6 FUTURE YEAR FORECASTING

6.1 Purpose

Design Hour Volumes (DHV) are used for ODOT planning and project level analyses. These are based on the existing year volumes developed in Chapter 5. The DHV is generally defined as the future year 30th highest hour (30 HV). Depending on scope and complexity of the analysis, different future methodologies are needed from simple historical trends to complex travel demand models. This chapter will outline the procedures for developing DHV and future Average Daily Traffic (ADT) used for ODOT planning and project level analysis. In addition, the processes for developing pavement design traffic volumes are also discussed. Future design hour volumes are a key input in following analysis steps and methodologies explored in later chapters. For more details on many of the methods in this chapter also refer to NCHRP Report 765.

6.2 General Considerations

The DHV typically controls the design of the project or represents a planning horizon year such as in a Transportation System Plan (TSP). These volumes can either be for no-build or build conditions. If a travel demand model is available for a study area, that is the preferred tool for future forecasting. If the study area is within a metropolitan area, then it is a federal requirement that a travel demand model is used.

6.2.1 Rounding

The DHV's need to be rounded before the network is balanced. The traffic volumes are not that precise to go down to one vehicle, especially considering projections that may be out 20 plus years. Balancing the network is easier if the network is not down to the individual vehicle. Future years five or ten years out should be rounded to the nearest five vehicles. Twenty-year future volumes can either be rounded to the nearest five or ten vehicles. Volumes less than five vehicles should use the "<5" symbol instead of using zero.

6.2.2 Need for Balancing

The DHV networks need to be balanced, even more so than with the existing conditions. Small differences in the existing year can become large differences in future years. Future planned changes in the network or land use remove the ability to use relationships between the obtained traffic counts as multiple growth rates are likely in effect. For areas that have travel demand models, balancing is critical to the success of post-processing. Refer to Section 5.3.2 for additional details on the balancing techniques.

6.2.3   Documentation

It is critical that after every step in the DHV process that all of the assumptions and factors are carefully documented, preferably on the graphical figures themselves. While the existing year volume development is relatively similar across types of studies, the future year volume development can go in a number of different directions with varying amounts of documentation needed. Growth factors, trip generation, land use changes are some of the items that need to be documented. If all is documented then anyone can easily review the work or pick up on it quickly without questioning what the assumptions were. The documentation figures will eventually end up in the final report or in the technical appendix. The volume documentation should include:

- Figures/spreadsheets showing starting volumes (30 HV)
- Figures/spreadsheets showing growth factors, cumulative analysis factors, or travel demand model post-processing.
- Figures/spreadsheets showing unbalanced DHV
- Figure(s) showing balanced future year DHV. See Exhibit 6-1
- Notes on how future volumes were developed:
  - If historic trends were used, cite the source.
  - If the cumulative method was used, include a land use map, information that documents trip generation, distribution, assignment, in-process trips, and through movement (or background) growth.
  - If a travel demand model was used, post-processing methods should be specified, model scenario assumptions described, and the base and future year model runs should be attached.

Exhibit 6-1 Balanced Future Year DHV Figure
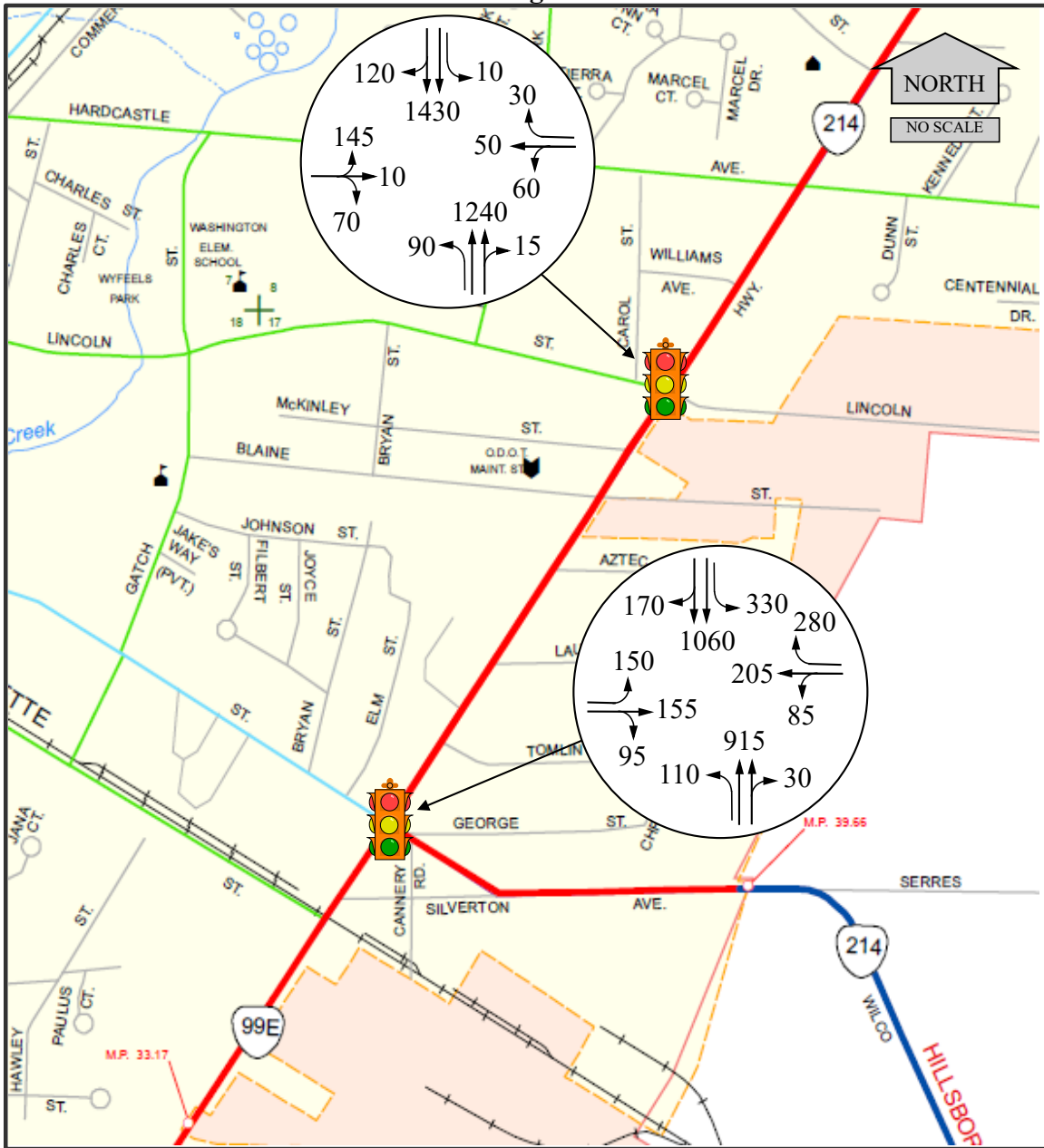
6.3 Determining the Future Year(s)

The analyst should work with the region project leader/planner ideally during the scoping phase to determine the future year before beginning any future year forecasting. The future year determination is typically documented in a methodology and assumptions memorandum in addition to the overall scope of work/work plan.

The design hour that is used for many projects is 20 years after the year of project opening. It can be a considerable period of time between when the traffic analysis is

completed and when the project is completed. Environmental documents (EA/EIS), Final design and approvals, permits, environmental clearances, right-of-way purchases, and funding availability/STIP programming, may add anywhere from two to five years before a project starts the construction phase. Depending on the project complexity, construction may take from one to many years with phases.

In planning, a 20-year horizon is typically used when evaluating transportation needs and solutions. Future horizon years should be, at a minimum, 20 years after the estimated plan completion/adoption year. This is typically two years after the plan starts. For refinement and other similar plans, the horizon year should be 25 to 30 years out, which would increase the life of the plan, especially if the project development process does not directly follow. Existing policies may determine the planning horizon such as the Transportation Planning Rule. Transportation Impact Analysis (or Study) (TIA/TIS) horizon year procedures are provided in the [Development Review Guidelines](#).

Many times, additional future years are necessary beyond just the typical 20-year future. In projects, the year of opening (build year) plus interim future years may be needed to support project phases or environmental air/noise/energy analyses. For example, if a project base year is 2011, its build year could be 2014, a 10-year future year would be 2024, and the project future (design) year would be 2034. This would mean three separate future years to be developed by the analyst.

For TSP's, build years are not typically done, but there may be interim years to support Urban Growth Boundary (UGB) expansions or to maintain consistency with adopted plans. For example, a TSP refinement plan with an existing conditions year of 2011 may have a 2025 year to stay consistent with the earlier TSP, but would still have a 2033 planning horizon year for a 20 year life beyond adoption.

Refinement plans that will be directly supporting later project development efforts will typically have year of opening (build year) future years. Planning efforts with three or more years between the plan and a start of a following project generally do not need build year analyses as the traffic analysis will likely need to be redone anyway.

Care should be taken to not extend the horizon year beyond the normal accuracy level. The limits of detailed analysis go out to about 30 years; anything beyond this is an estimation/approximation. If a travel demand model is used, five years is the limit of extrapolation beyond the model future year. If a project/plan requires more than five years, then the model needs to be updated, which typically involves creating a new future year (reference year) for the model. Contact TPAU or modeling staff in Metro for the Portland metropolitan area, Mid- Willamette Valley Council of Governments (MWVCOG) for the Salem-Keizer metropolitan area, and the Lane Council of Governments (LCOG) for the Eugene-Springfield metropolitan area immediately if a model update seems necessary. In some cases, if the travel demand model area is slow-growing, the extrapolation limit can be longer.

To support planning for a future in which some motor vehicles are no longer human-driven, but instead are connected and automated vehicles (CAVs), Appendix 6B includes guidance on adjusting the future capacity of freeway segments and facilities, roundabouts, and signalized intersections in planning scenarios where CAVs are assumed to be part of the traffic stream. This guidance is based on methods presented in the HCM, which were developed by a multi-state pooled-fund study led by ODOT.

> *As of 2022, no vehicles were available commercially that met the definition of a CAV for the purposes of an HCM analysis (i.e., a vehicle with an operating cooperative adaptive cruise control system that is capable of communicating with other vehicles and driving without human intervention in any situation). The capacity adjustment process presented in Appendix 6B is intended for use only in longer-range planning analyses.*

> *Because CAVs are not yet commercially available, capacity adjustments for CAVs should not be made in near-term analyses such as traffic impact studies.*

6.4 Growth Patterns

Different growth pattern types can all be present in a study area. There can be areas of fast growth (i.e. next to an urban fringe interchange), steady growth, or slowing growth (infill). Growth can be negative over the short or long term (i.e. recessions, declining industries, migration, or competition with nearby areas). The analyst must have knowledge of the study area in order to make the proper future year assumptions. The typical long-term growth curve can be a combination of three conditions on the overall timeline (see Exhibit 6-2). For instance, for the first 5 years the growth is exponential (compound), the next 10 years is linear, but the last 5 years the growth is declining (logistic). Growth curves can also be estimated by using a combination of differently sloped lines (piecewise, such as linear with different growth rates).

Exhibit 6-2 Traffic Volume Growth Types
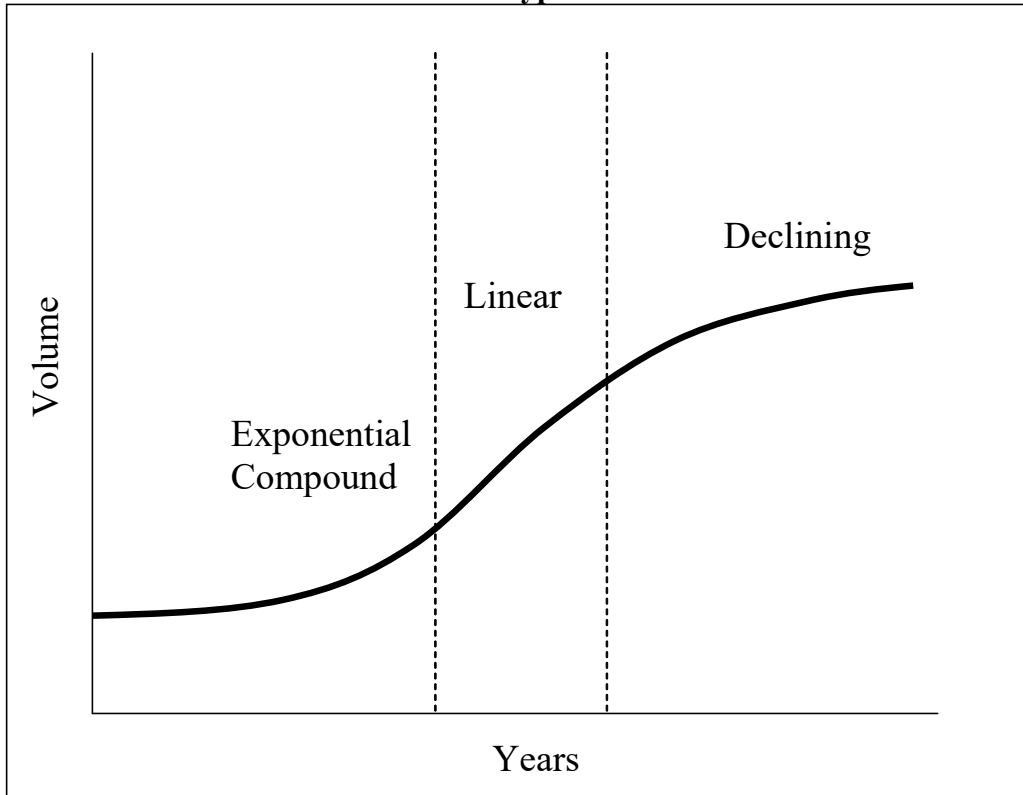
- **Exponential Growth (Compound)** – An exponential increase in traffic volumes, typically associated with brand new growth in an area that has plenty of land and road capacity. Exponential growth predicts the future volume for a given year based on a percentage of growth from the previous year. This is typically limited to five years or less. Use of an exponential curve over a prolonged period can seriously overestimate future growth.

> Future Volume = Base Year Volume $(1 + \text{Growth Rate})^{\text{Number of Years}}$
> $\text{Volume}_{FY} = \text{Volume}_{BY} \times (1 + Gr)^{(FY-BY)}$
>
> Where:
> Gr = Geometric growth rate
> FY = Future year
> BY = Base Year

> This method is not generally recommended unless it can be supported by data.

- **Linear Growth** - Linear increase in traffic volumes over time. This method assumes a constant amount of growth in each year and does not consider a capacity restraint. Areas that have or will likely have capacity constraints should use the declining growth curve shown below as long as there is sufficient evidence of a potential change. In many cases a linear growth rate is used since often there is insufficient data to support use of a more specific type of curve.

Future Volume = GF x Base Year Volume, or

VolumeFY = GF x VolumeBY

Where:

GF = Growth Factor = 1 + (G x N)

G = Linear annual growth rate, expressed as a decimal, calculated per Section 6.5

N = Years beyond the base year

FY = Future year

BY = Base Year

- **Declining Growth (Logistic)** - Growth tapers off as land approaches built-out status and capacity of roadways. Future growth is mainly contributed by growth in background (through) traffic.

$$V = \frac{V_0 C}{V_0 + (C - V_0)e^{-rt}}$$

Where:

t = time (years)

V = the volume at time t

V_0 = the initial volume at time 0

C = capacity (maximum sustainable volume)

r = rate of volume growth when volume is very small compared to the capacity.

C (capacity) is defined as service flow or saturation flow per lane. For interstates, multilane highways, and two-lane highways, it would be the maximum service flow at level of service (LOS) E. Signalized arterials would start with the ideal saturation flow which is reduced to the actual saturation flow with a few basic parameters as shown in Equation 18-5 in the 2010 Highway Capacity Manual (HCM) . Alternatively, the capacity estimator in the Highway Design Manual (HDM) Section 10.12 can be used and then use a characteristic K-factor to convert to an hourly value or can leave everything as ADTs (so C is an ADT-based value instead of hourly).

Once a "C" is found, then use the FVT/model to project linearly as a test to see if C is exceeded within the design/planning horizon or close (no more than 30-40 yrs.). If volumes exceed or get close to C then this curve would be used instead of linear. This would be the curve to use for future no-build. For the build, a determination would have to be made of the potential change in C. A significant increase in capacity may result in a linear relationship while a small change may affect it only a little in which the same curve could be used but with a higher C value. Use of this curve may indicate that there is peak spreading effects in play (see Chapter 8).

Estimates for rate (r) are done for the linear portion of the curve, so they can be based from the Future Volume Tables (see Section 6.5) or from a travel demand

model. Growth rates have to be large enough over time (t) to be affected by the capacity value so the curve will flatten out. Small growth rates may never reach the capacity level so the curve will remain linear.

Exhibit 6-2 shows the three types of curves, starting off as exponential (compound), transitioning to linear, and then to declining growth.

6.5 Historical Trends

The historical trends method uses traffic volumes from previous years to project future volumes. This method assumes that the future growth trend will be similar to the historical trend. It is used mainly in rural or small urban areas where significant growth is not anticipated. Current and future year traffic volumes are available in the Future Volumes Table webpage. More detail on the Future Volume table structure is in Section 5.5. If desired, different growth curves can be used on historical trend data if the overall trend does not seem to be linear. Most of the time, the differences between alternate growth curves and the linear growth curve are small and not worth the effort to create the trend.

Certain areas may be in long-term decline with negative growth rates. It is not generally appropriate to forecast a negative linear growth rate as many areas could result in a zero or an unrealistically low volume before the horizon year is reached. A conservative method is to assume no growth (base year = future year). It may be warranted to do a detailed investigation of the past trends to see if a different growth curve should be used. TPAU has data on past trends (20+ years) on the state highway system and can help with these types of issues.

Recessions/economic downturns can cause short-term dips in growth trends. It is possible to have a short-term low, none, or negative growth while still maintaining a long-term positive growth. Short- term recessions have little effect on a long-term analysis. Longer term recessions or slow growth periods need to be reviewed to make sure that the analysis is not starting from the low point (could underestimate volumes) or is projecting off the high point (could overestimate future volumes). These kinds of situations typically require a sensitivity or "bookend" type of analysis where both conditions are analyzed. While the terms, "growth rates" and "growth factors" appear to be interchangeable, they are not. Growth rates are decimal percentages versions of the yearly percentage growth. For example, if the growth rate is 2.5% per year, this would be 0.025. Growth factors are used in calculations and may represent one or more years (i.e. 1.025). Adding a "1" will convert a growth rate into a factor. It is important to remember when to convert or not. When converting multiple year growth factors into a single growth rate, make sure to remove the "1" before dividing (See Example 6-1). The basic growth rate and factor equations are shown below:

Growth Rate = (Growth Factor -1) / Number of Years

Growth Factor = 1 + (Growth Rate x Number of Years)

Example 6-1 Future Volumes Using Historic Trend

In this example, the forecast 20-year traffic volumes are developed based on historical counts.

For the Lava Butte ATR (#09-003) located on US 97 at MP 142.41, The following table shows the 1999 traffic volume, Year 2019 traffic volume and the R-squared value.

Example Future Volumes Table

Hwy#	DIR	MP	Description	1999	2019	RSQ
4	1	141.01	.01 miles S of Badger Rd	28400	47200	0.9212
4	1	141.52	.22 miles S of Murphy Rd	24000	41400	0.656
4	1	142.21	ATR 09-003 - Lava Butte	19600	32000	0.9338
4	1	143.47	.01 miles S of Galen Baker Rd	14200	23600	0.7328
4	1	153.09	.01 miles S South Century Dr	9600	11100	0.5788

RSQ = R-squared is an indication of data fitting to a line.

Based on the data above, the 20-year growth factor would be 1.63 (32,000/19,600). Assuming linear growth in the future, the annual growth rate would be (1.63 –1.0) /20 = 0.032, or 3.2%. The R-squared value of 0.9338 is acceptable, indicating a strong relationship. To convert the 1997 30 HV from this example to a 2019 DHV, the 1997 30 HV is multiplied by the 20-year growth factor, with an additional two years of growth added to this.

> 2019 DHV = 1997 DHV x (20-Year Growth Factor + 2 x Annual Growth Rate) =
> 112 vph x (1.63 + (2 x 0.032))
> = 112 vph x 1.694
> = 190 vph

When dividing the estimated future year volume by the most recent count volume it is important to note the numeric difference between the two years. In the example above, a 20-year growth rate was used between 1999 and 2019. Other highways may have been last counted in 1997 or 1998. This would mean that a 21- or 22-year growth rate should be applied. Dividing the total growth by 20 years would, in these cases, overestimate the growth rate.

For areas with calculated multiple growth factors, discard any with an R-squared value less than 0.75. Remaining growth factors that are within 1 or 2 percent can be averaged.

6.6 Trip Generation (For Traffic Impact Analysis & Zonal Cumulative)

Vehicle trips generated by future development are estimated using the Institute of Transportation Engineers (ITE) Trip Generation Manual (if manual trip calculations are

used) or a travel demand model for larger studies (see Section 6.10, Chapter 17, and the [Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012](#)). ITE trip generation rates are based on a database of trip generation studies conducted in the U.S. These studies collected data at existing land use generators including driveway vehicle counts and land use characteristics such as floor area size, number of parking spaces, etc. For each land use type, models were developed from the counts and the characteristics of the land uses, resulting in trip rates or equations for various time periods. ITE trip generation should not be confused with travel demand model trip generation, which is based on household surveys of person trips rather than vehicle counts. The following is a summary of ITE trip generation manual procedures. The manual itself should be consulted as part of any trip generation estimation process.

Trip generation rates are typically average values. There can be a large difference between the local trip generation potential and the national average values in the ITE manual. For common uses, such as single-family homes, gas stations, and shopping centers there have been plenty of studies done over the years that make up the research that is the basis for the trip generation rate or equation. Many land uses such as some commercial types have only a few studies, so the data should be used with caution. It is not uncommon for the standard deviation to exceed the averages if only a few studies exist. The ITE Trip Generation manual has guidance and cautions on the data limitations, what the assumptions/definitions for each land use are, procedures for use and conducting local trip generation studies if necessary.

Note that trip generation software such as Trip Generation by Trafficware is not standalone as it does not have the necessary background information on each land use like the manual does. The software is just a calculator tool that needs to be used in conjunction with the ITE Trip Generation Manual.

Trip generation may be composed of three basic types of trips: new/primary trips, pass-by trips, and diverted linked trips. New or primary trips are those trips that are new to the study area specifically attracted to or produced by a land use. Pass-by trips already exist along the roadway fronting the site, but now access the site before continuing on. Diverted linked trips exist in the study area but must divert onto local roads in order to access the site. Each of these types of trips is illustrated in the following Examples.

External versus Internal Trips

ITE Trip Generation rates are based primarily on single-use, free-standing sites. There are some exceptions such as shopping centers. Multi-use or mixed use developments may have interactions such as where some trips may occur internal to the site, whether by motor vehicle or by walking. The total external trip generation of these sites may be less than the sum of the individual stand-alone trip rates calculated using the ITE trip generation rates. ITE Trip generation Manual provides a methodology to estimate this effect, called internal capture (Volume 1, Trip Generation Handbook, Chapter 7 Multi-

Use Development). This is a percentage reduction applied to the sum of the individual land use trip generation.

Other Considerations

The ITE trip rates are based on data collected primarily at suburban locations with little or no transit service, nearby pedestrian amenities, or travel demand programs. The ITE Trip Generation Manual suggests the user may modify trip generation rates to reflect the presence of public transportation, Transportation Demand Management (TDM) measures, enhanced pedestrian and bicycle trip making opportunities, or other special characteristics of the site or study area. The Transportation Planning Rule (TPR) contains such a provision. OAR 660-012-0060 (6)(a) states that a ten percent reduction in ITE trip generation rates (that do not specifically account for mixed use effects) shall apply for proposed land use plan amendments which consist of mixed-use, pedestrian-friendly development and **prohibit** uses which rely solely on auto trips, such as gas stations, car washes, storage facilities, and motels.

ITE encourages users to supplement trip generation analysis with local data where practical. If local studies are conducted they should follow the ITE Trip Generation Manual guidelines for conducting a trip generation study.

