-933452-53-1; ISBN-10: 1-933452-53-6.

2. **Transportation Research Board.** *Highway Capacity Manual, 6th Edition: A Guide For Multimodal Mobility Analysis.* Washington, D.C. : National Academy of Sciences, 2016. ISBN 978-0-309-36997-8.

3. **Federal Highway Administration.** *Traffic Monitoring Guide.* Washington, D.C: U.S. Department of Transportation, 2016. FHWA-PL-17-003.

4. **Transportation Research Board.** *NCHRP Report 255: Highway Traffic Data for Urbanized Area Project Planning and Design.* Washington, D.C. : National Cooperative Highway Research Program (NCHRP), 1982. ISBN 0-309-03450-7/ISSN 0077-5614.

5. **Shaw, J.** Automated Optimal Balancing of Traffic Volume Data for Large Access-Controlled Highway Networks and Freeway-to-Freeway Interchanges. *Proceedings from the TRB 2014 Annual Meeting.*

6. **Ren, J. & Rahman, A.** Automatically Balancing Intersection Volumes in a Highway Network. 12th TRB Transportation Planning Applications Conference, 2009.

# Attachment 20.1 O-D Process Flow Chart