Example 6-2 Trip Generation

A supermarket with floor area of 30,000 square feet is proposed as a new development within a suburban area as shown below. The proposed use is adjacent to an east-west arterial and located to the west of a north-south arterial. It is desired to estimate the trip generation for the site.

Site Development Location
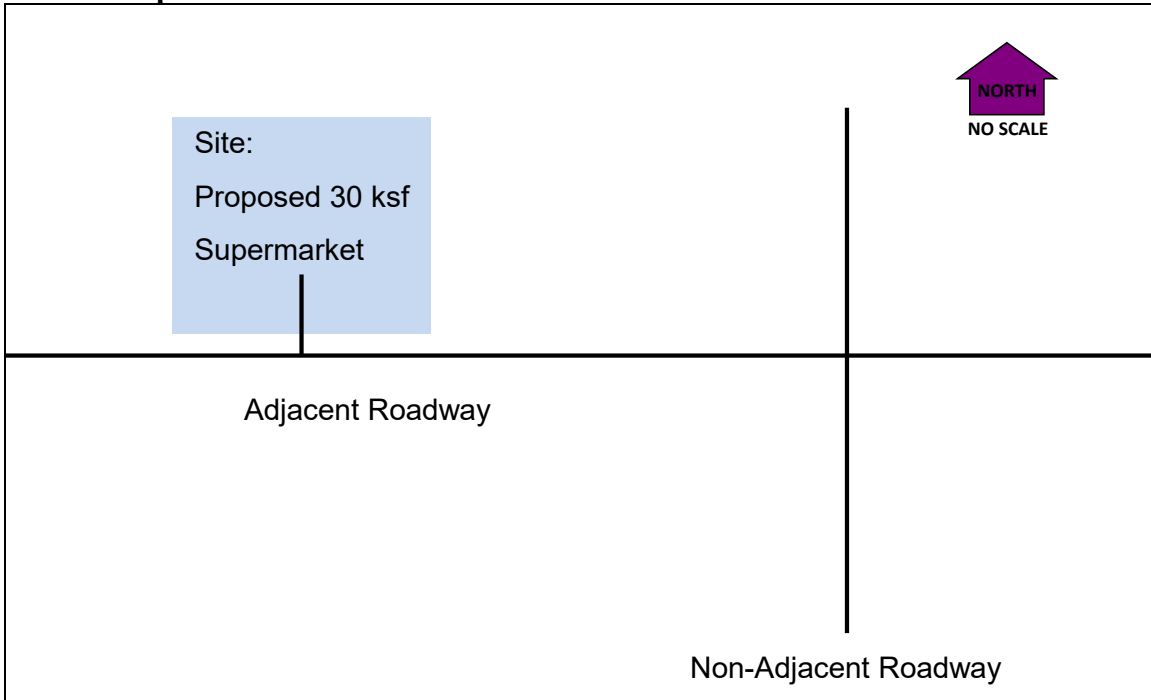
From the ITE Trip Generation Manual, 9th Edition, Volume 3, a supermarket is assigned Land Use Category 850. This is only a single land use so neither the internal trip capture reductions apply nor does the TPR mixed use reduction. The trip rates or equations, as appropriate, for this land use type are obtained from the manual and shown below. The manual provides trip generation data for certain days of the week such as the average weekday, Saturday and Sunday, as well as for specific hours of the day, such as the peak hour of the adjacent street traffic, or the peak hour of the generator. In this example the peak hour of adjacent street traffic is used. Average percentages of trip entering and exiting the site are also provided. Calculations are performed either in a spreadsheet or using commercial software. The resulting trips are typically summarized in a table as shown below. These represent all motor vehicle trips with origin or destination external to the site.

Site Trip Generation Summary

	ITE Land Use[1]	Trip Rate or Equation[2]	Enter	Exit	Total
AM[3]	850	3.40X	63 (62%)	39 (38%)	102
PM[3]	850	Ln(T)=0.74Ln(X) +3.25	163 (51%)	157 (49%)	320
Average Weekday	850	102.24X	1,534 (50%)	1,534 (50%)	3,067

[1] ITE Trip Generation 9th edition
[2] X = independent variable (thousand square feet of floor area) = 30.0 ksf
[3] Peak hour of adjacent street traffic

For commercial/retail types of land uses, peak hour site trips need to be further subdivided into new (primary), pass-by, and diverted linked trips. The ITE Trip Generation Handbook may have estimates of those percentages. These ITE estimates vary by land use size and other characteristics, so the chosen estimates should be close to the size of the proposed land use. Ideally, there will be more than one applicable estimate which can be averaged together. If not, other studies may be used or conducted, along with engineering judgment.

In this example, the ITE Trip Generation Handbook lists studies of average PM peak hour pass-by and diverted linked trip generation rates for supermarkets. Average rates are taken from data points where both pass-by and diverted linked rates are provided. Select those locations with size near that of the subject site. There are five study locations near 30,000 square feet in size. Of those, four locations provide both pass-by and diverted linked trip percentages. The average of these four sites is used. The average pass-by percentage is (32 + 44 + 19 + 28)/4 = 31%. The average diverted linked trip percentage is (20 + 27 + 45 + 32)/4 = 31%. The average primary trip percentage is (48 + 29 + 36 + 40)/4 = 38%. The number of PM peak hour trips by type are then calculated and displayed in a table as follows.

Site PM Peak Hour New, Pass-By, and Diverted Linked Trips[1]

	Percentage	Enter	Exit	Total
New	38%	62	60	122
Pass-by	31%	51	49	100
Diverted Linked	31%	51	49	100
TOTAL	100%	164	158	322

[1] ITE Trip Generation Handbook and Manual, 9th Edition

6.7 Trip Distribution (For Traffic Impact Analysis & Zonal Cumulative)

Traffic generated by a future development is distributed from the site based on existing origin-destination (O-D) study data if available, traffic count patterns for nearby similar land uses, local knowledge, or use of a travel demand model for larger studies (see Section 6.10, Chapter 17, and the Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012), together with engineering judgment. Use of a travel demand model typically involves creation of the land use in a model scenario then having a select-zone analysis performed to determine in/out percentages from the site.
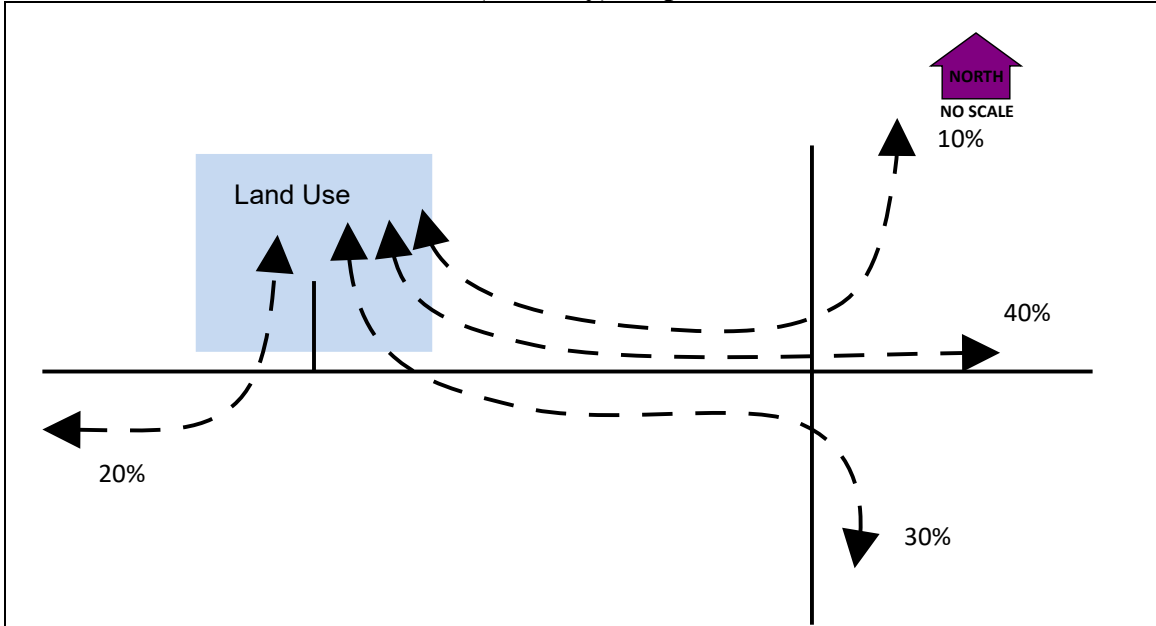
Example 6-3 Trip Distribution

The existing PM peak hour volumes in the study area are shown below. All of the site trip adjustments will be added or subtracted from these values.

Background PM Peak Hour Traffic Volumes
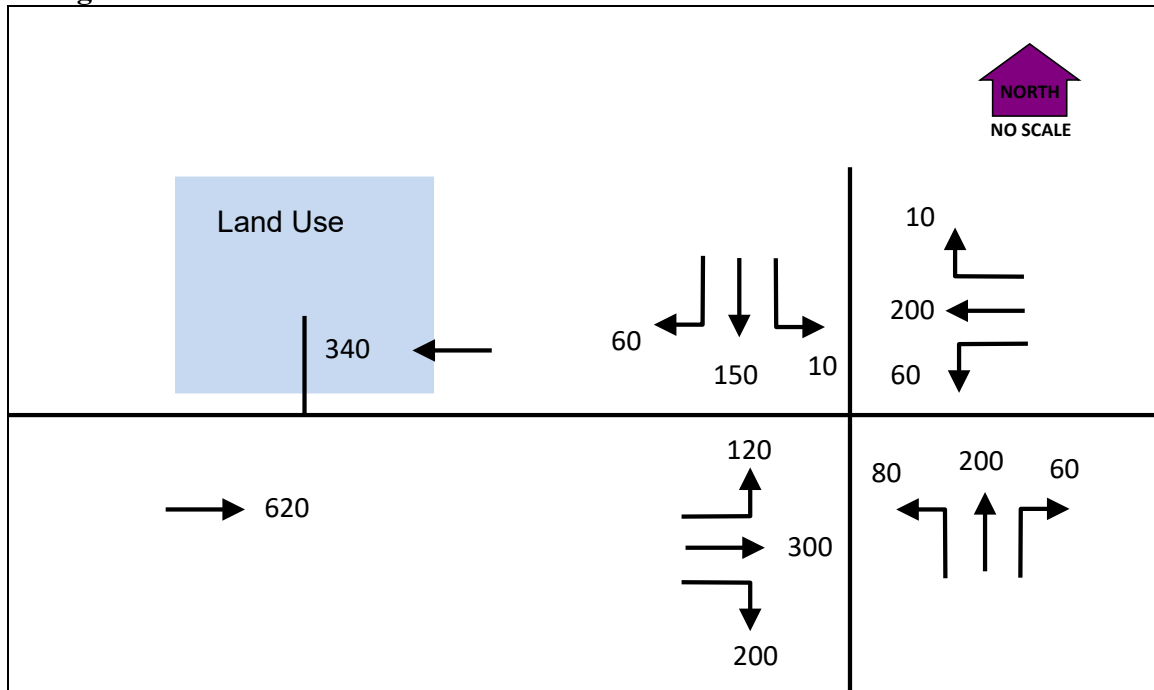
Continuing from the previous example, the distribution of new trips to/from the proposed supermarket has been determined based on existing count patterns and engineering judgment and is shown in the diagram below.

PM Peak Site Distribution of New (Primary) Trips

The distribution of pass-by and diverted linked trips should also be determined if present. Typically pass-by and diverted linked trips are based on traffic counts or travel demand models. In this example, the pass-by trip percentages are assumed to be proportional to

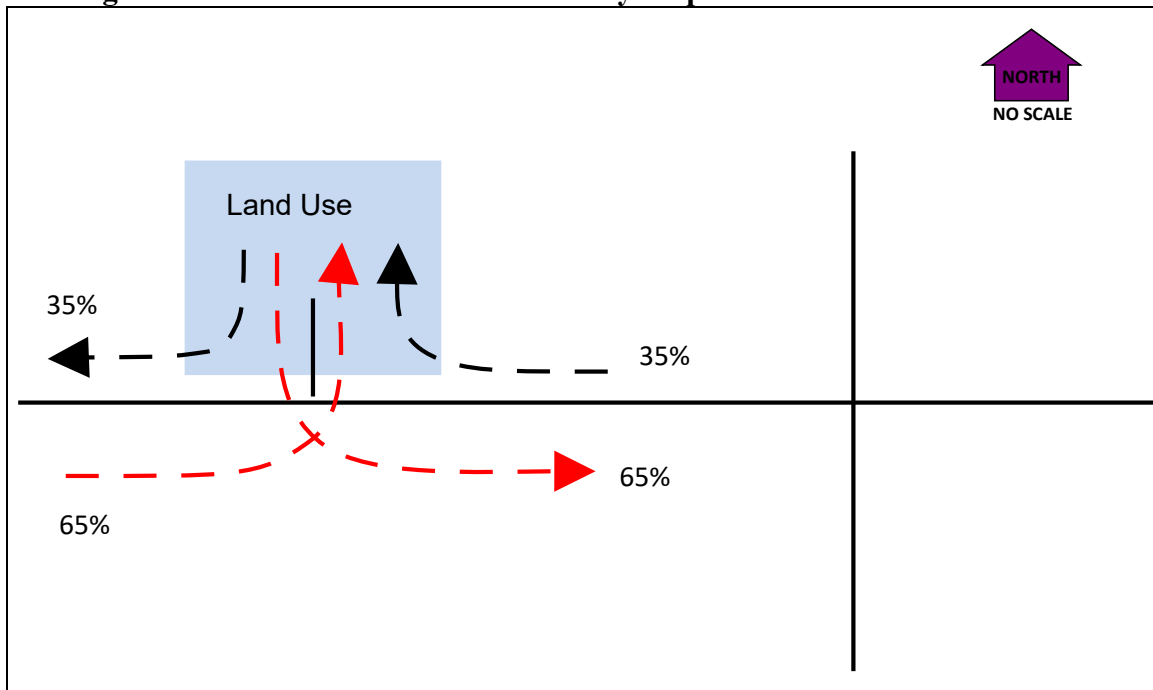the existing east-west PM peak hour directional volume of traffic on the adjacent roadway, as shown below.

Adjacent roadway volume both directions = 340 + 620 = 960 vph.
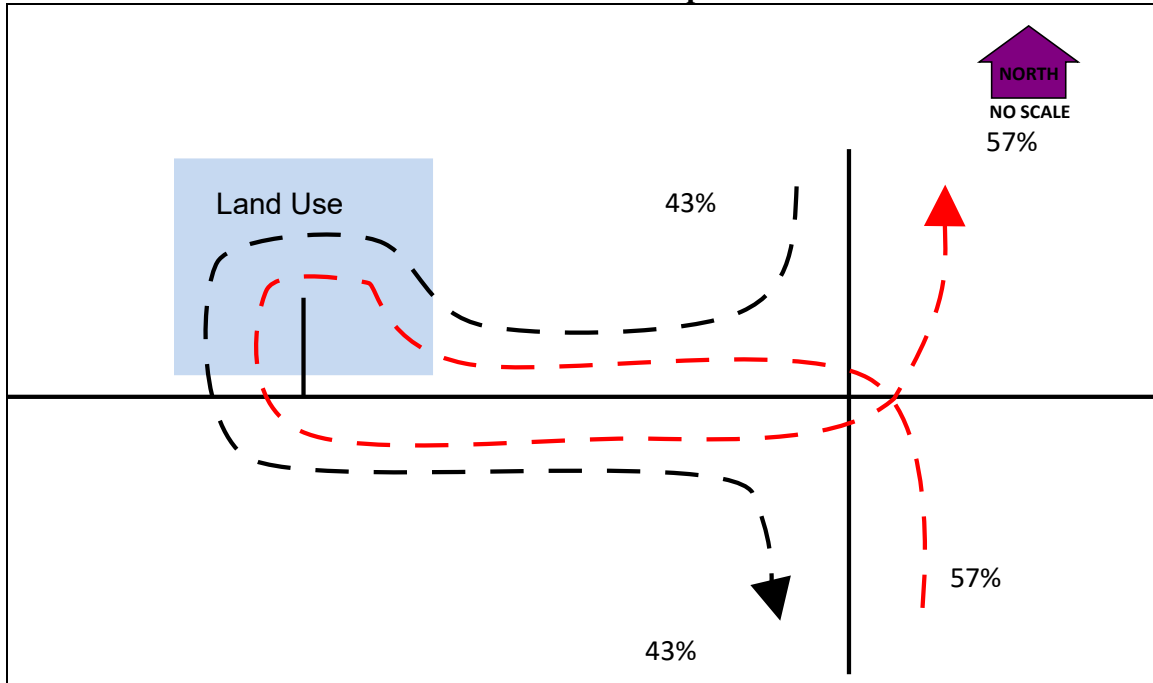Westbound proportion = 340 / 960 = 0.35
Eastbound proportion = 620 / 960 = 0.65

Existing PM Peak Distribution of Site Pass-by Trips

The diverted linked percentages in this example are assumed to be proportional to the north-south PM peak hour directional volume on the non-adjacent roadway, as shown in the next diagram.

Distribution of PM Peak Site Diverted Linked Trips

6.8 Trip Assignment (For Traffic Impact Analysis & Zonal Cumulative)

Traffic distribution to and from a future development is assigned to specific roadways either manually or using a travel demand model for larger studies (see Section 6.10, Chapter 17, andthe Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012). To create the trip assignment, apply the percentage distribution to the trip generation for the assignment of new, pass-by and diverted linked site trips. Summing up the background, new, pass-by and diverted linked trips results in the final total trip assignment.

The assignment of each of the components of site trips (primary, pass-by, and diverted linked) should be calculated and displayed on separate flow diagrams. Calculations are typically performed in a spreadsheet or with a specific software application such as Vistro.
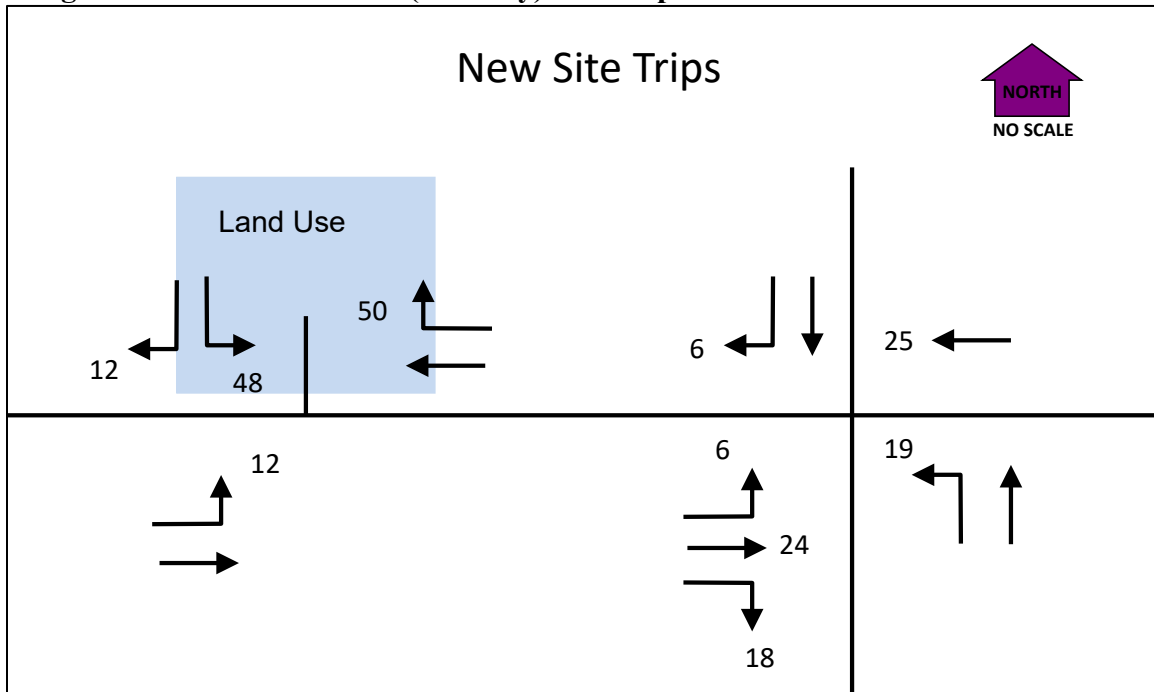
Example 6-4 Trip Assignment

The assignment of new (primary) trips for each turning movement is calculated by multiplying the previously determined number of directional new (primary) trips (trip generation) by the new (primary) distribution percentage applicable to that movement.

Sample calculation for eastbound to northbound left turn movement at the nearby intersection:

        This movement is outbound from the site.
        Trip generation of outbound new (primary) trips = 60
        Trip distribution of outbound new (primary) trips = 10 percent
        Trip assignment = 60 x 0.10 = 6 PM peak hour new (primary) site trips

Assignment of PM Peak New (Primary) Site Trips

The assignment of pass-by trips for each turning movement is calculated by multiplying the previously determined number of directional pass-by trips (trip generation) by the pass-by distribution percentage applicable to that movement.
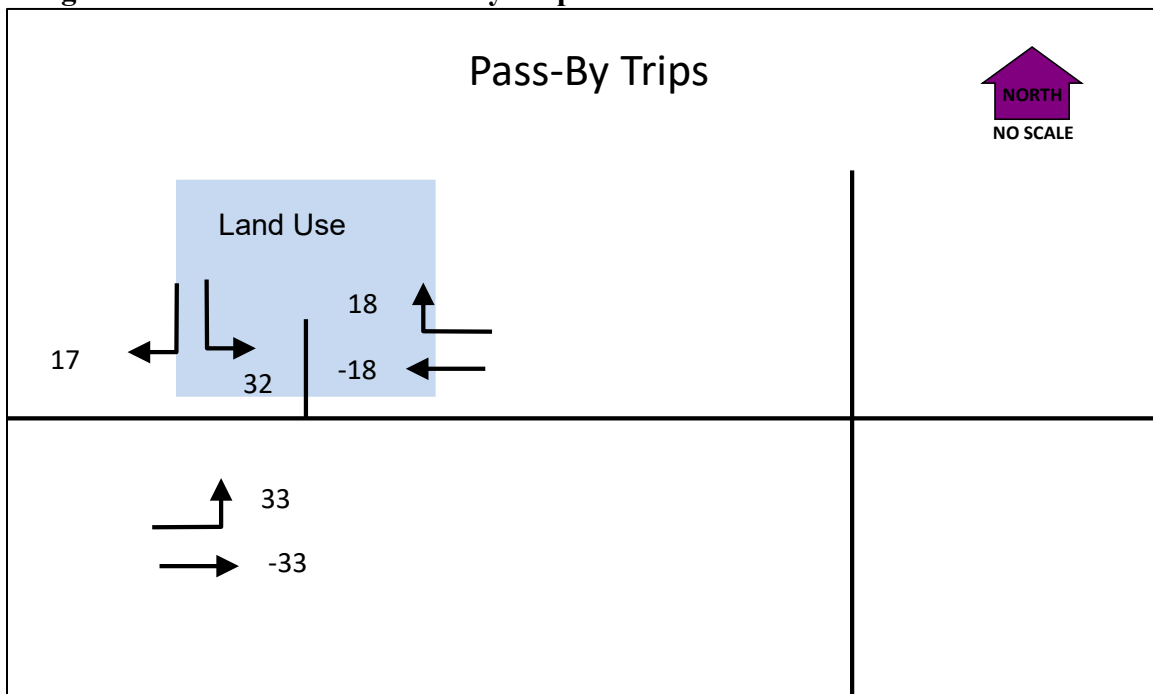
Sample calculation for westbound right turn movement from the adjacent roadway onto the site driveway:

> This movement is inbound to the site.
> Trip generation of inbound pass-by trips = 51
> Trip distribution of inbound pass-by trips = 35 percent
> Trip assignment = 51 x 0.35 = 18 PM peak hour pass-by site trips

> Note that at the intersection of the adjacent roadway with the site driveway, through movement pass-by trips will have negative values, since they turn into the site instead of traveling through.

> Also note that beyond the site driveway intersection, pass-by trips are zero. Pass-by trips do not add new trips to the system; they only change turning movement volumes at the site driveway(s).

Assignment of PM Peak Site Pass-by Trips

The assignment of diverted linked trips for each turning movement is calculated by multiplying the previously determined number of directional diverted linked

trips (trip generation) by the diverted linked distribution percentage applicable to that movement.

Sample calculation for northbound to westbound left turn movement from the non-adjacent roadway to the adjacent roadway:

> This movement is inbound to the site.
> Trip generation of inbound diverted linked trips = 51
> Trip distribution of northbound diverted linked trips = 57 percent
> Trip assignment = 51 x 0.57 = 29 PM peak hour diverted linked site trips

> Note that at the intersection of the non-adjacent roadway with the adjacent roadway, northbound and southbound through movement diverted linked trips will have negative values, since they turn onto the adjacent roadway instead of traveling through.

Assignment of PM Peak Diverted Linked Trips

Diverted Link Trips
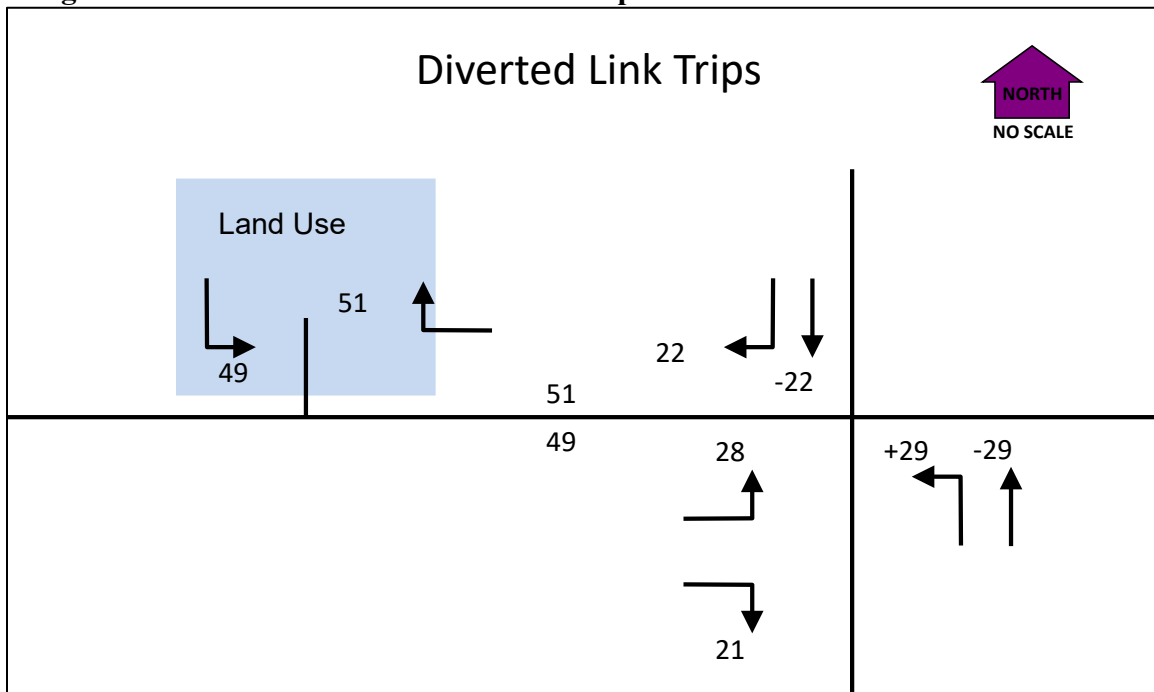
Each of the components of site trips are then summed for each vehicle movement and displayed in a flow diagram of total site trips as shown below.

PM Peak Total Site Trip Assignment

Total Site Trips

NORTH
NO SCALE

Land Use

29
128
118
-18

28
-22

25

45
-33

33
24
38

47   -29
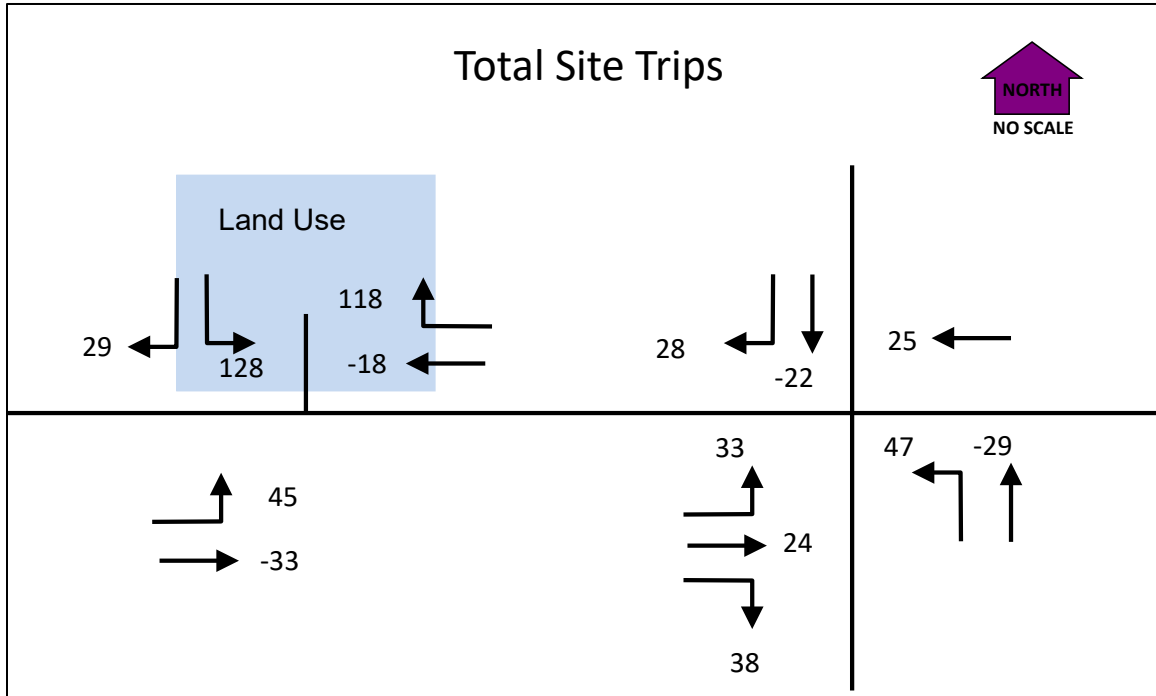
The total site trips are then combined with Background Traffic to create Background plus Site trips as shown below.

PM Peak Total Trips (Background + Site)

6.9 Travel time-based Trip Assignment (Optional; For any cumulative analysis)

Traffic distribution to and from a future development is assigned to specific roadways either manually or using a travel demand model for larger studies (see Section 6.10, Chapter 17, and the Modeling Procedures Manual for Land Use Changes (MPMLUC) - February 2012).

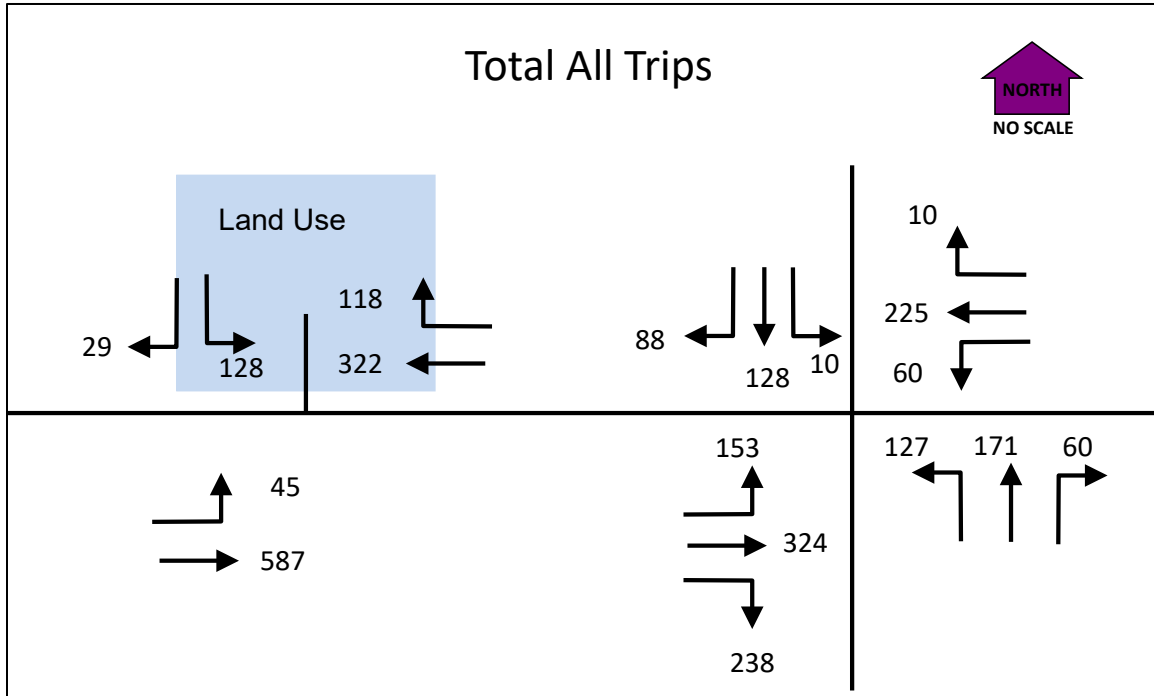Future development trip assignment is often made based on shortest path distance or travel time. Shortest path travel time in some cases may be approximated using segment lengths and posted speeds. However, this method does not account for intersection delay, which can be a significant component of total travel time in some situations. The following methodology identifies path travel times inclusive of intersection delay.

In this method, for a specified origin and destination, competing O-D paths are evaluated iteratively by assigning trips, calculating resulting nodal delay values, computing overall travel times, and repeating the process until the competing paths have roughly the same travel time. It should generally be assumed that if travel times are within 20%, there will be some split of the site trip assignment. If the travel time difference exceeds 20%, all of

the site trips can generally be assigned to the shortest travel time path. If the travel time difference is less than 10%, an equal split of site trips can be assumed. The end result is the number of site trips assigned to each route.

Travel time on the paths is the sum of the travel time on links, based on link distance and posted speed, and control delay at intersections, based on deterministic analysis results such as using HCS or Synchro. Note that this method assumes relatively uncongested conditions.

Analysis Steps

1. Develop background traffic volumes.
2. For the initial site assignment, assign 100% of site trips to the shortest distance path.
3. Add the site trip assignment in Step 2 to the background volumes to obtain initial Total Traffic volumes.
4. For each alternative O-D path and direction (inbound or outbound from the site) being studied,
   a. Calculate segment travel times using posted speed and link lengths.
   b. Using initial Total Traffic volumes, apply HCM 2010 methodology to calculate delays for the movements along the path that pass through stop-controlled or signalized intersections.
   c. Sum the segment travel times and delays from Steps 2a and 2b to determine the total travel time for each path. Identify the path with the shortest travel time.
   d. If the shortest distance path travel time is significantly shorter than the next competing path, the site trip assignment is complete (100% of site trips are assigned to the shortest distance/travel time path).
   e. If the shortest distance path travel time is close to or greater than the travel time of the next competing path, further iterations are required.
5. Re-assign some proportion of the site trips to the shortest travel time path identified in step 2c. Using this site trip assignment, sum with Background Traffic to develop second iteration Total Traffic volumes.
6. Repeat Steps 2b and 2c using the revised iteration of Total Traffic volumes developed in Step 5b. Incrementally re-assign a proportion of site trips until each path is equal in travel time. The site trip assignment is then complete.

The following example illustrates this method.

Example 6-5 Estimating Trip Assignment Based on Travel Time

A land development is proposed near a state highway. The site is located near the unsignalized intersection of Main Street at Oak Street, as shown below. There are two potential paths for outbound site trips from the development onto the highway in the westbound direction. By inspection, the shortest distance path is ABC. This requires site trips to turn left at the intersection of Main Street at Oak Street, an unsignalized two-way

stop controlled intersection. The stop-controlled left turn movement at this intersection experiences high delay. The alternate path, ADEC, is less direct. However, this path has less intersection delay where it accesses the highway at the signalized intersection of Maple Street and Main Street.

It is desired to assign the outbound site PM peak hour trips such that either path will provide an equal travel time from the development.

Site Vicinity Diagram
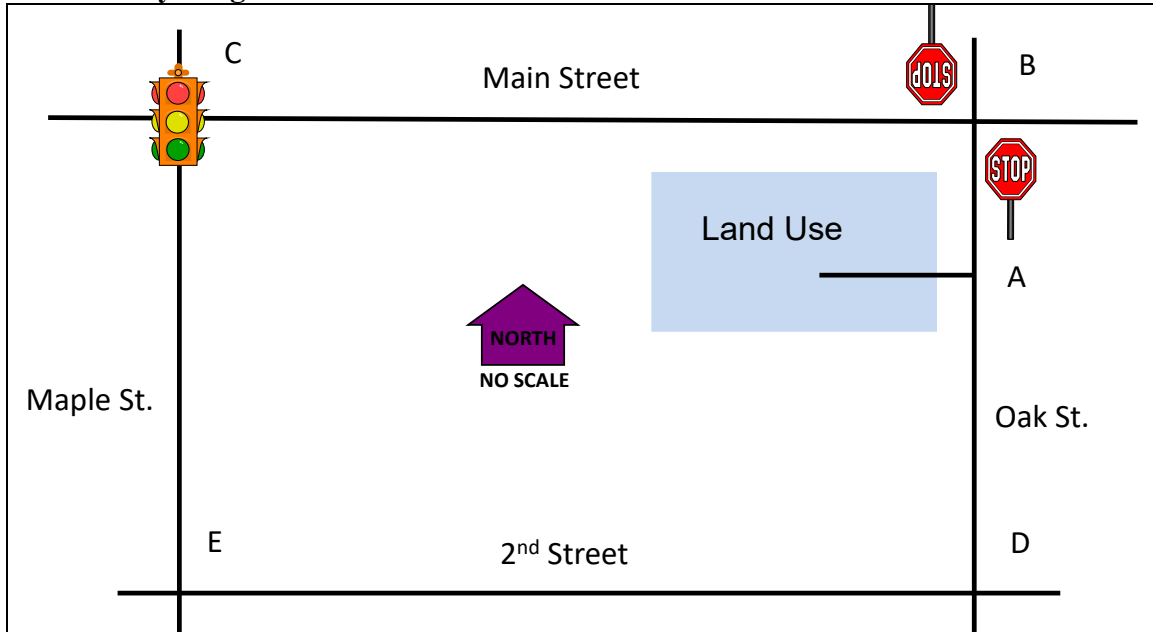
Step 1. For the purpose of this exercise it is assumed that background traffic volumes have been previously developed.

Step 2. Site trips are initial assigned 100% to the shortest distance path, ABC.

Step 3. The initial site trip assignment from Step 2 is added to Background Traffic from Step 1 to create Initial Total Traffic volumes.

Step 4a. Link lengths and posted speeds are obtained and shown in the next figure below. Link lengths are typically measured from aerial photos and posted speeds collected from a field visit.

Link Lengths and Posted Speeds
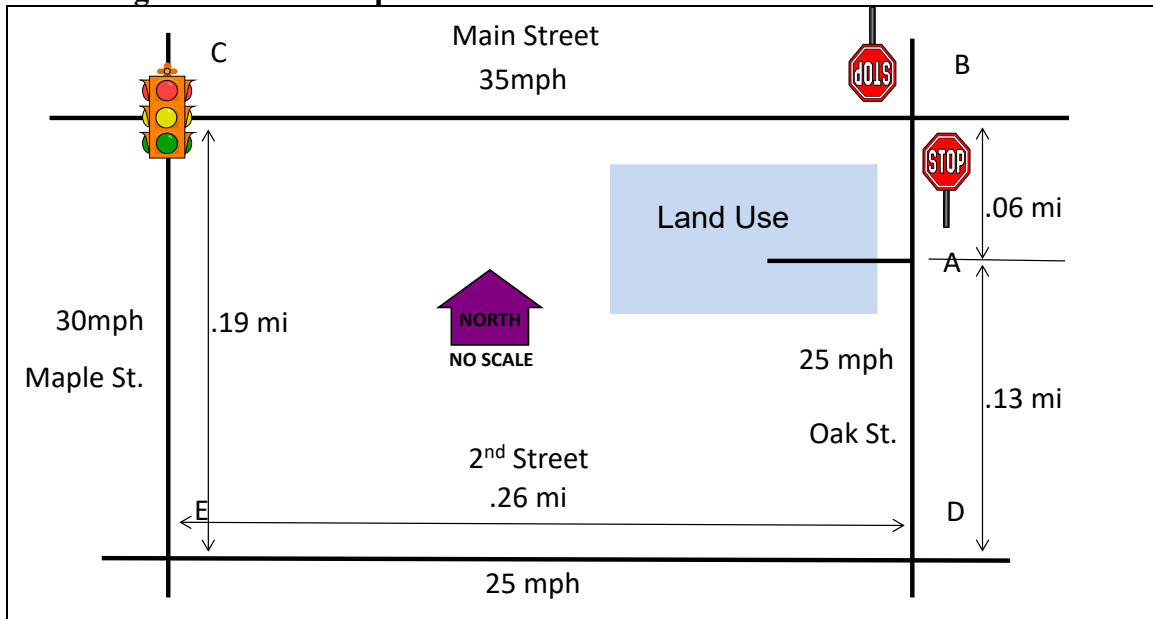
Segment travel times are calculated as follows, using sample segment BC.

$$\text{Travel Time Segment BC} = \frac{0.26 \text{ mi}}{35 \text{ mi/hr}} \times \frac{3600 \text{ sec}}{\text{hr}} = 26.7 \sim 27 \text{ sec}$$

Travel times for each segment are summarized in a table:

Roadway	Segment	Segment Travel Time
Oak St	AB	9
Main St	BC	27
Oak St	AD	19
2nd St	DE	37
Maple St	EC	23

Origin-destination (O-D) path segment travel times are calculated by summing the segment travel times.

O-D Path ABC   = AB + BC = 9 + 27 = 36 sec
O-D Path ADEC = AD + DE + EC = 19 + 37 + 23 = 79 sec

Step 4b. For the purpose of this exercise, assume that HCM intersection analysis has been previously conducted for background volumes, resulting in the following intersection delays. Please note that the delay values in this example are for illustrative purposes only and are not actual HCM-calculated values. For this example, it is assumed that delay at other intersections along each path is negligible.

Background Traffic Movement Delay

Intersection	Movement	Movement Delay (s)
Main St at Oak St	South to West left turn	44
Main St at Maple St	Westbound through movement	14
Main St at Maple St	South to West left turn	21

Intersection movement delays are summed for each O-D path

> O-D Path ABC = 44 + 14 = 58 sec
> O-D Path ADEC = 21 sec

Step 4c. Segment travel times and delays are summed to determine the total travel time for each path.

O-D Path	Segment Travel Time (s)	Intersection Delay (s)	Total Travel Time (s)
ABC	36	58	94
ADEC	79	21	100

The O-D path with the shortest travel time is path ABC.

Step 3. Site trips are assigned 100% to the shortest path ABC.

Step 4. The site trip assignment in Step 3 is added to the background volumes to obtain initial Total Traffic volumes.

Step 5. HCM methodology is applied to re-calculate intersection delays based on Total Traffic volumes.

Total Traffic Movement Delay (First Iteration)

Intersection	Movement	Movement Delay (s)
Main St at Oak St	South to West left turn	58
Main St at Maple St	Westbound through movement	16
Main St at Maple St	South to West left turn	24

Intersection movement delays are summed for each O-D path

> O-D Path ABC = 58 + 16 = 74 sec
> O-D Path ADEC = 24 sec

Segment travel times and delays are summed to determine the total travel time for each path.

O-D Path	Segment Travel Time (s)	Intersection Delay (s)	Total Travel Time (s)
ABC	36	74	110
ADEC	79	24	103

At this point, the shortest path based on travel time is now path ADEC. Since path travel times are close, the next iteration would be to assign some of the site trips to path onto path ADEC. Step 5 is then repeated. When path travel times are approximately equal, the site trip assignment is complete.

6.10 Zonal Cumulative Analysis

In quick growing areas or for entire cities, where a more accurate analysis is needed of the impacts (differing growth and trip patterns across the study area), the zonal cumulative analysis process should be used rather than the first-level TIA-level cumulative analysis. The zonal cumulative analysis process is essentially a manually-constructed travel demand model. The process includes the major three modeling steps (trip generation, trip distribution, and trip assignment). The major difference between the zonal cumulative and a travel demand model is that the zonal cumulative uses ITE trip generation instead of population and employment, and projects the incremental growth in trips rather than creating separate base year and future year assignments. Generally, this level of effort is too complex for a TIA.

Like with other cumulative analyses, the zonal cumulative method should be limited to cities of 10,000 or less population or a chunk of no more than 10,000 of a larger urban area. Areas larger than these can theoretically be done, but the number of zones and network size becomes overwhelming to do manually. In addition, anywhere multiple analyses (TSP, corridor or refinement plans, projects) are likely in the near (5-10 year) future then construction of a travel demand model should be considered (refer to Chapter 17). Re-purposing a zonal analysis for another project can be more time consuming than just building a travel demand model initially. These larger areas would require the enhanced zonal cumulative analysis process shown in Section 6.11 or use of a travel demand model as discussed in Section 6.12 and Chapter 17.

The basic steps for a zonal cumulative analysis are:
1. Identify the study area and divide into transportation analysis zones (TAZ)
2. Identify vacant lands, in-process developments, comprehensive plan allowed land uses/densities, and development rates.
3. Estimate future trip generation potential
4. Determining the through trip percentages (external – external, E-E) and E-E trips for the external stations
5. Determining the internal – external (I-E) and external –internal (E-I) trips at each external station (external zone)

6. Determining the trip distribution for the internal – external (I-E) and external – internal (E-I) trips for each internal TAZ.
7. Determining the trip distribution for internal-internal (I-I) trips
8. Calculating network link travel times
9. Assigning total trips to the network

The above process is setup for multiple traffic assignments based on a single land use scenario. Doing an additional land use scenario would require repeating of Steps 3-9 or using the more-automated enhanced zonal cumulative analysis. Use of software such as Vistro and its predecessor, Traffix, may help streamline the accounting of generated trips and the distribution/assignment of them if the network and land uses assumed are not too complex.

6.10.1 Step 1 – Identification of Study Area and TAZ's

The study area should completely cover the project limits and all adjacent land areas that would affect the project area. The study area should be defined such that all relevant facilities are included, since there may be other roadways that could directly influence the traffic patterns on the facilities being analyzed. The location where each relevant roadway facility crosses the outside edge of the study area needs to be noted as an "external station." The external station is where traffic enters/exits the study area and can also be considered an external zone. The study area needs to be broken into homogenous land-use zones (i.e. residential, commercial, or industrial) called transportation analysis zones (TAZ). There generally is no need to break the land use into further sub-categories (i.e. low vs. medium density residential). If zones are not completely homogenous, there will need to be additional accounting of internal trips between residential and commercial for example as there will be trips generated that will never extend beyond the zone boundaries.   It is likely that a Geographic Information Systems (GIS) land-use or tax-assessment file is available from the local city or county that will be of great assistance and streamlining of this and the following tasks.

Each TAZ boundary generally needs to follow physical or man-made boundaries. This would include rivers, railroads, and major roadways. Property lines generally break on these major features, and the GIS file can be used to help ensure that the TAZ boundaries do not cross or break up properties.

Example 6-6 Study Area and Zone Identification

This example is based on an actual zonal cumulative analysis done for the US97/South Century Drive project in the Sunriver resort area south of Bend. The overall project area is shown in the figure below. The study area reflects the area that would feed into South Century Drive and eventually to US97. Areas to the south of the project area would most likely feed into the next major road to the south (LaPine State Recreation Road) or into the City of LaPine.

TAZ's were split on land use or on natural or man-made boundaries. Examples for land use:

- Zone 1 is the current Sunriver resort development and is generally residential.
- Zone 2 is the existing Spring River residential subdivisions
- Zone 9 is vacant Forest Service forest lands (although zoned for resorts).
- Zone 10 is the Sunriver business district and is generally commercial uses.
- Zone 12 is the Crosswater resort/golf course

TAZ zone boundary splits examples:

- The Deschutes River forms the boundaries between Zones 1 and 2 and Zones 3 and 4.
- The Little Deschutes River forms the boundary between Zones 5 and 6.
- The BNSF railroad tracks forms the boundary between Zones 7 and 11.
- South Century Drive forms the boundaries between Zones 1 and 10, Zones 12 and 9, and between Zones 6 and 7.

Study Area Zones
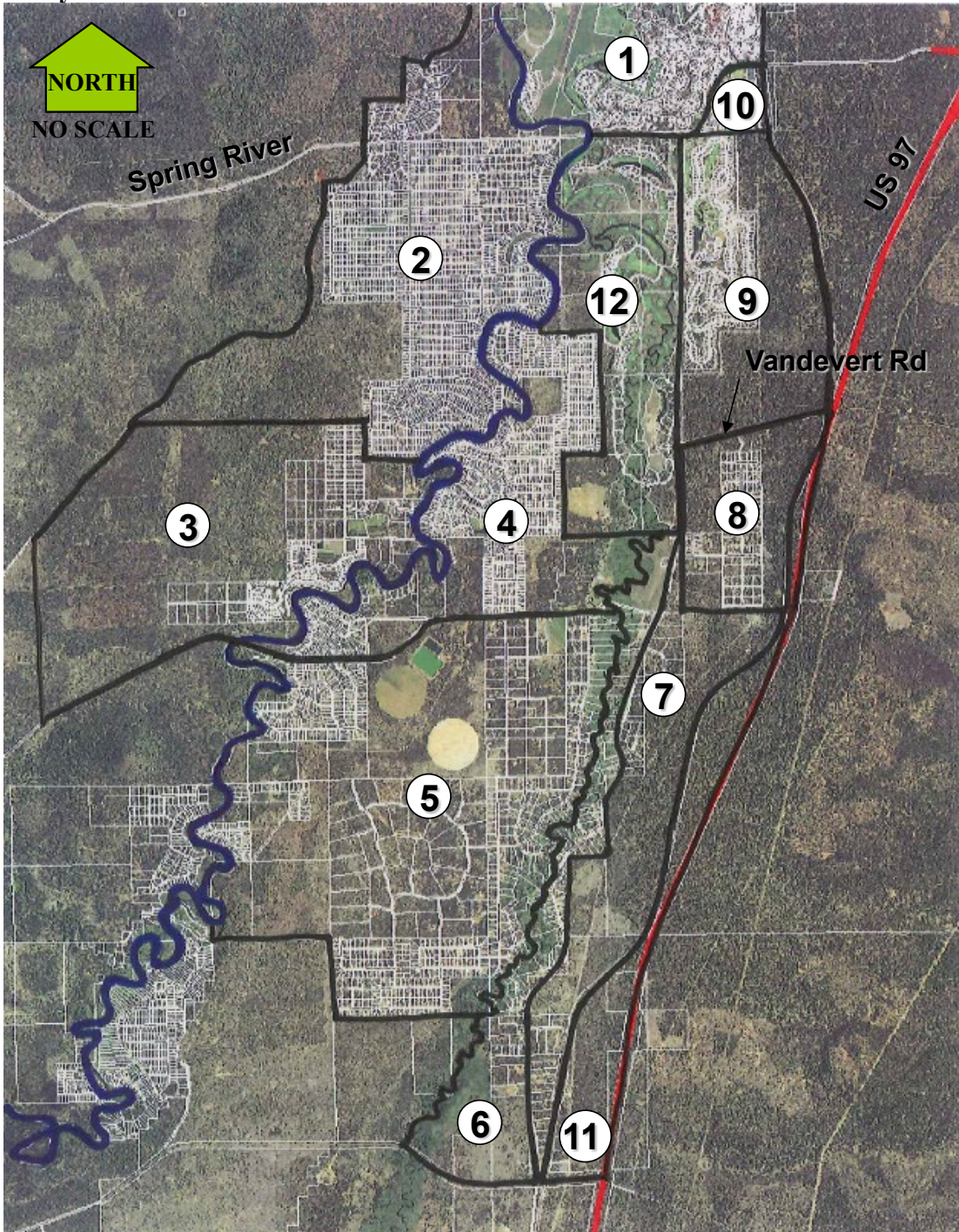
6.10.2 Step 2 – Identification of Land Use Characteristics and Zoning

After the homogenous TAZ's have been developed, all of the land use characteristics and related zoning needs to be identified. This will create the parameters necessary for

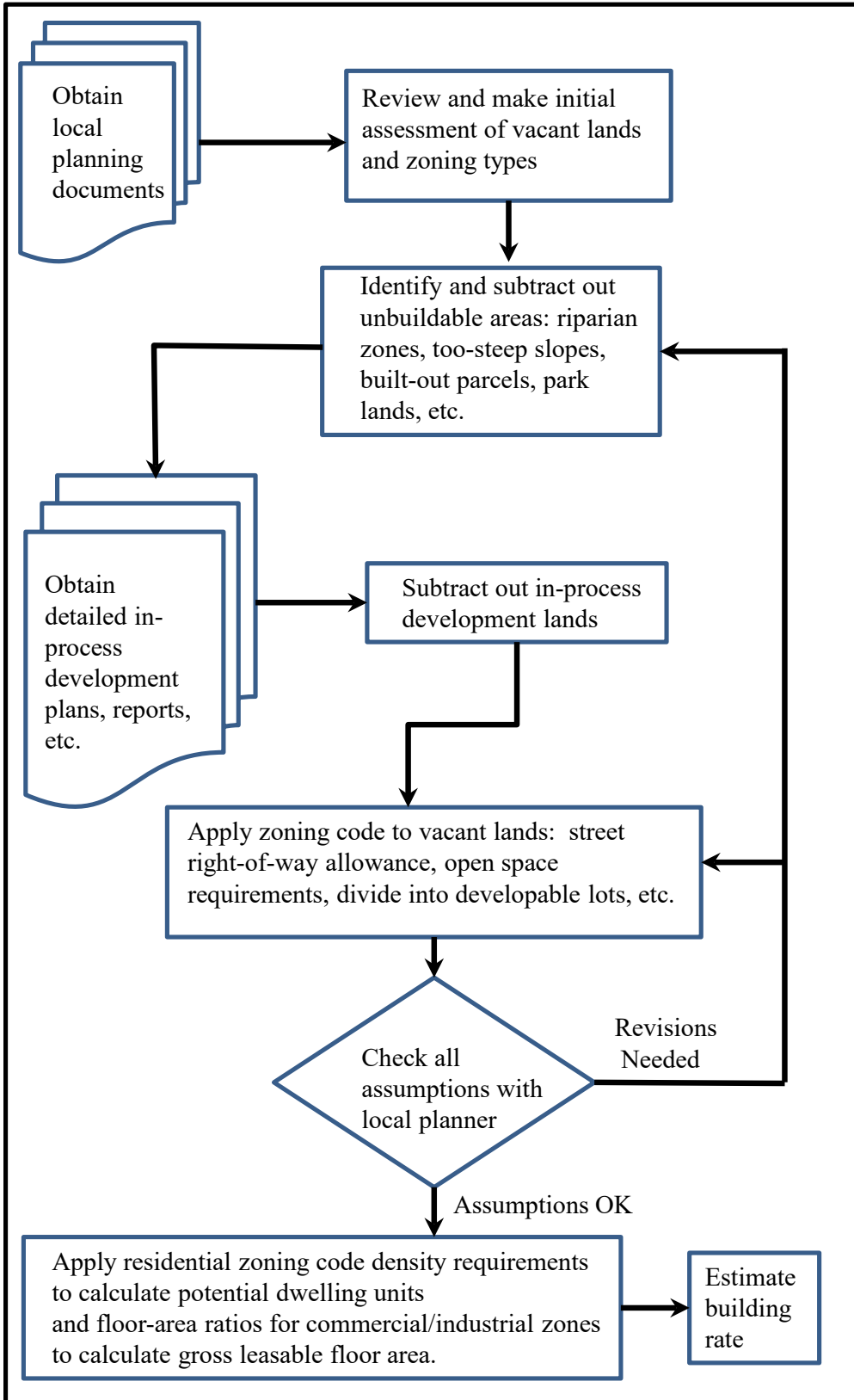estimating the future trip generation in Step 3. The zonal cumulative process assumes that the traffic counts (and the resulting 30 HV) obtained for the study area account for all built properties. The main focus of the process is to determine the total change from the base to the future condition. Areas that are vacant or partially built will need additional data to help determine the future growth potential. Exhibit 6-3 shows the process for determining the TAZ land use data for vacant lands.

Vacant Lands

For each TAZ, any vacant buildable lands need to be identified. This can be facilitated by obtaining the following items:
- Buildable Lands Inventory (BLI) – Not every study area will have an applicable BLI available, but when available, they will limit the amount of data needed. The BLI will specifically identify buildable areas that can be coordinated directly with the study area TAZ's. Detail levels vary but at a minimum, the truly developable vacant lands can be determined. The BLI will help identify areas that are not suited for future development such as wetlands, riparian zones, flood plains, steep slopes, resource areas, etc. The BLI needs to be relatively recent (no more than 3-5 years old for normal growth areas but longer periods might be okay for slow growth areas).
- Comprehensive Plan, Zoning Map and Code – Obtaining the comprehensive plan, zoning map and zoning code is the minimum information needed in order to do a zonal cumulative analysis. The comprehensive plan and related zoning code (see Exhibits 6-4 and 6-5.) will tell what the allowed (permitted outright and through the conditional use permit process) uses are, and lot requirement details such as minimum/maximum sizes, development densities, building heights, floor-area-(coverage) ratios, green/open space requirements, etc. The zoning map allows for easy identification of where the different zoning is applied (see Exhibit 6-6). Generally, land uses should be limited to outright permitted uses only as there is no guarantee that a conditional use would be granted. Exceptions need to have concurrence with the local planning staff.
- GIS-based land-use/property/tax assessor's database – If available, a GIS-based property database will greatly streamline the identification of zoning and whether a property is vacant. These databases generally include, location, tax-lot numbers, zoning, acreage, ownership, improvements (structures), and year of improvement (building permit issued). Use of GIS allows the properties to be grouped by TAZ.

Exhibit 6-3 TAZ Land Use Data Process

Obtain local planning documents

Review and make initial assessment of vacant lands and zoning types

Identify and subtract out unbuildable areas: riparian zones, too-steep slopes, built-out parcels, park lands, etc.

Obtain detailed in-process development plans, reports, etc.

Subtract out in-process development lands

Apply zoning code to vacant lands: street right-of-way allowance, open space requirements, divide into developable lots, etc.

Check all assumptions with local planner

Revisions Needed

Assumptions OK

Apply residential zoning code density requirements to calculate potential dwelling units and floor-area ratios for commercial/industrial zones to calculate gross leasable floor area.

Estimate building rate

- Transportation System Plan (TSP) – Newer TSP's may show environmental baseline information such as wetlands, park lands, greenways, historic properties, etc. that can be used to further identify non-buildable areas (especially if a BLI is not available). The TSP will also show future road improvements that can be used to modify the road network.
- Other land-use plans – These cover a wide range of planning maps such as subdivision plats and development master plans that can identify in-process or future developments. Certain areas may not have BLI's so park plans, school district plans, wetland plans, park plans, and other plans of this type fall into this category. All of these can be used for identification of future growth potential. Contacting the local planning office is the best source for this information.
- Current aerial photos – If current aerial photos are available, identification of vacant lands can be easily done with a GIS database or comprehensive plan. However, use of aerials can be a potential pitfall if the aerial has not been verified to be recent. Please note that commercial aerial mapping such as Google Maps could be 3-5 years out of date and is not recommended to be used (unless extensively field-verified) for this process.

Exhibit 6-4 Urban Standard Residential Zone Excerpts

(1) Purpose. The RS Zone is intended to provide for the most common urban residential densities in places where community sewer services are or will be available and to encourage, accommodate, maintain and protect a suitable environment for family living.

(2) Permitted Uses. The following uses are permitted:

    (a) Single-family dwelling.

    (b) Agriculture, excluding the keeping of livestock.

    (c) Rooming and boarding of not more than two persons.

    (d) Home occupations subject to the provisions of Subsection (15) of Section 25.

    (e) Park rehabilitation, minor betterment and repairs.

    (f) Accessory dwelling in a subdivision or Planned Unit Development (PUD) approved after December 2, 1998, provided that overall density in subdivision or PUD does not exceed 7.3 dwelling units per gross acre.

(5) Lot Requirements. The following lot requirements shall be observed, provided that the approval authority may allow smaller lots of different housing types in a new subdivision or Planned Unit Development (PUD) approved pursuant to this ordinance and consistent with the Comprehensive Plan designations for preservation of areas of significant interest when these lots or housing types are internal to the subdivision or PUD.

    (a) Lot Area: A lot in a subdivision or planned unit development approved after (date of adoption) shall have a minimum area of 4,000 square feet provided that the overall density does not exceed 7.3 dwellings gross per acre, and provided that where new subdivisions abut lots of 20,000 square feet or less the exterior lots shall be at least 75% of the abutting lot sizes and lot lines or be approved through a hearing process. All other lots shall have a minimum area of 6,000 square feet.

Exhibit 6-5 Mixed Employment Zone Excerpts

(1) <u>Purpose</u>. The zone is designed to provide for a mix of uses such as office, retail, services, light manufacturing and warehousing that offer a variety of employment opportunities in an aesthetic environment and having a minimal impact on surrounding uses.

(2) <u>Permitted Uses</u>. The following uses are permitted in the ME Zone subject to the provisions of Design Review and Site Plan review in Section 23 and Section 23 A.

    (a) Automobile and truck repair and service, provided wholly within an enclosed building.

    (b) Automobile, truck, and recreation vehicle sales of new vehicles, including service facilities and outdoor storage of vehicles.

    (c) Bakery for wholesale and retail distribution.

    (d) Banks, savings and loan institutions, credit unions and other financial institutions.

(4) <u>Height Regulations</u>. No building or structure shall be hereafter erected, enlarged or structurally altered to exceed a height of 45 feet, without a Conditional Use Permit approval.

(5) <u>Lot Requirements</u>. The following lot requirements shall be observed:

    (a) Lot Area: Each lot shall have a minimum area of 6,000 square feet.

    (b) Lot Width: No requirements.

    (c) Lot Depth: Each lot shall have a minimum depth of 100 feet.

    (d) Front Yard: The front yard setback area shall be a minimum of 10 feet.

    (e) Side yard: None except a side yard setback area shall be a minimum of 15 feet when abutting a lot in a residential zone.

    (f) Rear Yard: None except a rear yard setback area shall be a minimum of 15 feet when abutting a lot in a residential zone.

    (g) Lot Coverage: The maximum lot coverage by buildings and structures shall be 50 percent of the total lot area.

(6) Off-Street Parking and Loading. Off-street parking and loading space shall be provided as required in Section 24.

The first step to obtaining any of the above is to get in contact and establish a good relationship with the local planning office or local planner. They will know all of the details, recent and past development history, insight on building rates and typical/likely growth patterns. You will need to have them review your development assumptions that you make, vacant lands, and growth potential to make sure that the analysis is reasonable before moving on to more detailed steps.

Once the unbuildable areas have been identified, then any in-process developments need to be identified. Contact the local planning office and ask about any approved but not yet built residential or commercial developments. Obtain documentation such as plats, site plans, or transportation impact analyses (TIA) describing the development. The total number of lots, units, or square footage needs to be noted for the later trip generation calculations. These developments need to be subtracted from the total vacant land to determine the truly vacant buildable land available for future growth.

Exhibit 6-6 Sample Comprehensive Plan (Zoning) Map
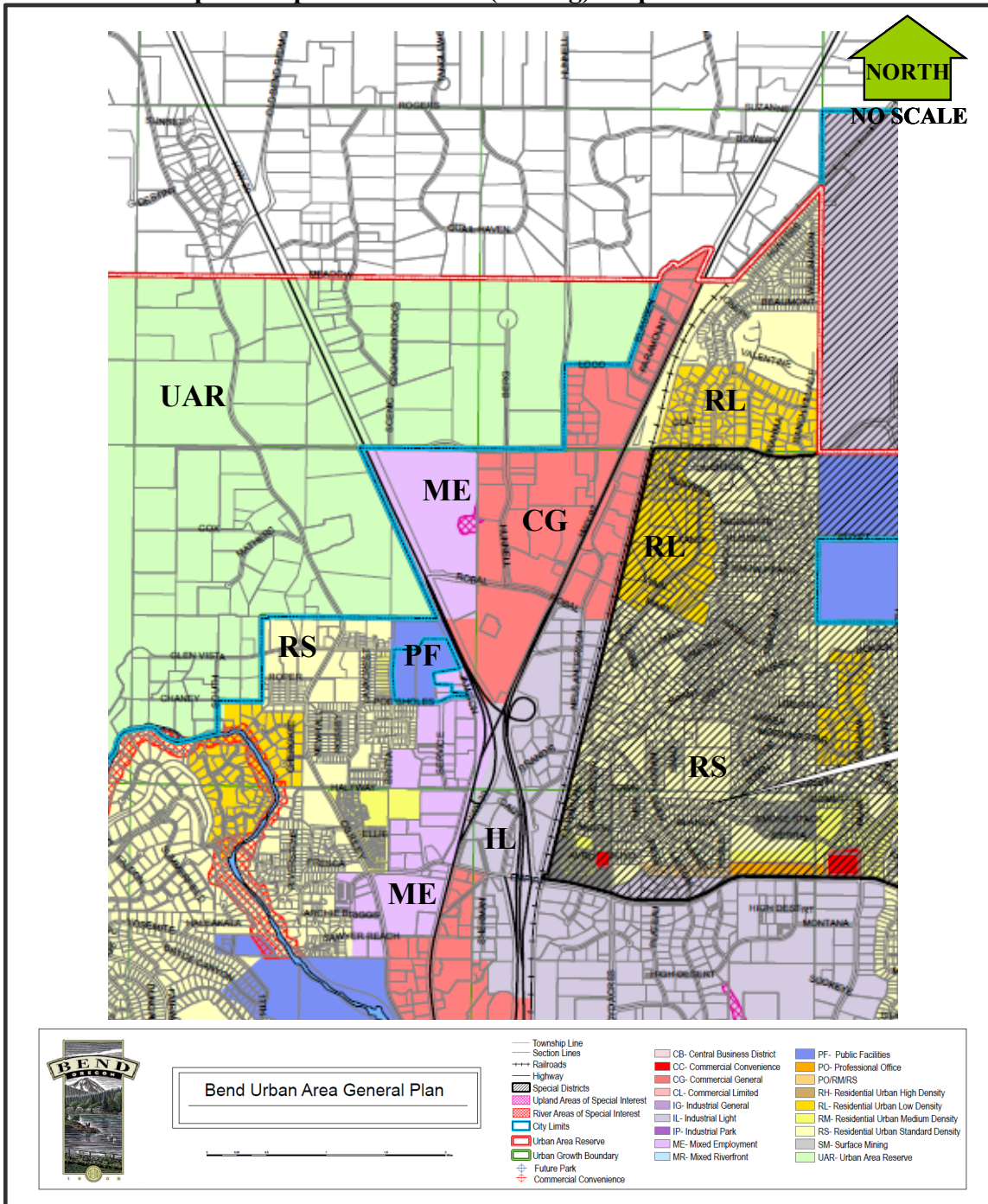
Estimating Potential Future Land Use

At this point, the remaining vacant land would be available for future development but is not planned as such. For each TAZ and/or parcel clumps within a TAZ, the zoning code requirements need to be applied.

For residential lands, there will be likely minimum lot sizes or minimum/maximum dwelling unit per acre requirements. A good way to judge what these might be is to take a

GIS-based survey of adjacent similarly-zoned single-family home subdivisions and figure out a typical lot size (this is one of those assumptions that the local planner should review for reasonability). About 24% of vacant residential lands should be reserved for local street right-of-ways. The zoning code may indicate additional specific values for green or open space requirements that will need to be accounted for. Buildable residential lands then would be calculated by subtracting the local street and green space requirements from the total land area and then dividing by the typical lot size to determine the number of single-family dwelling units for each TAZ.

Multi-family residential lands such as apartments, condominiums or townhouses need to be figured on a dwelling units per acre basis. The zoning code should tell the range of acceptable densities regardless of building heights. GIS can be used to help determine a typical value by surveying similarly-zoned areas in the local area. The local planning office should be able to give some guidance in this area. Once a typical dwelling unit per acre value is determined then this can be directly multiplied by the vacant buildable multi-family lands to determine the total amount of multi-family dwelling units. The final value may need to be summed from multiple parcels depending on how these lands are spread around in a single TAZ.

Non-residential (commercial/industrial) lands are generally figured on a parcel basis as parcels are generally large. Zoning codes typically use floor-area-ratios (FAR) for determining maximum lot coverage. The typical FAR range is between 25 and 35% of the lot size which covers green/open space, access roads and parking. For denser areas or industrial areas, height requirements may allow more than a single story which would allow more square footage for the maximum lot coverage. However, if maximum square footage requirements are shown, then these apply to the total of all floors. Multiplying the lot size by the FAR or using the maximum square footage per parcel will determine the maximum potential gross leasable floor area. Commercial and industrial lands need to be kept separate as trip generation multipliers will be different.

Example 6-7 Estimating Future Buildable Land Use

For a particular TAZ, there are 100 acres of vacant buildable zoned RM (medium-density single family residential) land. The zoning code indicates that lot sizes are to be 5,000 square feet at a minimum. A survey of recently completed subdivisions in the area shows that the average lot size is about 6,000 square feet. This particular TAZ is covered by additional provisions that require 10% of the total development to be common open space. This TAZ also has 5 acres of neighborhood commercial at a maximum FAR of 35%.

Deduct the common open space from the total land area = 100 ac – 100 ac x 0.10 = 90 ac.

Subtract out the typical 24% allotment for local streets = 90 ac – 90 ac x 0.24 = 68.4 ac

Calculate the total number of potential dwelling units = (68.4 ac x 43,560 sq ft/ac) / 6,000 sq ft = 496.6 = 496 lots (need to round down).

Calculate the commercial maximum gross leasable floor area = 5 ac x 0.35 x 43,560 sq ft/ac = 76,230 sq ft = 76, 200 sq ft.

Building Rates

Typically at this point a spreadsheet is setup by TAZ showing the potential dwelling units for residential and square footage for commercial or industrial areas. These TAZ totals represent build-out which may or may not occur within the study horizon (future or design year). Some TAZ's will be currently mostly built out, so it may only take a few years to reach build-out while other TAZ's are vacant and build-out may be over 40 or more years. Faster growing areas (i.e. Central Oregon) will take less time than historically slower growing areas (South Coast).

For each land use type within each TAZ, a building rate needs to be calculated. This aspect of the zonal cumulative method can be one of the most difficult to obtain accurately. The best way to help determine this is to use a GIS-based tax assessor's database to group properties by TAZ and to indicate in which year an improvement occurred. Non-GIS spreadsheets/databases can also be used, but these will require visual matching of tax- lots with the TAZ's. An alternate source is to use issued building permits assuming that these are available for at least the last 10 years. These values can be plotted over the long-term to determine a curve or best-fit regression line to determine a rate of growth. The rate curve will be the best with a good amount of data points covering at least 10 or more years. Another method is to take the total amount of improved lots divided by the number of years those improvements represent to get an average historical building rate.

There may be areas with little or no historical growth, so these should be estimated by using nearby areas with similar characteristics. If an area is relatively homogenous (i.e. all residential) then the building rates could be simplified to a few or a single area-wide value. Commercial or industrial areas building rates could be simplified to a few or a single value depending if the characteristics are similar. Keep in mind that if there are a lot of in-process developments, these may skew the historic building rate. Any of these results need to be tempered by the advice of the local planner on the historic or future building rates. At a minimum, there needs to be a single building rate for each land use type used. If a database or permits are not available or available for enough years, then the application of this method becomes difficult at best and the enhanced zonal cumulative method should be used. The enhanced zonal cumulative method uses explicit base and future models and is less concerned with a historical building rate.

Example 6-8 Historical Building Rate

Within a residential TAZ, there are a number of subdivisions that were ready for development in the year 2000. These subdivisions made up a total of 400 lots. The future

year for this analysis is 2030. From the county tax assessor's database the following data were obtained from 2000 to 2010:

Year	Number of Permits Issued
2000	20
2001	27
2002	6
2003	4
2004	22
2005	42
2006	37
2007	9
2008	0
2009	0
2010	3

From a review of the data, it is apparent that growth was relatively unsteady and that a regressed trend would not give a good predicted rate. The residential area has the same general characteristics so an average TAZ historical rate is probably the best method.

From 2000 to 2010 a total of 170 lots had building permits issued. This equates to 170 lots / 11 years = approximately 15 lots per year

This TAZ was not built out in 2010 with 170 of the 400 total built. There are 400 – 170 = 230 vacant lots remaining. With a 15 lots / yr rate, this TAZ would be built out in 230 lots/15 lots per yr = approximately 15 years or 2025. Since the future year is 2030 we would use the maximum potential 230 new lots in the analysis.

6.10.3 Estimating Future Trip Generation

At this point, the land uses for each TAZ have been calculated. Use the ITE Trip Generation manuals or Trip Generation software to compute the increase in peak hour trip generation potential for each TAZ as per Section 6.6. Use major ITE land uses (i.e. shopping center, office park, apartments, etc.) that have ideally equations or reasonable data points. For each land use, make sure to specify the split between the entering and exiting trips. Depending on zone structure and land uses, commercial trips should be primary (new trips on the system) trips, unless there is not enough background traffic to accommodate the potential pass-by trips. Trip generation documentation should be in a spreadsheet form.

**Example 6-9 Projected Trip Generation**

A zonal cumulative analysis was performed for a growing rural residential community along a state highway. This example study area will be used throughout the rest of this section. The study area was split into four zones (1-4). The number of vacant lots and the building rate were estimated following Section 6.10.2. The current year is 2002 with a project horizon year of 2027. All of the zones except for Zone 2 reach build-out. The trip generation is based on the ITE Trip Generation PM peak single family home rates (Category 210) of 1.01 trips per dwelling unit in the peak hour.

(1) Zone	(2) Vacant Lots (2002)	(3) Building Rate (Homes/yr)	(4) New Homes built by 2027	(5) 2027 Trip Generation Total (Enter/Exit) (vph)
1	537	80	537	542 (349/193)
2	984	30	750	758 (488/270)
3	167	17	167	169 (109/60)
4	640	35	640	646 (416/230)

6.10.4 Trip Types

The total trips in the study area are made up of internal and external trips. External trips are those trips that have at least one end located outside of the study area, as defined by the study area boundary. Internal trips begin and end within the study area. There are four trip types that make up the total trips that are the focus of the next three sections. The trip types are external-external (E-E), external-internal (E-I), internal-external (I-E), and internal-internal (I-I). See Exhibit 6-7.

Exhibit 6-7 External and Internal Trip Types
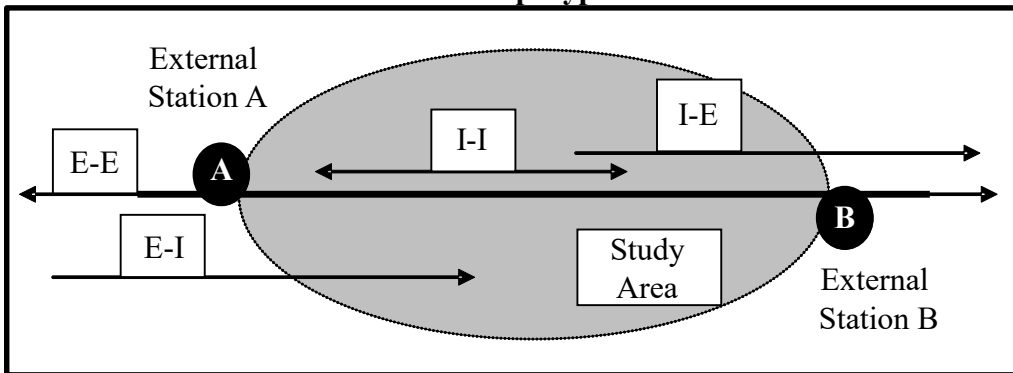
6.10.5 Estimating Through (External-External) Trips

External-external or E-E (through) trips are trips that have both ends (origin and destination) outside of the study area. The E-E trips are the first of the four basic trip types that need to be created from the overall study area volumes. The objective of this

section is to calculate the proportion of E-E trips compared to the total trips and eventually the total E-E trips.

The point where each study area roadway crosses the study area boundary is known as an external station. This point represents the connection to the outside world. The external stations are shown as the black circled "A" and "B" in Exhibit 6-7. External stations are treated essentially as additional zones in this methodology, so number them to not conflict with the TAZ number to avoid confusion. Examples could be using letters (A, B, C…) or a completely different and distinctive number series (500, 501, 502…).

The E-E trips for the base and future years are calculated at each external station. Only roadways with significant volume in the study area should be counted as having external stations. While it is possible to have every local road study area boundary crossing an external station, the complexity of the analysis rapidly increases, the extra work may not be justified, and the necessary detail level needed may not be achievable. Use of origin-destination, license plate matching, or a Bluetooth MAC-address matching study are desired with areas having multiple external stations to simplify finding the E-E trip proportions.
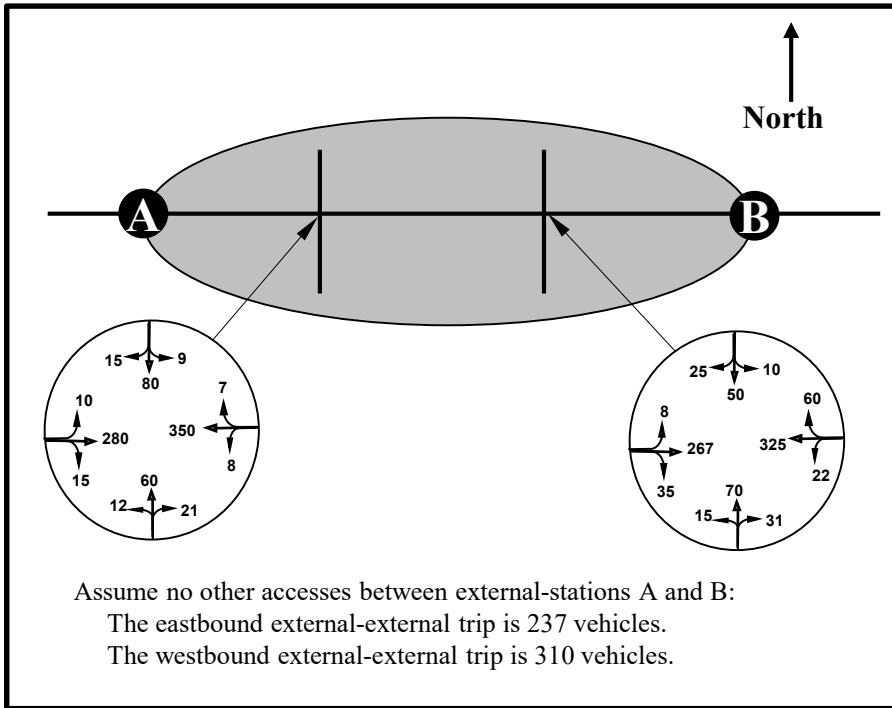
At each external station, the proportion of E-E trips needs to be calculated. This can be obtained directly from an origin-destination or other matching study between each external station pair and for each direction of travel. In most cases, an approximation procedure is necessary to estimate the E-E proportion. Using the directional peak hour (30HV) volumes at an external station, hold that volume and proceed to the other external station by subtracting all turn volumes at each intersection downstream, The remaining volume is the E-E trip volume. This remaining volume is divided by the total directional volume at the external station to determine the percentage of E-E trips. The process is repeated in the other direction and for each external station and for each external station pair (i.e. three external stations: 1-2, 2-1, 1-3, 3-1, 2-3, 3-2).

It is possible to end up with a negative value upon reaching the other external station especially if there are a large proportion of turning volumes compared to the non-turning volume. The turn movements inside the study area are made up of all the trip types so it is possible that large internal-internal trip patterns skew the turning movements to an extent so a negative value is obtained. A negative value indicates a need to investigate the higher local turn movements to see where they are destined to and to make sure that other external trips are not mixing in. For areas with complex trip patterns or a good amount of external stations, some sort of origin-destination study is recommended for all or part of the study area.

Example 6-10 E-E Approximation Process

In the figure below, there are two external stations, labeled A and B representing the roadway as it enters and leaves the study area. The volumes at intermediate study area intersections are shown below. The initial external station volume is determined from the

given volumes. For example, at External Station A, the eastbound volume starts with 305 vph (280 EBT + 10 EBL + 15 EBR) entering the study area.

Assume no other accesses between external-stations A and B:
  The eastbound external-external trip is 237 vehicles.
  The westbound external-external trip is 310 vehicles.

Starting with the first intermediate intersection and proceeding eastbound, the turning volumes are subtracted from the initial 305 vph value. The resulting value is the total E-E trips for the eastbound External Station A movement. This is repeated for the westbound direction.

Total EB E-E trips = 305 – 10 – 15 – 8 – 35 = 237 vph
Total WB E-E trips = 407 – 60 – 22 – 7 – 8 = 310 vph
At External Station A, the total EB trips are 10 + 280 + 15 = 305
At External Station A, the total WB trips are 12 + 350 + 15 = 377
At External Station B, the total EB trips are 31 + 267 +10 = 308
At External Station B, the total WB trips are 22 + 325 + 60 = 407

The External Station A E-E EB trip percentage = 237 / 305 = 0.77
The External Station A E-E WB trip percentage = 310 / 377 = 0.83
The External Station B E-E EB trip percentage = 237 / 308 = 0.77
The External Station B E-E WB trip percentage = 310 / 407 = 0.77

Therefore, there is a 77% chance that trips entering or leaving External Station A are E-E trips. There are 305 total trips on the EB approach at External Station A and it was calculated that 237 of them travel all the way to External station B above. So, 237 / 305 = 0.77 or 77%. In the WB direction at External Station A, there are 377 trips on the approach and it was determined that 310 trips travel from External Station B to A. So 310 / 377 = 0.83 or 83%.

Example 6-10 determined the base year E-E trips. In order to calculate the future year E-E trips, a growth factor needs to be calculated for each external station. This growth factor is computed from the Future Volume Tables for the road segment(s) in question. Non-state roadways can be estimated from historical local counts if available or using a state highway with similar volumes and characteristics as a surrogate. The growth factor is a multi-year factor depending on the number of years between the base and future year. For example, if the base year was 2002 and the future year was 2027, then a 25-year growth factor would need to be computed. See Section 6.5 for more information.

Example 6-11 Future Year E-E Calculations

Given in this example:

- Traffic volumes at the External Station A are 625 entering and 700 exiting.
- Traffic volumes at the External Station B are 735 entering and 630 exiting.

Assumptions:

Growth factors at External stations A and B are 1.83 and 1.53, respectively, over 25 years.
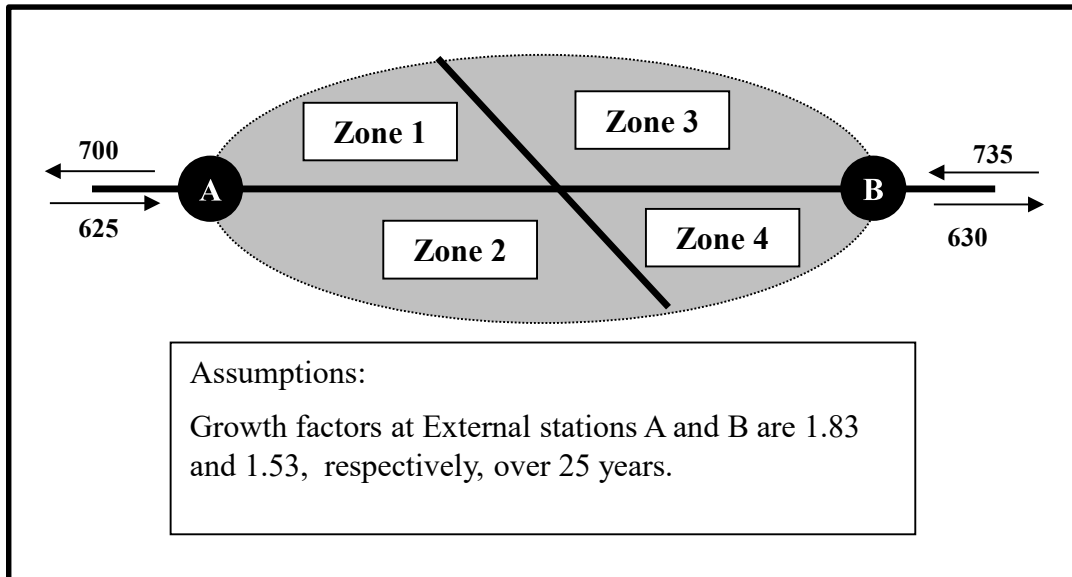
From the figure, the 25-year historical growth factor is 1.83 for External Station A and 1.53 for External Station B and shown in Column (2). The base year 2002 volumes shown in Column (1) are multiplied by the appropriate historical growth factor to obtain 2027 design hour volumes and are shown in Column (3).

The E-E trip proportions were calculated using the method in Example 6-10 for each direction at each external station and are shown in the below table in Column (4):

- External Station A – Entering = 0.83
- External Station A – Exiting = 0.86
- External Station B – Entering = 0.82
- External Station B – Exiting = 0.82

The total new E-E trip growth from 2002 and 2027 is calculated by multiplying the E-E proportions times the difference between the 2002 and 2027 DHV and is shown in Column (5).

Ext. Trip Table	Direction	(1) 2002 DHV (vph)	(2) Growth Factor	(3) 2027 DHV =(1)*(2) (vph)	(4) E-E Trip Prob.	(5) 2027 E-E Trip Growth =(4)*((3)-(1)) (vph)
External Station A	Enter	625	1.83	1144	0.83	431
	Exit	700	1.83	1281	0.86	500
External Station B	Enter	735	1.53	1125	0.82	320
	Exit	630	1.53	964	0.82	274

6.10.6 Estimating External-Internal (E-I) and Internal – External (I-E) Trips

Once the total E-E trips have been determined, the External-Internal (E-I) and Internal-External (I-E) trips can be determined. The E-I and I-E trips have one end of the trip in the study area and one end outside of the study area.

The E-I trip growth is the total external station growth entering the study area minus the directional E-E growth. Conversely, the I-E trip growth is the total external station growth exiting the study area minus the directional E-E growth.

Example 6-12 Future Year E-I and I-E Trip Calculation

From the information in Examples 6-10 and 6-11, the 25-year growth of E-I and I-E trips are calculated as shown in Column (6).

Ext. Trip Table	Direction	(1) 2002 DHV (vph)	(2) Growth Factor	(3) 2027 DHV =(1)*(2) (vph)	(4) E-E Trip Prob.	(5) 2027 E-E Trip Growth =(4)*((3)-(1)) (vph)	(6) 2027 E-I, I-E Trip Growth = (3)-(1)-(5) (vph)
External Station A	Enter	625	1.83	1144	0.83	431	88
	Exit	700	1.83	1281	0.86	500	81
External Station B	Enter	735	1.53	1125	0.82	320	70
	Exit	630	1.53	964	0.82	274	60

6.10.7 Trip Distribution of E-I and I-E trips

Trips entering a zone are also known as an "attracted" trip while trips leaving a zone are a "produced" trip. The zonal cumulative analysis uses a gravity-based method for determining a TAZ's distribution of attractions and productions. Larger zones (on a trip generation basis, not geographical area) attract and produce more trips than smaller zones on a relative basis. This process is known as trip distribution.

After the external-external trip growth has been removed from the total external trip growth, the remaining trips are distributed to the internal zones according to the following procedure.
- Distribution of growth in external-internal trips:
  - Calculate the attraction probability of each zone's new trip attractions by dividing its new trip attractions by the study area's total new trip attractions.
  - Distribute the growth in external-internal trips for each external station by multiplying these trips by each zone's attraction probability.
- Distribution of growth in internal-external trips:
  - Calculate the production probability of each zone's new trip productions by dividing its new trip productions by the study area's total new trip productions.
  - Distribute the growth in internal-external trips for each external station by multiplying these trips by each zone's production probability.

When distributing trips, care needs to be taken considering the land use within each zone. For the typical afternoon peak hour analysis, trips will be traveling from employment zones (commercial/industrial) to residential zones; from residential zones to commercial zones (i.e. shopping/eating after work); and from commercial to other commercial zones (trip chaining). Residential to residential trip distribution should be avoided as it will likely cause unrealistic results.

Example 6-13 E-I and I-E Trip Distribution

Distribute the new external-internal and internal-external trips in Example 6-12 to the four zones shown in Example 6-11.

Solution:

The total new trips are obtained from the trip generation done in Example 6-9 (Column 5). All zones are summed up to determine the grand new trip total for the entire study area. The trip attractions and productions are the entering and exiting trips, respectively, also from Example 6-9. The attractions and productions are also summed up across all zones to determine the total attracted and produced trips.

The calculation of the attraction and production probabilities is shown in the external trip attraction and production probability table below. All trips are in vehicles per hour. For example, Zone 1's attraction probability is 349/1362 = 0.256 and its production probability is 193/753 = 0.256.

External Trip Attractions and Productions Probabilities

Zone	1	2	3	4	Total
Total New Trips (from Example 6-9)	542	758	169	646	2115
Trip Attractions (from Example 6-9)	349	488	109	416	1362
Attraction Probability	0.256	0.358	0.080	0.306	1.000
Trip Productions (from Example 6-9)	193	270	60	230	753
Production Probability	0.256	0.359	0.080	0.305	1.000

The distribution of new external-internal trips is shown in the E-I table below. For example, Zone 1's new external-internal trips at External Station A are 88*0.256 = 23 vph.

External-Internal Trip Attraction Distribution

External Station	New E-I Trips	Zone 1	Zone 2	Zone 3	Zone 4
A	88 (from Example 6-12)	23	31	7	27
B	70(from Example 6-12)	18	25	6	21

The distribution of new internal-external trips is shown in the I-E table below. For example, Zone 1's new internal-external trips at External Station A are 81*0.256 = 21 vph.

Internal-External Trip Production Distribution

External Station	New I-E Trips	Zone 1	Zone 2	Zone 3	Zone 4
A	81(from Example 6-12)	21	29	6	25

External Station	New I-E Trips	Zone 1	Zone 2	Zone 3	Zone 4
B	60(from Example 6-12)	15	22	5	18

6.10.8 Trip Distribution of Internal – Internal Trips

After the new external-internal and internal-external trips have been distributed for each zone, the remaining new attractions and productions are internal-internal trips. While these attractions and productions balance in the examples for simplification, typically they do not. The I-I table would need to be balanced using a Frater methodology (i.e. see NCHRP Report 765). External-External proportions or zone production/attraction probabilities may need to be slightly adjusted for balance to occur. Internal –internal (I-I) trips are trips that both start and end in the study area. The total I-I trips are determined by subtracting the total new E-I/I-E trips from the total new trips for each TAZ.

Example 6-14 I-I Total Trip Calculation

From the previous example, the total new attraction/production trips for each zone in vehicles per hour are shown on the first line of the trip attractions and productions probability table. The total E-I and I-E trips for each zone are summed up and subtracted from the total new trips.

For Zone 1, the total new trips are 542. The total E-I trips (from Example 6-13's trip attraction distribution) are $23 + 18 = 41$ while the I-E trips are $21 + 15 = 36$ (from Example 6-13's trip production distribution table).

Trip Type	Zone 1	Zone 2	Zone 3	Zone 4	Total
Total New Trips	542	758	169	646	2115
Total E-I trips	41	56	13	48	158
Total I-E trips	36	51	11	43	141
Total resulting I-I trips	**465**	**651**	**145**	**555**	1816

The total I-I trips are calculated by subtracting the total E-I and I-E from the total new trips: Total Zone 1 I-I trips = $542 – 41 – 36 = 465$ trips

This is repeated for all remaining zones. Note that the table is balanced as the sum of the total new trips minus the total E-I and I-E trips equals the sum of the column totals. For the above table: $465 + 651 + 145 + 555 = 1816$ and $2115 – 158 – 141 = 1816$.

To distribute the internal-internal trips for each zone, use the same distribution process as described in Section 6.10.7. Once the total I-I trips are determined for each zone following the process shown in Example 6-13, the total internal attractions and productions need to be calculated. The total internal attractions are determined by subtracting the total external-internal attractions from the total attractions. Likewise, the total internal productions are determined from subtracting the total internal-external productions from the total productions. Attraction probabilities are calculated by dividing the total attractions for each zone by the total attractions. Production probabilities are done similarly.

Example 6-15 I-I Trip Distribution

For each zone, the total internal attractions and productions need to be calculated. For Zone 1, there were 464 total internal-internal trips determined in Example 6-14 and shown below in the internal-internal trip attraction/production probability table. In Example 6-13 the total external-internal trip attractions were 349 while the total external-internal trip productions were 193. The total external-internal trip attraction distribution table has a total of 41 (23+18) trips for Zone 1. Likewise, the corresponding internal-external trip production table has a total of 36 (21 + 15) trips for Zone 1.

Total I-I trip attractions = 349 – 41 = 308 trips
Total I-I trip productions = 193 – 36 = 157 trips

The calculations are repeated for all zones and are shown in the below table. The total I-I trip attractions and productions are summed up across all zones for a grand attraction and production totals. Attraction and production probabilities are also calculated for all zones. For Zone 1 the 308 internal attracted trips are divided by the total 1204 attracted trips = 308 / 1204 = 0.256 Production probabilities for Zone 1 are 157 / 612 = 0.256.

Internal Trip Attractions and Productions Probabilities

	Zone 1	Zone 2	Zone 3	Zone 4	Total
Total Internal-Internal Trips	464	650	145	553	1812
Internal Attractions	308	432	96	368	1204
Attraction Probability	0.256	0.358	0.080	0.306	1.000
Internal Productions	156	218	49	185	608
Production Probability	0.257	0.358	0.081	0.304	1.000

The distribution of new internal-internal attractions is shown in the table below. For example, the attraction trips to Zone 1 from Zone 2 are 308*0.358 = 110.

Internal Trip Attraction Distribution

Zone	I-I Attraction	Zone 1	Zone 2	Zone 3	Zone 4
1	308	79	110	25	94
2	432	111	155	34	132
3	96	25	34	8	29

Zone	I-I Attraction	Zone 1	Zone 2	Zone 3	Zone 4
4	368	94	132	30	112

The distribution of new internal-internal productions is shown in the table below. For example, the production trips from Zone 1 from Zone 2 are 156*0.358 = 56.

Internal Trip Production Distribution

Zone	I-I Production	Zone 1	Zone 2	Zone 3	Zone 4
1	156	40	56	13	47
2	218	56	78	18	66
3	49	13	18	4	15
4	185	48	66	15	56

6.10.9 Initial Trip Assignment

Following trip distribution, the next step in the procedure is trip assignment, which involves placing the growth in trips on the road network. Trip assignment is the process used to estimate paths the trip will take, which ultimately results in traffic flow on the network. It assigns the trips to specific routes and establishes volumes on links, taking into consideration network characteristics to find the shortest path between origins and destinations.

The trip assignment is based on the shortest path in the network by time. A travel time needs to be identified for each link on the network. At the minimum, each route should be traveled at least once in each direction during the analysis hour to help estimate a travel time for that direction on the link. The ideal method to determine travel times would be following the procedures in Chapter 3 for travel time studies. For roadways that do not exist, speeds should be estimated using distance and likely travel or posted speed.

The analyst has to establish the travel times for the four trip-types. For each production-attraction pair in the trip table, the likely paths need to be identified. There is likely to be more than one path for each pair, depending on the network. The link travel times are summed to create the total path travel time.

Where there are multiple paths for an individual production-attraction pair, the appropriate path needs to be selected. The selection should be based on the smallest travel time. If the path travel times are within 10% of each other, the trips can be assigned equally across those paths. When the times are more than 50% different then assign the trips all to the shortest path. When the difference is between 10 and 50 %, the trips should be assigned on a weighted average based on the inverse proportion. For example, assume that the paths were 4 minutes versus 3 minutes. Since the 4 minute path is 33% longer than the 3 minute path, the trips are assigned 33% to the longer 4-minute path and 67% to the shorter 3-minute path. Engineering judgment must be used when review travel times of closely spaced parallel paths to assure that actual driver behavior is modeled and not just a mathematical difference.

The analyst must now assign the trips by trip types starting with E-E and progressing to E-I, then I-E and finally I-I as illustrated in the example.

6.10.10 Total Trip Assignment

Once all the trips have been assigned by trip type, the analyst must check for links that have been over assigned based on capacity. The analyst should first review the base year analysis to determine whether certain links are below, near/at or over capacity. For links in the base year that are approaching or over capacity, a flag for possible trip reassignment is identified. Also, links with a large amount of growth in traffic should be identified as needing a check for over capacity conditions.

Any flagged linked may require that the assignment of the growth trips be reassigned to links with available capacity. The analyst needs to use an HCM segment methodology to determine the link capacity. The analyst will need to convert the base year intersection volumes into link volumes. The growth trips need to be added to the base year trips to determine total trips assigned to a link. The analyst then identifies any links that have trips assigned in excess of the capacity. For the over-capacity links, the excess trips above capacity from growth need to be reassigned to other logical paths. This iterative process should be continued until the excess trips have been assigned logically onto the network. Depending on the network, there may be limited additional paths so the excess trips cannot always be completely reassigned.

Example 6-16 Trip Assignment for Eastbound Through

This example illustrates the aggregation of the individual trip types for the future for one movement on one approach at an intersection within the study area. This would need to be repeated for the other movements and other intersections. This example focuses on the eastbound through (EBT) movement.
Base Year Trips

The process starts with the existing year (base year) 30HV volume previously calculated using procedures from Chapter 5. From the figure below, there are 525 base-year trips to be assigned to the EBT movement.
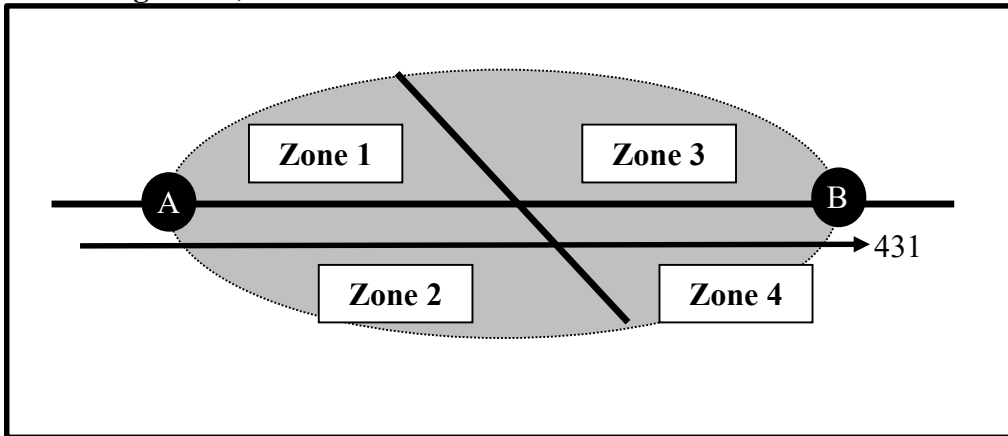
EBT Assignment, Base Year 30 HV
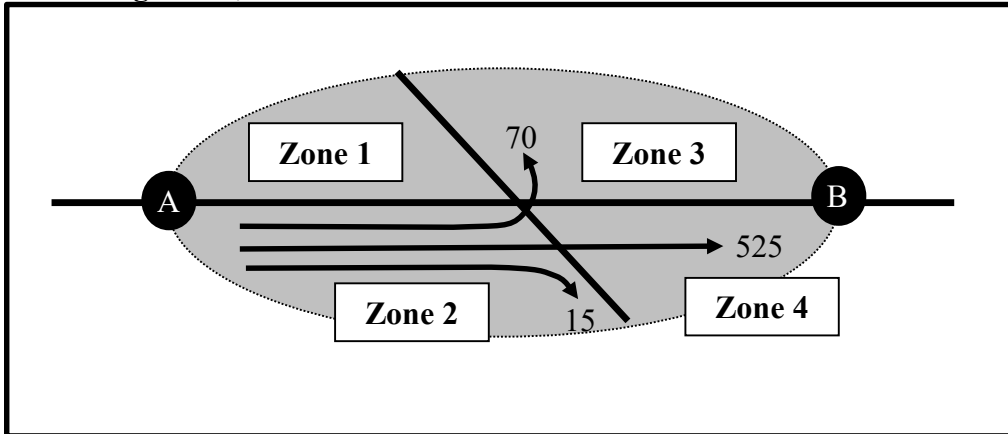
External-External Trips

Next, the external-external trips are added. From Example 6-11, the future year eastbound E-E trips are 431 and are shown in the next figure below.
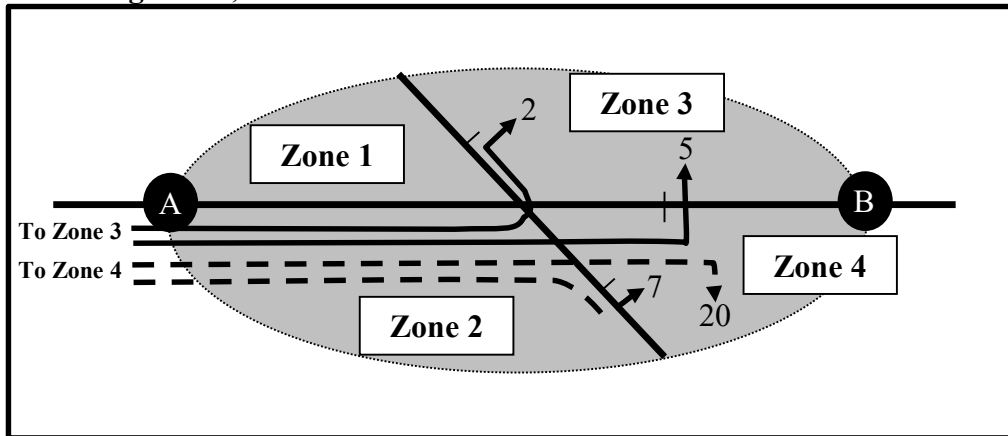
EBT Assignment, External-External

External-Internal Trips

From the figure below, note that Zone 1 and 2 E-I trips will leave the roadway before the intersection at access points or turning left or right at the side street. Both of these do not add to the assignment for the eastbound through (EBT) movement. However, they would be part of the assignments for the eastbound left and right.

EBT Assignment, External-Internal

There are seven total external-internal trips from External Station A to Zone 3. These seven trips can access to Zone 3 by turning left at the intersection or through downstream accesses via the mainline based on assignment assumptions. Two of the seven trips will travel to Zone 3 by turning left at the intersection and the remaining five trips will travel to Zone 3 through downstream accesses via the mainline.

The same process is followed for trips from External Station A to Zone 4. The total external-internal trips from External Station A to Zone 4 are 27. The same accessibility assumptions from Zone 3 apply to Zone 4. Here, assuming 20 out of the 27 will access to Zone 4 by downstream accesses on the mainline and seven via the side street.

The resulting total E-I trips for the EBT movement is 25 (20 +5).

Internal-External Trips

From the figure below, note that Zone 3 and 4 I-E trips will turn onto the mainline roadway at the intersection or access it downstream of the intersection. These movements would not be counted into the EBT movement assignment. They would be part of the assignment for the northbound right and southbound left movements.

EBT Assignment, Internal-External
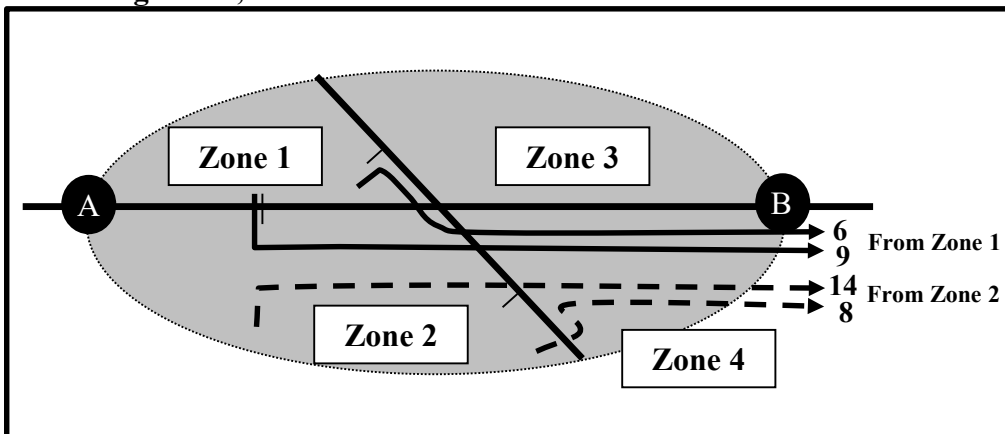
The total internal-external trips from Zone 1 to External Station B are 15. The assignment of these trips depends on the accessibility from Zone 1 to the external station B. Nine (9) of the 16 trips (depending on the accessibility from Zone 1 to the road network) will travel to External Station B by using upstream access points. The remaining six trips will travel to External Station B by turning left at the intersection.

The total I-E trips are 23 (9+14) for the EBT movement.

Internal-Internal Trips

There are internal-internal production trips from Zone 1 to Zones 2, 3 and 4, and from Zone 2 to Zones 1, 3 and 4. The internal-internal production trips from Zone 1 to Zones 2 and 3 and from Zone 2 to Zones 1 and 4 do not go through the subject intersection as they use other smaller connectors or accesses. The only applicable internal-internal production trips are between Zone 1 and 4 and Zones 2 and 3.

The total internal-internal production trips from Zone 1 to Zone 4 (See Example 6-15) are 47 trips and from Zone 2 to Zone 3 are 18 trips. The internal-internal trip assignment from Zone 1 to Zone 4 and from Zone 2 to Zone 3 is based on the network accessibility assumptions.

On the side street, I-I trips from Zone 1 to 4 will take a couple different paths by either traveling through the intersection southbound (10 trips) or turning left (6 trips) as seen in the figure below. On the mainline, the I-I trips from Zone 1 to 4 will access the mainline mid-block and travel through the intersection eastbound (20 trips) or turn right at the intersection (12 trips). Of the 48 total I-I trips from Zone 1 to 4, only 20 trips are assigned to the EBT movement.

EBT Assignment, Internal-Internal: Zone 1 to 4
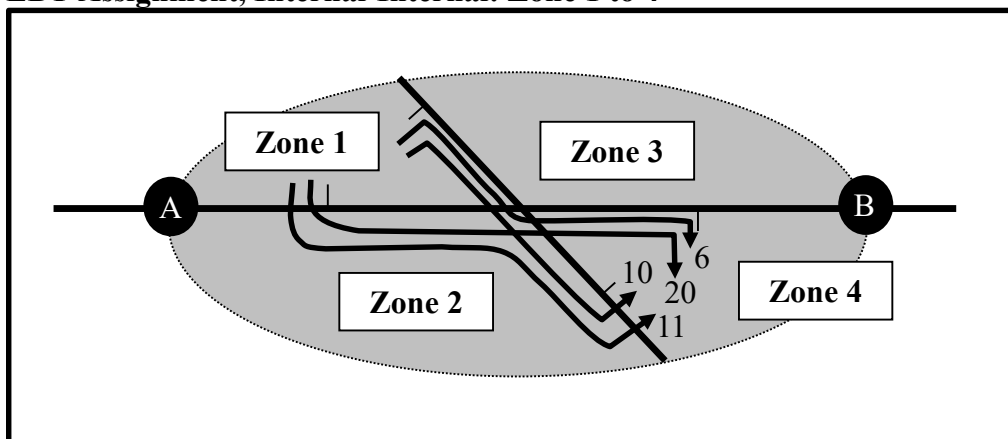
Likewise, between Zone 2 and 3, the I-I trips will either travel between the two zones by the side street or the mainline. On the side street, I-I trips from Zone 2 to 3 will either travel northward through the intersection (3 trips) or turn right (2 trips) as seen in the

figure below. On the mainline, I-I trips from Zone 2 to 3 will turn left at the intersection (3 trips) or travel through the intersection to downstream accesses (10 trips). Of the 18 total I-I trips between Zone 2 and 3, only 10 trips are assigned to the EBT movement.

EBT Assignment, Internal-Internal: Zone 2 to 3
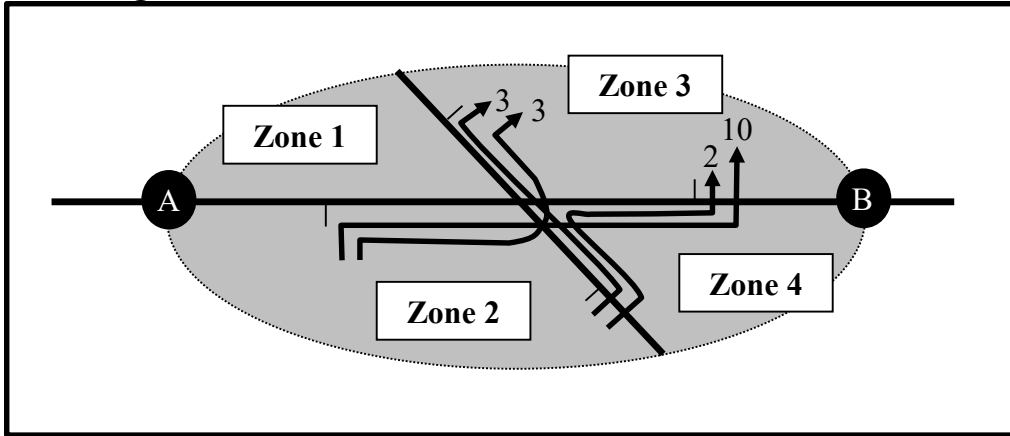
The total I-I trips on the EBT movement is 30 (20 + 10) from both zones.

Total Trip Assignment

The resulting total trip assignment is created by summing up the base year trips, the external trips and the internal trips as seen in the table below.

Total Trip Assignment – EBT (vph)

Trip Type	Trips (vph)
Base Year 30HV	525
E-E	431
E-I	25
I-E	23
I-I	30
Total	**1034**

For Build Alternatives, the trip generation and distribution are fixed, so only the trip assignments need to be modified. The travel times would have to be determined for the new roadway network and then the trips assigned by the methods above.

6.11 Enhanced Zonal Cumulative Analysis

> *EZCA is not and shall not be considered the equivalent of a travel demand model, even though it uses similar techniques and tools. It should not be used for analysis other than the original use without coordination with TPAU to determine if significant re-evaluation and possible updating of information is required.*

The enhanced zonal cumulative analysis (EZCA) methods provide a series of enhancements to the typical application of zonal cumulative analysis methods. The purpose of the EZCA application is to enhance traffic circulation and operations analysis that can account for details that are otherwise not captured in the cumulative analysis approach. The full application of these enhancements has also been referred to as the small community forecast tool (SCFT) methodology. The EZCA methods can be used wherever the regular zonal cumulative analysis process is used, as well as larger areas (greater than 10,000) that do not have a travel demand model in place[1]. The development and application of the EZCA methods can be cumbersome and labor-intensive; however, the methods provide significant refinements and application beyond the typical zonal cumulative analysis. Larger areas will still require the manual spreadsheet-based setup, however, the enhanced zonal cumulative allows greater automation in trip assignment using VISUM (or other modeling assignment software). By using assignment software tools, the process can be streamlined to more closely resemble a travel demand model. The creation of an enhanced zonal cumulative analysis should be weighed against the creation of a full travel demand model (refer to Chapter 17). As with a travel demand model, analysts should coordinate with TPAU to determine if subsequent project application (i.e., use for project analysis beyond the original study) is appropriate for the scope and development of the EZCA. Appendix 6A provides a sample application of the EZCA process that was performed for Canby.[2]

6.11.1 Process

The general process for developing an EZCA tool follows a similar process to the zonal cumulative analysis, while adding enhancements that address some of the key limitations. Primary enhancements include:

- Scope of land use and trip assignment - The major difference (enhancement) is to include an estimation of base year and future year total land use (and trips), instead of only using a growth increment. This allows redistribution and reassignment of existing trips that may occur due to adjacent changes in land use or the transportation network. For example, an existing trip from a residence to a grocery store may use a different route (assignment change) if a new street

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[1] While larger areas may trigger development of travel demand model, in some cases full model development may not be feasible given project application needs and schedule. In these areas, EZCA may still provide an alternative tool for forecasting traffic volumes or other project application. An example of a larger area with EZCA application is Canby, Oregon, which had a population over 15,000 in 2010.
[2] Technical Memorandum #3: Canby TSP – Future Forecasting, DKS Associates, March 31, 2010.

connection is build. Similarly, if a new grocery store is built and is located closer, the driver may decide to travel to this store instead of the other store (distribution change). This fundamental difference provides additional flexibility and options for project application.

- <u>Trip Matrix</u> – All trips in the network are typically assigned using a trip matrix, including existing trips. Fixed trips (such as driveway pass-by trips) can be added, but doing so removes trip assignment flexibility and routing effects due to network condition and changes. Existing count data are used for calibration purposes, but is not considered "background" trips.

- <u>Trip assignment approach</u> - The EZCA utilizes an equilibrium assignment procedure that automates the routing choices with improved accuracy over manual assignment. Depending on the assignment software tool used, more detail such as link and/or nodal delay can be added to better represent the effects of congestion. This will allow a more responsive, accurate and comprehensive analysis of the base and future conditions. This approach provides two key benefits:
    - Fundamentally, assignment and routing is automated based on a comprehensive, analytical check of available routes and travel times.
    - Network detail (connector loading, street system, traffic control, etc.) can be scaled by project need, as described in Chapter 8 (Mesoscopic Analysis)[3].

- <u>An iterative process of checks, back-checks, and balances</u> – The use of spreadsheets (land use summaries and matrix development) and assignment software (trip assignment) allows for a semi-automated process that can be used to perform iterative checks and testing.

- <u>Calibration of a base year "tool"</u> – Since all internal trips (rather than just the growth increment) are being estimated through land use, trip generation, trip distribution, and trip assignment, the network coding and analysis assumptions (including land use and trip generation) can be validated in a way that is not feasible with the standard TIA level and zonal cumulative analysis methods.

- Various other enhancements that may be performed to refine a standard zonal cumulative analysis application, such as data to refine land use development (Section 6.8.2) collection of Bluetooth data (Section 6.8.5) to inform external trip patterns.
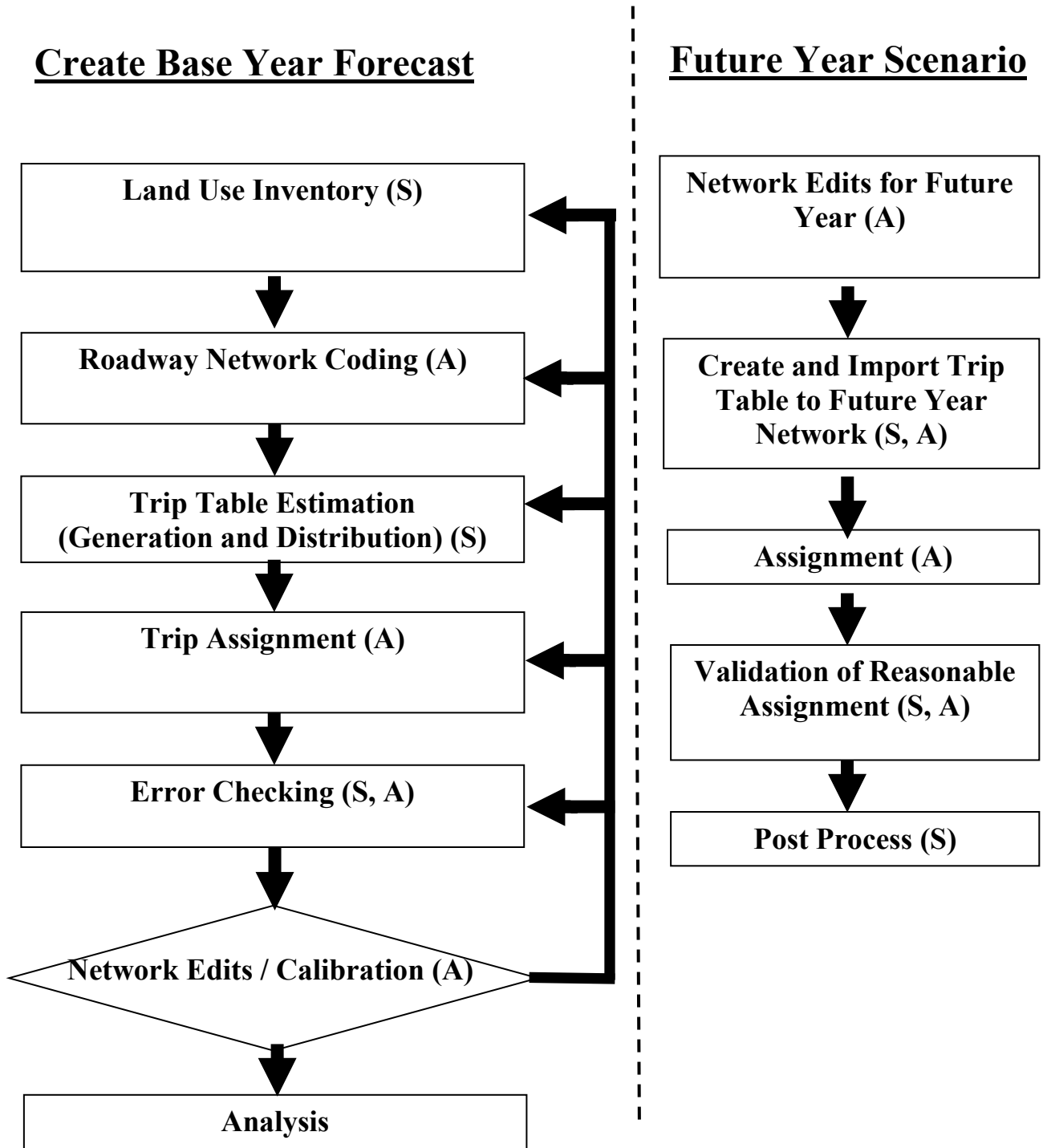
---

[3] Typical applications of EZCA will include an all-street system reflecting comprehensive traffic control, as described in Windowed Area Models.

The overall EZCA Process (Exhibit 6-8) is generally similar to the typical zonal cumulative analysis method. However, subtle differences exist as listed in Exhibit 6-8.

> *The analysis results are impacted by the combined effects of the integrated EZCA components (land use, trip rates, loading locations, network coding, etc.). For this reason, it is important to balance the level of detail and effort that is put into each component to minimize compounded errors. For instance, trip generation relies on both land use and trip rates. A perfect inventory of land uses will not provide true enhancements to this procedure unless trip rates are also appropriate.*

Exhibit 6-8 EZCA Process

Create Base Year Forecast
Future Year Scenario

```
Land Use Inventory (S)
        ↓
Roadway Network Coding (A)
        ↓
Trip Table Estimation
(Generation and Distribution) (S)
        ↓
Trip Assignment (A)
        ↓
Error Checking (S, A)
        ↓
< Network Edits / Calibration (A) >
        ↓
Analysis
```

```
Network Edits for Future
Year (A)
        ↓
Create and Import Trip
Table to Future Year
Network (S, A)
        ↓
Assignment (A)
        ↓
Validation of Reasonable
Assignment (S, A)
        ↓
Post Process (S)
```

Note: Typical tools for the above process include spreadsheets and the traffic assignment software. Steps noted with (S) are typically conducted in a spreadsheet, while those marked with (A) are typically performed in the assignment software.

Exhibit 6-9 Comparison of Standard Zonal Cumulative Analysis and EZCA

Zonal Cumulative Analysis Step (Standard Approach)	Enhanced Zonal Cumulative Analysis (EZCA)
General Set Up	
1- Identify the study area and divide into transportation analysis zones (TAZ)	Study area typically whole community or large subarea
(Step not used)	Set up the transportation network coding
Land Use & Trip Generation	
2- Identify vacant lands, in-process developments, comprehensive plan allowed land uses/densities, and development rates.	Determine all existing and future land use totals (not just growth)
3- Estimate future trip generation potential	Estimate <u>existing</u> trips using ITE average trip rates as the initial assumption.
Trip Distribution	
4- Determining the through trip percentages (external – external, E-E) and E-E trips for the external stations	Approximation by subtraction procedure is difficult due to larger network size, and typically need OD data such as Bluetooth.
5- Determining the internal – external (I-E) and external –internal (E-I) trips at each external station (external zone)	Completed for all trips, not just growth increment.
6- Determining the trip distribution for the internal – external (I-E) and external – internal (E-I) trips for each internal TAZ.	Complete for all trips, not just growth increment.
7- Determining the trip distribution for internal-internal (I-I) trips	Complete for all trips, not just growth.
Trip Assignment	
8- Calculating network link travel times	Not done manually. Assignment software uses the "free flow" travel time as the initial assumption (updated through an iterative assignment process) based on link and/or nodal travel times. Link delay may be needed to account for congestion on free-flow facilities.
9- Assigning total trips to the network	Not done manually. Assignment software is used.
Additional Steps for EZCA	
(Step not used)	Calibration of tool estimation of traffic volumes compared to counts

Although this process is not a travel demand model, many of the elements are similar so general background information can be obtained from Chapter 17 and the Modeling

[Procedures Manual for Land Use Changes (MPMLUC)](). See Chapter 8 for related information for developing traffic networks for subarea models.

The following sections provide details for each component of the ECZA process, with a focus on methods that differ from the standard zonal cumulative analysis approach. Unless otherwise noted, the approach generally follows Section 6.8.

6.11.2 Land Use

Land use inventories for EZCA are required similar to the standard zonal cumulative analysis approach (typically collected at the parcel level and aggregated to the zonal level), with the following differences:

- Inventories include all land use, not just the growth increment. For this reason, both base year and future year inventories are developed for the study area.
    - Base year inventories should be consistent with traffic data that was collected for calibration.
    - Future year inventories include not only development, but potential redevelopment as well.
- The study area is typically comprised of a large area, and may even represent an entire community. Larger study areas that encompass the entire community provide the ability to compare to coordinated population projections that may not provide as much value to a smaller area.
- The land use data are typically grouped into five main categories – households (which may be split between single family and multifamily uses), retail employment, service employment, education employment, and other employment. However, these categories may vary by application depending on the community, allowed zoning uses, and context. These land uses should generally correlate with ITE categories or combinations of ITE categories based on related uses that exist in the community. For instance, a community may have the following uses, grouped as shown:
    - Single Family Residential Household
    - Apartment/Condo
    - Retail Employment (Gas station, Fast Food, Bank, Shopping Center)
    - Service Employment (Strip mall offices, auto shops, and specialty shops that do not generate as many trips as active retail uses)
    - Education Employment
    - Other Employment (Office Park, Industrial Uses)
- Land use inventories are aggregated to transportation analysis zones, as shown in Exhibit 6-10.
- For future conditions, the future population projection from the analysis must be consistent with the county-coordinated population forecast for the city. The future employment needs to be at a level that can be supported by the population in the study area[4]. The future employment and population must be consistent with

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[4] The *Modeling Procedures Manual for Land Use Changes*, ODOT Transportation Planning Analysis Unit, February 2012 identifies employment ratios that are reasonable.

the local jurisdiction's comprehensive plan. The analyst will need to consult with the local jurisdiction to determine where future growth is to be allocated. The local jurisdiction will also need to review the final allocations for consistency. The modular integration of the EZCA elements allows the ability to easily test different land use scenarios (update trip generation and copy resulting trip matrix to assignment software).

Exhibit 6-10 Sample Land Use Totals (Households and Employees) by TAZ

TAZ	HH_BASE	RETL_BASE	SERV_BASE	EDUC_BASE	OTHR_BASE
101	26	0	0	0	0
102	9	8	0	0	0
103	295	0	0	0	0
104	68	0	0	0	40
105	0	0	0	0	25
106	149	0	0	0	0
107	175	0	0	0	0
108	162	0	0	0	0
109	163	0	0	0	0
110	131	0	0	0	0
111	70	0	0	0	0
112	109	0	0	0	0
113	66	0	0	0	0
114	164	0	0	0	0
115	140	0	0	0	0
116	85	0	0	0	0
117	63	0	0	0	0
118	124	0	0	0	0
119	121	0	0	0	0
120	105	0	0	0	0
121	45	0	12	0	29
122	214	0	1	0	62
123	0	0	0	0	0
124	134	0	0	0	0
125	1	0	25	0	300
126	133	0	0	0	0
127	213	0	0	74.9	0
128	193	0	0	0	0
129	111	0	0	0	0
130	75	30	105	0	13

6.11.3 Roadway Network

The standard application of zonal cumulative analysis can require rigorous manual calculations and checks to determine appropriate assumptions about travel time and vehicle routing. As an enhancement, assignment software can be used to provide a platform for assigning the trip matrix in place of manual assignment methods. This enhancement provides a technical basis (such as travel time or other factors) for assumptions related to trip routing. For this reason, the roadway network needs additional detail that is not typically included in a standard travel demand model (See network details in Chapter 8 regarding mesoscopic modeling and subarea models).

The network should include, at a minimum, arterial and collectors within the study area. Local streets may also be desired. Additional details can be added which include posted speeds, traffic control, lane geometries and the number of travel lanes. The analyst in consultation with the local jurisdiction must determine whether committed (funded), financially constrained and/or all planned projects are to be added to the future network. Elements of the transportation network should include:

- Link (Street) Detail
    - Location – the more roadways included the more flexibility of assignments is included, specifically roads that are subject to cut-through traffic and any roads that are parallel to major routes. Some software allows for importing GIS shapefiles from sources such as local agency inventories, or the Open Street Network which has much of this information. However, the amount and accuracy of these data need to be (field) verified or edited. More links in the network does not necessarily increase the accuracy of the assignment results, and care should be taken with calibration.
    - Speed – free flow speeds initially based on posted speeds. In some cases the addition of a volume-delay-function (vdf) may be needed to account for delay accrued on uncontrolled facilities.
    - Lanes – number of lanes based on field conditions. This input affects the number of fully developed approach lanes at intersections and is utilized for intersection geometry and delay.

- Node (Intersection) Detail
    - Control – type is specified based on field inventory and is used to calculate the turn-based travel delay using HCM methodology for the given control type. Calibration may require modifying the control (i.e. yield to stop) to better match field operations.
    - Lane Configuration – (turn lanes) based on field inventory to determine the intersection turn delay

- Zone Detail
    - Centroid connectors represent the non-modeled minor streets and accesses within a zone to load trips from a TAZ centroid onto the network. Extra

connectors should be added, as needed to represent a particular network scenario, to distribute trips from the TAZ to match the loading of the trips onto the network such as from new roads, minor streets and off-street parking.

6.11.4 Trip Table Estimation

Trip table estimation is a component that appears generally similar, yet is fundamentally different between the zonal cumulative analysis and EZCA. One notable deviation from the zonal cumulative analysis is including all trips in the forecast rather than just the growth component. This develops volumes for the base year that can be used to calibrate the analysis tool, as well as providing more reasonable trip distributions. The approach of distributing only new growth does not allow for the redistribution of existing trips. For this reason, all trips, including those that are currently part of the roadway system, are estimated in the trip table as E-E, E-I, I,E, or I-I trips (see Section 6.8 for additional information about trip types and distribution).

Trip Generation

External Trip Ends
- There are three steps to prepare for the distribution of external trips. First, the number of external trip ends is estimated based on design hour volumes at external nodes. Second, these external trip ends are separated into external-external (E-E), external-internal (E-I), and internal-external (I-E) trips. Third, projected future growth rates are applied (to determine future trips levels). The base year external trip ends are based on 30th HV design volumes at key gateway locations (Design Hour Volumes at External Nodes).
- Traffic counts should be collected at major external gateways
- The impact of low volume external gateways (typically minor rural roads serving less than 50 vehicles during a peak hour[5]) that do not serve as major regional connections may be important to the overall estimation of the trip table, but it may not appropriate to consume data resources collecting detailed traffic data at each location. The total number of external gateways needs to be coordinated and agreed upon with TPAU. For example, many communities have rural roads that extend outside the UGB that connect to outlying homes but do not provide regional connections to other communities. The traffic volumes at these gateways may be initially estimated based on agreement and coordination with TPAU and a combination of the following resources, as available:
  o An inventory of the land uses (typically number of homes) that are likely to be served.
  o Adjacent traffic counts with an assumption made about the difference in demand that would result. While traffic counts may not be collected at these specific gateways, there should be other internal network counts that are collected at key junctions that can be used to estimate if the inventory

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[5] This general threshold may vary based on the context of the area and system connectivity.

is reasonable. Counts that are too far away with many intersecting roads may result in overestimation at the gateway and a tube count should be obtained at these locations.

- Future external trip ends are estimated based on forecasted growth at each of the external gateways. The FVT growth projections are utilized to estimate the growth rate at the external gateways.

Internal Trip Ends

- The number of internal trip ends is determined using land use trip generation methodology by applying ITE trip rates to the land uses described in Section 6.9.2. In some cases, combinations or "blended" rates that represent multiple ITE uses and trip rates may be used depending on the grouping of land use categories. For instance, if a single category is used for households and both single family and multifamily homes are present, a blended rate that combines both the single family rate and multifamily rate may be used. For these cases, combinations of trip rates should be used that are representative of the land uses occurring in the community and reflected in each general land use category.
- National average ITE trip rate data may not reflect the unique characteristics of the study area. When sufficient data are available, trip rates may need to be adjusted during the calibration process. Any adjustments to the ITE trip rates need to be documented and reviewed by TPAU. (See calibration section for additional detail). Exhibit 6-11 shows a summary of land use and trips (inbound) for each zone.

Exhibit 6-11 Sample Internal Trip Generation (Trips Inbound) by Zone and Land Use

| TAZ | Land Use (HH, EMP) | | | | | | Trips (Inbound) | | | | | Total Trips |
	HH_BASE	RETL_BASE	SERV_BASE	EDUC_BASE	OTHR_BASE		HH_BASE trips	RETL_BASE trips	SERV_BASE trips	EDUC_BASE trips	OTHR_BASE trips	
101	26	0	0	0	0		12	0	0	0	0	12
102	9	8	0	0	0		4	15	0	0	0	19
103	295	0	0	0	0		139	0	0	0	0	139
104	68	0	0	0	40		32	0	0	0	2	34
105	0	0	0	0	25		0	0	0	0	1	1
106	149	0	0	0	0		70	0	0	0	0	70
107	175	0	0	0	0		83	0	0	0	0	83
108	162	0	0	0	0		77	0	0	0	0	77
109	163	0	0	0	0		77	0	0	0	0	77
110	131	0	0	0	0		62	0	0	0	0	62
111	70	0	0	0	0		33	0	0	0	0	33
112	109	0	0	0	0		52	0	0	0	0	52
113	66	0	0	0	0		31	0	0	0	0	31
114	164	0	0	0	0		77	0	0	0	0	77
115	140	0	0	0	0		66	0	0	0	0	66
116	85	0	0	0	0		40	0	0	0	0	40
117	63	0	0	0	0		30	0	0	0	0	30
118	124	0	0	0	0		59	0	0	0	0	59
119	121	0	0	0	0		57	0	0	0	0	57
120	105	0	0	0	0		50	0	0	0	0	50
121	45	0	12	0	29		21	0	11	0	1	35
122	214	0	1	0	62		101	0	1	0	3	105
123	0	0	0	0	0		0	0	0	0	0	0
124	134	0	0	0	0		63	0	0	0	0	63
125	1	0	25	0	300		0	0	24	0	14	38
126	133	0	0	0	0		63	0	0	0	0	63
127	213	0	0	74.9	0		101	0	0	59	0	160
128	193	0	0	0	0		91	0	0	0	0	91
129	111	0	0	0	0		52	0	0	0	0	52
130	75	30	105	0	13		35	58	102	0	1	196

Trip Distribution

Trip distribution estimates the percentage of trips from any one zone to another. In this analysis, trip distribution and generation are used to define the vehicle trip tables that are incorporated into the existing and future tools.

Distribution is based on the trip ends generated as either productions or attractions for each zone. The productions and attractions are used to determine an attraction probability and production probability for each zone relative to other zones in the network.

Trips are distributed between TAZs using two trip tables:
1. Production Trip Table – Each zone's productions are multiplied by the other zone's attraction probabilities resulting in a set of trips from one TAZ to every other TAZ.
2. Attraction Trip Table – Each zone's attractions are multiplied by the other zone's production probabilities resulting in a different set of trips from each TAZ to every other TAZ.

The distribution procedure includes the following steps:
1. Distribute E-E trips based on data collected from origin-destination study (such as Bluetooth data collection)
2. Allocate remaining external trips to E-I and I-E, based on directionality, as applied to zonal cumulative analysis.
3. Allocate remaining internal trips to I-I based on the attraction and production probabilities as done in the zonal cumulative analysis, resulting in a productions trip table and an attractions trip table. These steps need to be performed for trips generated by household land uses and then for trips generated by employment land uses. Household-based trips should use only employment land uses to calculate attraction and production probabilities.
4. Unlike a zonal cumulative analysis, this method requires the creation of a single I-I trip distribution table. To balance the trip productions and attractions and avoid double counting (since the trip generation process identifies trip ends, and every trip has two trip ends), the production and attraction trip tables must be averaged to result in a final I-I trip table.
5. The I-I trip table is combined with the I-E and E-I trip tables to address all identified internal growth. The E-E trips are then added to complete the trip table for all growth. The resulting trip table will be used as the input into the trip assignment tool. This procedure was followed for both the base and future years.

6.11.5 Trip Assignment

The use of Visum (or other assignment software) facilitates this trip assignment process by incorporating intersection delay which allows for the higher level of detail for approach delay. Route selection is set by the shortest path based on travel times between locations. The Visum travel times include both link (street) and node (intersection) components. The intersection delay in Visum is based on Highway Capacity Manual (HCM) methods. Including the concept of intersection turn delay allows for a greater level of detail than zonal cumulative analysis, and allows for comparing future network alternatives. Because this process has more HCM intersection level-detail, less calibration of and post-processing adjustments of turn movements are needed. In some cases link delay (in addition to free flow travel time) may also be considered using a volume delay function (vdf) to account for delay on uncontrolled facilities.

Other link-based tools like EMME can be used in place of a turn-based delay component, but requires more detail in the vdfs than is typically included. The route selection is also set by the shortest path based on travel times between locations. Because this is link-based delay, this method will take more calibration to match field conditions. Traffic assignment is applied in an iterative process until equilibrium is reached, similar to a travel demand model.

6.11.6 Calibration

The calibration process requires an iterative approach that assesses how well the EZCA tool is performing relative to real-world data (such as traffic counts). The integrated enhancement components allow for feedback in the form of "model error" if the tool is not performing well. Such error could be a result of many individual or combined factors, so it is important to have a systematic approach for calibrating and validating the tool prior to project application.

The calibration process includes three tiers, which should be approached *in the following order*:
1. Error Checking – Check for indication that an entry error has been made. Potential errors may include an allowable turn being closed in the travel network, incorrect stop sign orientation, or missing zone connectors, etc.
2. System Issues – Check for issues related to overall system assumptions. These issues may include system-wide trip generation rate used for all households in the system.
3. Spot Location Issues – Issues that are localized and do not have a greater system effect (such as local circulation patterns in the assignment that that do not match turn movement data and local circulation patterns).

Calibration Measures
Qualitative calibration checks outlined in Chapter 8 (Mesoscopic Analysis) should be used depending on the scale of the traffic assignment network. Typically, a windowed
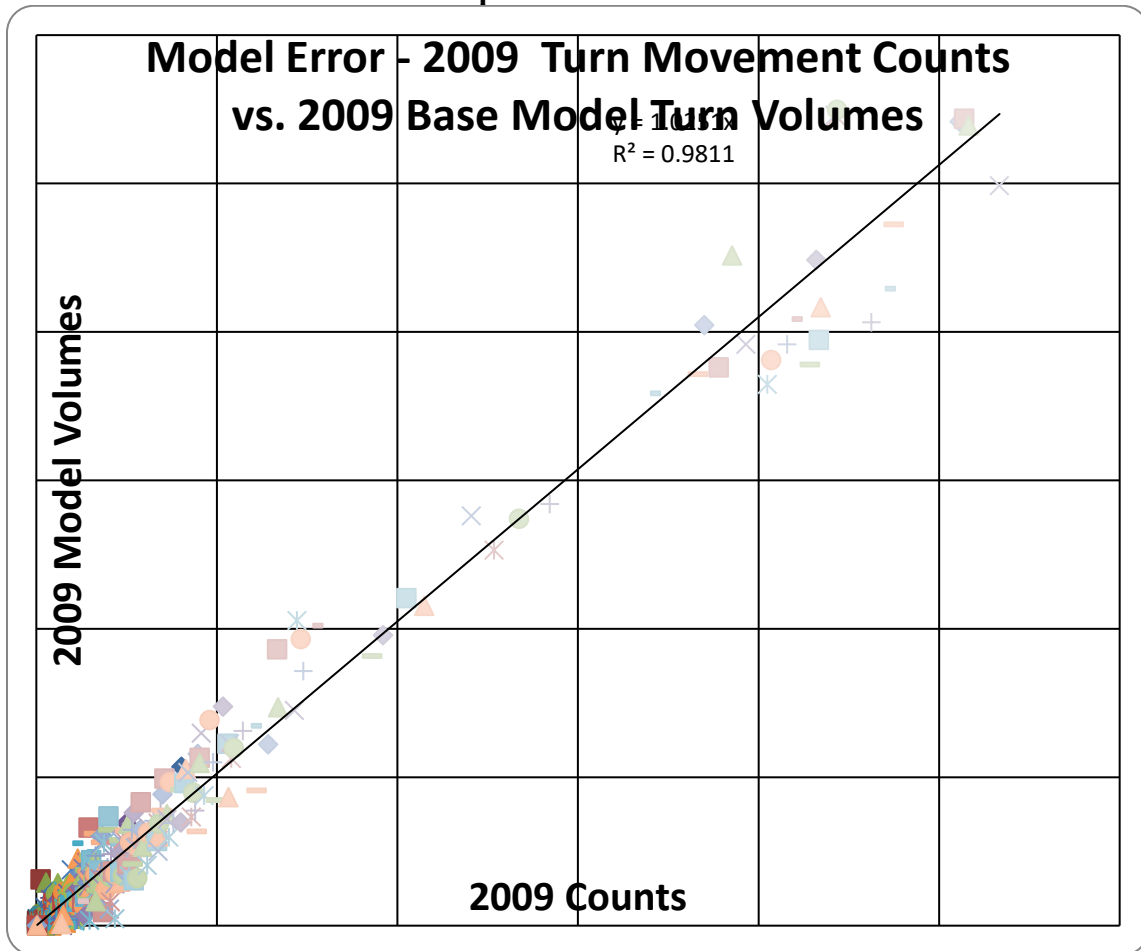
subarea-model will provide a similar approach. However, since the EZCA is not based on a travel demand model, there are additional checks and considerations.

The following series of checks should be used through the calibration process.
- Do assigned traffic patterns match general routes that are observed?
- Do traffic counts match data for roadway segments and the specified intersection turn movements? Calibration compares assigned volumes to the base year 30th Highest Hourly Volumes (30th HV) on links and nodes. Typically the volumes should be within 10% of each other. Major outliers should be investigated and remedied, as feasible.
- Do systematic comparisons of model error indicate that the tool is generally reflecting count data? A plot comparing the existing traffic counts and the base year tool volumes for all study intersection turn movements should be analyzed to evaluate the accuracy of the tool. In addition to a visual verification of the goodness of fit, the following quantitative measures should also be considered:
  - The slope of the fitted curve should be close to 1.0. This value is generally indicative of how the overall magnitude of traffic estimated by trip generation compares to the traffic counts. A value of 1.2 would indicate that the estimated volumes are generally skewed 20 percent higher than the existing counts.
  - The R^2 value should also be close to 1.0. This value generally indicates how well the estimated volumes fit the observed, target volumes.

Exhibit 6-12 demonstrates a plot of the estimated turn movement volumes with the observed (counted) volumes. The slope of the fitted curve is 1.025, indicating that the model volumes are generally only two percent higher than the existing counts and that the trip generation is appropriate and does not require further refinement. Furthermore, the R^2 value of 0.976 indicates that the model volumes are consistent with the target volumes.

Exhibit 6-12 Calibration Plot Comparison of Observed and Estimated Turns

Model Error - 2009 Turn Movement Counts vs. 2009 Base Model Turn Volumes

y = 1.0324x
R² = 0.9811

2009 Model Volumes

2009 Counts

Both system metrics are equally important and should be considered. An R2 value of 1.0 with a slope of 1.5 does not indicate a calibrated tool (since volumes are consistently being overestimated by 50%).

Calibration processes may include the adjustments to account for the following items. The resulting impacts of adjustments to these parameters can easily be measures using the calibration measures to determine if the adjustment is beneficial to the overall calibration of the tool. Model calibrations are performed in an iterative process to determine the relative effect of each calibration measure.

- Pedestrian Conflicts - The pedestrians crossing a roadway influences the capacity and travel time of the corridor. The additional delay attributed to vehicles stopping for pedestrians can be emulated using "dummy traffic signals" at midblock locations.
- Street Speeds – Speeds on some links may need to be adjusted to account for driver behavior, such as increasing the speed on a downtown link to have it remain as a primary attractive route. Conversely, lowering the speed on a link will make it less attractive, so trips use other routes.

- Centroid Connectors – These connections may be needed to added, deleted or changed to match the field operations within the study area. It may be determined that an initial approximation for centroid loading did not provide adequate detail and additional refinements (such as additional spreading of demand within the zone) may be needed.
- Trip Generation Rates – It may be that an individual land uses (such as residential or industrial uses) are isolated in the network with limited access, in a way that allows for determining how many actual trips (from count data) are being generated by the use. If the land use is sufficiently intense, it may provide adequate data to determine that a modification or reconsideration of the trip generation rates are needed. Any modifications of rates or uses need to be reviewed by TPAU. The following adjustments may need to be explored, in the following order:
    - o Consideration for a "special trip generator" in unique cases that a location exists that isn't reflected in the overall land use and trip generation estimates. These uses could include major landmarks, recreational areas, or tourist destinations that have more traffic than would be otherwise estimated using typical land use categories and rates. An example could be a waterfront area or park that is regionally popular. Sufficient traffic count data should be available to estimate the trips generated by such uses. The application of such uses and rates would generally be limited to a single zone or small set of zones, relative to the overall number of zones in the network.
    - o For more comprehensive or system-wide trip rate adjustments, the assumptions about representative ITE uses and rates (Section 6.9.4) may need to be reexamined. Such assumptions could include both the selected types of representative land uses as well as the overall share or weight within the category.
    - o Finally, it may be determined that a local trip generation rate is a better fit than the national average rate[6]. Adjustments to account for local trip rates that differ from the ITE national average should be taken with care and only performed in cases where there are sufficient traffic data to support the adjustment. Such traffic data would typically include a combination of a network-wide calibration measure (slope) that indicates an overall trend of traffic estimation being too high/low and specific traffic count locations that serve to somewhat isolate a homogenous set of land use (for example a gated community or other large development, residential or commercial, with limited, consolidated access points). Adjusted rates should typically stay within 25% above/below the average ITE rate and include data that were used for the basis of the adjustment.
- Zone Trips (Land Use or Trip Rates) – Origin-Demand Matrix Estimation (ODME) can be used as a general tool to indicate zones or O-D pairs that are skewing the calibration of the model. While the raw results of the ODME should

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[6] Adjustments made to trip rates should be made on the basis of traffic count data and taken with care. Areas that are forecasted to have larger amounts of land use growth have a higher sensitivity to adjustments that are made to trip generation rates.

not be applied directly to the model, running ODME can be used to discover zones that may require additional investigation into assumed land uses and/or trip rates for those land uses.

Because the EZCA process uses travel demand assignment software, the resulting volumes must be appropriately post-processed like other travel demand model outputs for formal traffic alternatives analysis[7]. However, depending on the amount of data and calibration success, turn-based post-processing may be feasible. See Section 6.12.1 for additional detail on post-processing traffic volumes.

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[7] Some preliminary alternative testing may be conducted within the forecast tool to inform a set of alternatives for further evaluation.

6.12 Urban Travel Demand Models

Chapter 17 provides an overview of travel demand models and their use in Oregon. The following procedures address how to apply traffic assignments from travel demand models in calculating future volumes for facility level analysis. If a travel demand model is available for the study area then that is the preferred tool for future forecasting. If the study area is within a metropolitan area, then it is a federal requirement that the corresponding regional travel demand model is used.

6.12.1 Post Processing Methods

Growth Method

The Growth Method uses growth equations to calculate future design hour volumes. Caution should be used with the method as it may severely overestimate growth on links that have little volume in the base year and significant volume in the future year. The basic form of the growth method (per [NCHRP Report 765](), the replacement for the old Report 255) is:

Future model year / Base model year = Future DHV / Base 30 HV

Example 6-17 Post-Processing – Growth Method, No Build

- Example: 2035 DHV = (2035 Model / 2014 Model)* 2014 30 HV
- If the 2035 Model had 800 vph, the 2014 Model had 50 vph and the 2014 30 HV had 550 vph, the growth method using a simple linear method would be:

2035 DHV = (800/50)* 550 = 8,800 vph

Note that the future model year link volume is 16 times that of the base model year. Large differences like this will result in a volume overestimation and indicate that another method should be used.

Difference (Incremental) Method

The Difference (Incremental) Method should be used in areas where large differences in base and future model link volumes exist. This method is preferred in NCHRP Report 765. The basic form of the difference method is:

Future DHV = Base 30 HV + (Future model year – Base model year)

Example 6-18 Post-Processing – Difference Method, No Build

2035 DHV = 2014 30 HV + (2035 Model -2014 model)

Using the same numbers from the growth method above, using the difference method would be: 2035 DHV = 550 + (800 – 50) = 1,300 vph.

Comparing the results between this and the above example show that this example represents the more appropriate, truer value to use.

Selection of Method to Use

Both methods should be compared in a spreadsheet on a directional link basis using percent and absolute difference. Areas with large percent and absolute differences (greater than 10-15%) should use the difference method. Areas that compare favorably can use one or the other or an average of the two (a.k.a. Average or Combined Method). The analyst will need to analyze the data to find the natural breakpoints of when and where to use each method.

The two previous examples show the large difference between the growth and difference methods where the growth method overestimates the future 2035 volume because the base year model volume is much smaller than the future model year volume. In this case the difference method would be used.

If the 2014 Model had 600 instead of 50, the growth method would result in 733 vph and the difference method would result in 750 vph. When the base and future models are closer, the results from the two methods are much closer. In this case, the growth method or an average of the growth and difference method would be used.

Adjacent link growth rates can be averaged together to reduce the number of calculations/adjustments necessary if they are close together (less than 10%).

Spreadsheet Application

A spreadsheet is necessary to track the post-processing calculations, especially on larger networks. A sample spreadsheet area is shown in Exhibit 6-13. Directional links are represented as rows. Columns represent the post-processing calculations through Step 4. In this case, since the model base and future years do not match the project existing and future years, they are adjusted according to the following formula:

Existing Year Model Volume = Base Year Model Volume x (1+ Annual Growth Rate x (Project Existing Year - Model Base Year))

The growth and difference methods are then applied. In the spreadsheet, conditional formatting was used to help identify links where the difference in future year volumes between the difference and growth methods exceeded 10 percent, in which case the difference method was selected, or where it is less than or equal to 10 percent, in which case the average of the two methods was used.

Exhibit 6-13 Post-processing Spreadsheet, No Build

Post-Processing - No Build Directional Link Volumes											

Existing Year	2008	
Project Design Year	2034	
Model Base Year	2009	
Model Future Year	2034	

Link Identification					Model Volumes					Post Processed Volumes			
					Model Assignment		Adjustment to Project Years			Future No Build Project Year			
								Base Adj. to	Future				
					Raw Model Base	Raw Model Future	Annual Growth Rate	Existing Year	Adj. to Project Year	Difference Method	Growth Method	Percent Difference[1]	Selected Method
Route	Direction	From	To	Existing 30HV									
Blackwell Rd	SB	Tolo Rd	Kirtland Rd	255	110	154	0.02	108	154	301	364	17%	301
Blackwell Rd	NB	Kirtland Rd	Tolo Rd.	400	228	291	0.01	226	291	465	515	10%	490
Blackwell Rd	SB	Kirtland Rd	I-5 NB Ramps	360	295	466	0.02	289	466	537	580	7%	559
Blackwell Rd	NB	I-5 NB Ramps	Kirtland Rd	465	303	402	0.01	300	402	567	623	9%	595
OR 99	SB	I-5 NB Ramps	I-5 SB Ramps	310	157	194	0.01	155	194	349	388	10%	369
OR 99	NB	I-5 SB Ramps	I-5 NB Ramps	575	435	665	0.02	426	665	814	898	9%	856
OR 99	SB	I-5 SB Ramps	Eric Ave	400	218	354	0.02	214	354	540	662	18%	540
OR 99	NB	Eric Ave	I-5 SB Ramps	495	380	562	0.02	372	562	685	748	8%	717
OR 99	SB	Eric Ave	Seven Oaks Rd	395	218	383	0.03	211	383	567	717	21%	567
OR 99	NB	Seven Oaks Rd	Eric Ave	485	380	574	0.02	372	574	687	748	8%	718
OR 99	SB	Seven Oaks Rd	Jaybee Ln	385	218	383	0.03	211	383	557	699	20%	557
OR 99	NB	Jaybee Ln	Seven Oaks Rd	480	380	574	0.02	372	574	682	741	8%	712
Kirtland Rd	WB	High Banks	Blackwell Rd	395	216	362	0.03	210	362	547	681	20%	547
Kirtland Rd	EB	Blackwell Rd	High Banks Rd	340	133	202	0.02	130	202	412	528	22%	412
I-5 WB	WB	I-5 OFF RAMP	Blackwell Rd	180	201	235	0.01	199	235	216	213	1%	215
I-5 WB	WB	Blackwell Rd	I-5 NB ON Ramp	395	443	737	0.03	430	737	702	677	4%	690
Willow Springs	EB	RR	OR-99	145	99	95	0.00	99	95	141	139	1%	140
Willow Springs	WB	OR-99	RR	115	82	78	0.00	82	78	111	109	2%	110
Willow Springs	EB	OR-99	I-5 SB Ramps	125	137	162	0.01	136	162	151	149	1%	150
Willow Springs	WB	I-5 SB Ramps	OR-99	280	236	424	0.03	229	424	475	518	8%	497

[1] Shaded cells indicate use of the Difference method. Non-shaded cells indicate use of the Growth method.

6.12.2 Assessing Induced & Latent Demand Effects

All forecasts involve uncertainty. When sources of uncertainty are known, it is important to evaluate potential impacts. For traffic forecasts this is especially important in order to avoid unexpected outcomes and ensure facility designs meet future goals and objectives. Demand effects are one of the biggest uncertainty issues surrounding today's current projects, especially in congested metropolitan areas. These come up frequently when analyses, project reports, or environmental documents are reviewed by a wide range of participants from federal agencies to the public. Definitions are continually confused or misused and these can frequently become "hot-button" issues which can wreak havoc on project schedules. A consistent and clear definition of all types of demand, including induced and latent demand, is critical for the analyst to evaluate and communicate their potential effects. This section explains the different definitions of travel demand, the relevant context and background surrounding them, and how to analyze the effects of various projects on demand.

This section applies to all projects especially those with applicable National Environmental Policy Act (NEPA) classifications (i.e. Categorical Exclusion, Environmental Assessment and Environmental Impact Statement). It also applies to transportation system plans and ODOT corridor, facility and refinement plans. Transportation Planning Rule (TPR) plan amendment application is optional, however, anything that is deemed to have a significant effect and triggering TPR requirements should consider it as induced and latent demand effect questions may arise in the approval process.

Definitions

- **Forecasted (planned) demand** – represents expected demand given forecast land use, economic growth, and the available transportation network, which is based on city and county comprehensive plans and reflected in the zoning code. Assumptions that underlie project alternatives need to be consistent with comprehensive plans. Travel demand models use comprehensive plan land use and transportation availability assumptions to forecast travel demand, which provides housing, economic development, and urban land supply context within the travel model.

- **Latent Demand** - this is demand for transportation that consumers do not utilize because they cannot afford the cost or it is not currently available. Latent demand responses are typically associated with network limitations, such as capacity constraints, incomplete networks for non-auto modes, sub-optimal operational performance, travel time costs and reliability on a specific route. Network investments that resolve limitations impact the cost of using a route and generate potential change in system use – shifting routes, time of day, mode choice, and destinations. System investment that reduces travel time and cost may result in users changing their use of the system. For example, trips that have shifted the time of day that they travel may move back into the peak hour. Trips that

diverted to other travel routes may shift back to the improved route. Latent demand is also referred to as *pent-up demand* in the field of economics. Latent demand does not include induced demand.

- **Diverted demand** – this is a common term that defines one aspect of latent demand. These terms may be used to describe the same phenomenon. This is existing system demand diverting from typical patterns related to routes and time of day, and day of week. This is the largest aspect of what typically makes up latent demand effects in Oregon and typically occurs over a short time span as users readjust their travel patterns.

- **Induced demand** – new demand for travel that did not exist prior to the build scenario. This is above and beyond forecasted and latent demand associated with planned land use, it is demand that is the result of changes in land use (zone changes) or economic conditions that create new trips. Induced demand can be identified on a regional scale when there is an increase in demand that cannot be attributed to other types of demand, such as demand diverting from one facility to another. Induced demand typically occurs over a long time span and may relate to land use changes outside of the study area or a reduction in the cost of accessing destinations previously too costly to access.

When reviewing and considering these definitions it is critical to keep in mind that they apply to any travel mode. Most users may typically think of how the auto mode reacts to new transportation infrastructure, but similarly, the walk, bike, transit, or freight modes apply within these definitions.

For example, if an improved bicycle facility is added and bike trips redirect or a mode shift occurs, then that is latent (pent-up) demand for that bicycle infrastructure. If a freight bottleneck is eliminated and brings back diverted freight trips then that is also latent demand. If a large light rail project is built that spurs new transit-oriented-development (TOD) land use changes beyond what was originally planned, then that is induced demand for transit ridership and the other modal trips that come along with that new land use.

The key statement here is that latent and induced are mode-neutral terms. The key difference is whether or not a land use shift is occurring that is different than previously projected (planned) land use growth due to the transportation investment. That transportation investment can be for any mode.

Demand Context

The land-use/transportation/economic relationship is dynamic. Land too expensive to develop now may hit a trigger point in the future that spurs development earlier than expected. Investment (or lack of) in one transportation facility may impact system use region-wide in unexpected ways. Changes in travel behavior can result in users choosing new routes, new times of the day to travel, reducing or adding new trips.

> *It is important to understand why demand exists and its relationship to the transportation system. The purpose of the transportation system is to accommodate movement of people and goods for household and business activity. Investment decisions must take into consideration many statewide goals and objectives, while meeting federal mandates, efficient use of scarce resources and minimizing negative outcomes.*
>
> *Transportation users represent a large set of individual decision makers with their own goals and objectives related to personal travel, business travel and freight movement. Households choose where to live in order to meet accessibility needs, such as access to jobs, schools, shopping and recreational activity within their budgets for time and money. Businesses locate in order to access goods and services they need for their business, acquire workers, and reach customers within their budgets for time and money. Meeting these economic needs results in demand for transportation locally, regionally, nationally and internationally.*

In general, Oregon faces low risk related to induced demand because of the state's strong land use laws, which exist to prevent sprawl. Changes to land use must be approved by local jurisdictions, so a facility project cannot induce demand just by itself. However, it should be noted that a presence of a new facility regardless of jurisdiction could increase pressure on the land use and or economic trigger/tipping points. Local jurisdictions could approve future zone changes above the forecasted demand in response to economic development pressures, for example, so most of the backstop against future demand effects will fall to local governments. Dense land use developments built in response to improved multimodal facilities (e.g. high frequency/capacity transit) could end up producing more vehicle trips (as not all new residents would use transit) than in the original planned uses.

> *Land use planning in Oregon consists of a system of laws and government collaboration after voters approved the overall framework in 1973. This statewide coordination process now preserves vast areas of land for farm and forest production, protects habitat, conserves natural resources, and protects air and water, all while continuing to allow development of land for homes and businesses. Comprehensive land use planning in Oregon is based on 19 statewide land use goals, including transportation.*

Travel demand models are designed to represent behavioral changes in response to infrastructure investments within the context of forecasted/planned land use, because travel involves many different users with different transportation needs. Changes to the system via plans and projects that affect user cost (time and money) will impact demand. The challenge is to predict what the net impact will be on the system and determine whether mitigation to manage negative impacts is called for.

It is important to assess whether there is forecast risk associated with induced and latent demand. Measuring the two individually is not actually necessary, because the objective is to identify unexpected future demand with potential to impact the project design needed to accommodate future traffic volumes. However, measuring them individually may be necessary to answer specific questions or project-area concerns or to be proactive against future review. Generically, this is based on comparing model assignments between the future build alternative and the future no-build scenario, within the context of the same land use forecast from local comprehensive plans.

Analyzing for Induced Demand

Induced demand is typically land-use-based and occurs over a long time span, making it more difficult to assess for its potential impacts. Uncertainty associated to land use comes from multiple areas. Some impacts may arise from development occurring outside of the study area generating new trips through the study area. While the roadway jurisdiction has influence over some factors (e.g. roadway network improvements or lack of) that could contribute to induced demand, local agencies have greater influence through land use planning, economic development, and local transportation investments. As the state economy continues to grow, more people and businesses will lead to increased demand on the transportation system. How those trips are made, and the overall uncertainty surrounding them, will be governed by geography, land use, and the economy as well as the cost, convenience, and availability of different modes.

There are some considerations that should be assessed on a project/plan and/or alternative basis:

- Areas that are under development pressure from nearby larger urbanized areas;
- Areas within the study area close to development "trigger points" where changes to local market forces or economic factors (rents, development costs, energy costs, regulations) may induce development earlier than expected;
- Land-use zoning changes may attract development of a different form than expected with the original zoning, potentially inducing new travel demand;
- Evidence of systemic congestion with relatively high (12+) Average Daily Traffic to (hourly) Capacity (ADT/C) ratios (see Chapter 9) but with limited potential for diverted demand

A screening-level prediction of induced demand impacts can be done by running an unconstrained (i.e. infinite capacity) model assignment. This will indicate the paths, routes, and mode choices that drivers would want to use if capacity was not an issue. More information on unconstrained demand model runs are in Chapter 17 (Section 17.4). A related topic that usually comes up when discussing demand is determining what trips are local versus what is regional or long-distance through trips. This can be done using a series of select-link analyses and zones grouped into districts (see Sections 10.8.2 and 17.4).

This unconstrained assignment would be compared with the regular capacity-constrained assignment by comparing the total amount of volumes on key links or across screenlines summing across multiple facilities surrounding the project study area. This could indicate an induced demand potential if the unconstrained assignment was 10% or higher over the constrained scenario at those locations. This would show the potential for attracting additional volume into the study area if capacity was improved. There could be latent demand effects mixed in so actual project induced demand potential for reporting out would require a more specific analysis using the Oregon Statewide Integrated Model (SWIM).

SWIM can be used to evaluate the induced demand potential for changing land use and related economic conditions over time based on either a no-build or a build alternative scenario. Any build scenarios should be constructed to be as consistent as possible to the urban travel demand model scenario, keeping in mind that some models will have more detail than is possible in SWIM. Minor features and/or roadways may not be capable of being included within a SWIM scenario, however, the absence will likely be insignificant compared to the regional aspect of this analysis. SWIM can also be used to evaluate for induced demand effects in urban areas not covered by a travel demand model. See Sections 7.4 and 17.2.4 for more information on SWIM. Section 7.4.5 contains an example of an application that was done for determining the potential for any induced demand effects on the roadway system, land use or the economy for Newberg-Dundee Bypass.

STOP *There are some available high-level induced demand calculators available such as from the National Center for Sustainable Transportation (University of California at Davis) or variants developed for other areas. These are simple calculators that use a proportional relationship between empirical gathered lane miles and vehicle-miles traveled for different roadway types and geographies along with an elasticity constant. The use of these calculator types shall not be used to estimate induced and latent demand effects on ODOT-funded projects as they are inappropriate for use in Oregon.*

These do not take land use, location within the regional network, economics, population/demographic changes, route shifting, trip purpose, extra space needed to accommodate complex merging and weavings, or any specific improvement details into account nor do they consider the impacts of Oregon's land use planning laws to prevent sprawl effects. Latent demand is mixed into these and called "induced" in attempts to simplify. As such, it is unlikely that the results will be consistent with approved evaluation tools such as SWIM and will be potentially misleading.

Analyzing for Latent Demand

Latent demand can occur where the future no-build demand has reached or exceeded capacity, and a portion has shifted to other routes, destinations, modes, or time periods to avoid congestion. Once the facility is at capacity, peak hour volumes no longer increase over time, while latent demand may continue to grow.

As was done with screening for locations of induced demand potential, the same may be done for latent demand using an unconstrained model assignment. This will indicate the paths and routes that drivers would want to use if capacity was not an issue. If large shifts in volume are noted from going from one facility to another, then the destination facility, if improved by a build alternative, would likely be a location impacted by latent demand. The scope of the build alternative will determine how large the latent demand shift could be. This scoping test could be used to help size alternatives if latent demand shifts are an issue as it is possible to add too much improvement which shifts too many or the wrong type of trips (e.g. short local trips moving onto the highway facility meant for through or regional trips).

When a build alternative alleviates the congestion, a portion of the shifted demand may return, which is reflected by an increase in the future build volumes. Alternatives that add capacity to a system that is at or over capacity, especially in an urban area, should be checked for the potential for latent demand. Areas with persistent or systemic congestion (indicated by ADT/C ratios of 12 or more) could be also checked across the peak and off-peak periods if the model used was compatible.

Determining any latent demand effects may be facilitated by requesting a plot from a small urban or regional travel demand model that compares the build and no-build scenarios (e.g. showing the absolute differences or relative percentages) for each directional link. If the volume difference on each link is not significant, i.e., less than 10%, then the future no-build DHVs may be assumed to be the future build DHVs. If the difference is 10% or higher (meaning there appears to be a latent demand effect), the appropriate growth or difference post-processing method should be determined and applied to the future no-build DHVs as shown in either of the two processes shown below.

Documentation Needs

If analysis is done to analyze for induced and/or latent demand then this needs to be discussed in the future volume development section of the memorandum or report narrative. The results of the analysis whether it meets the significance thresholds or not must have the determination stated and clearly explained. This is especially important for documentation that will be eventually added to environmental assessments and environmental impact statements as this will be an area that federal, state, and local agencies as well as members of the public, and advocacy groups will cover closely in their review. Supporting calculations, plots, etc. should be available in appendices or in the technical records for future reference.

There should be, at the very least, a qualitative discussion with regional planners of the potential for induced and latent demand impacts in the appropriate documentation, if no model runs are performed. As a reminder, any federal or state transportation planning efforts in Oregon need to adhere to the urban growth boundary and current comprehensive plan zoning when considering land-use effects. It would also help to include language in summary statements such as, "changes to future land use beyond the comprehensive plan assumptions used could cause the future year volumes to be realized earlier which may impact the overall design life of the project alternative", which infers this uncertainty in the forecast.

Basic Steps - Build Alternatives

The basic steps to developing future Build link volumes links are outlined below.

1. Start with Future No-Build DHV directional link volume set.
2. Review the Build Alternative assignment plots to see whether any manual reassignments are needed.
3. Compare the model future No-Build and Build scenarios for latent demand effects. [*Note that No-Build as used here may not be the exact same scenario as the typical Model No-Build that does not have any projects included. The requested output needs to have the appropriate projects identified and included in the scenario run.*] To facilitate comparisons, difference plots (between Build and No-Build scenarios) may be obtained. An unconstrained model run (infinite link capacity) should be obtained to help screen for the potential for induced or latent demand effects. If differences are less than 10 percent, no further adjustments are needed and No-Build DHVs may be used for Build DHVs. Otherwise, proceed to next step.
4. If the potential for induced demand exists, the screening for it using an unconstrained model run should be performed. If the screening indicated the potential for changes greater than 10% then the Build scenario should be assessed for induced demand in the Statewide Integrated Model (SWIM). Apply any percentage adjustments to applicable facilities for potential induced demand effects.
5. Adjust model year volumes to match project future year. The model future year must be adjusted up or down to match the project future year.
6. Apply growth and difference equations between No Build and Build scenarios (see examples below). For each directional link, select growth, difference or averaged methods following the guidance provided previously. This will result in preliminary directional link volumes.
7. Use screenlines to determine volumes on any links that are not in both No-build and Build model scenarios
8. Calculate the inflows and outflows at each intersection based on link volumes. Determine the difference between the flows. The inflows and outflows must be equal for each intersection. Split the difference (typically 50-50) to each of the flows by increasing or decreasing link volumes in proportion to the total flow volume.
9. Determine intersection turn movements using a tool such as TurnsW32.
10. Re-balance network and round volumes to obtain Future Build DHVs.

Growth Method:

1. Divide the Future Year Build model scenario volume by the Future Year No-Build model scenario volumes to derive the factor.
2. This factor is then multiplied by the Future Year No-Build Design Hour Volume to arrive at the Future Year Build Design Hour Volume (DHV).

Example 6-19 Post-Processing – Growth Method, Build

- Example: 2025 Build DHV = (2025 Model Build/ 2025 Model No-Build)* 2025 No-Build DHV
- If the 2025 Model No-Build had 800 vph, the 2025 Model Build had 1,000 vph and the 2025 No-Build DHV had 1600 vph, the growth method using a simple linear method would be:

2025 Build DHV = (1000/800)* 1600 = 2,000 vph

Note in this case, for this particular link, the 2025 Model Build scenario was 20% greater than the 2025 No-Build scenario. Use of the no-build volumes for the build volumes is not permitted as the change is greater than 10% and so a new build volume forecast is necessary. The difference may be due to a latent demand shift if it is above and beyond any pure re-routing impacts because of physical network changes (new or removed roadways.)

Difference Method:

1. Subtract the Future Year No-Build model scenario volume from the Future Year Build model scenarios volumes *(Note: this change in volume can be either positive or negative)*.
2. Add the difference to the Future Year No-Build Design Hour Volumes (DHV).

Example 6-20 Post-Processing – Difference Method, Build

2025 Build DHV = 2025 No-Build DHV + (2025 Model Build - 2025 Model No-Build)

Using the same numbers from the growth method above, using the difference method would be: 2025 Build DHV = 1600 + (1000 – 800) = 1,800 vph.

Like with Example 6-19, the build volume is greater than a 10% change over the no-build volumes which could indicate a potential impact from latent demand.

6.12.3 Screenlines

Screenlines can be used for calculating overall growth rates or used for calculating volumes on new links (links that only exist in one of the scenarios that you are comparing).

Screenlines are useful where there are significant differences in growth within the study area. Screenlines should be strategically placed to cross the major links of the different

growth areas. Screenlines are drawn the same in both the base model year and the future model year on the model volume plots. The link volumes crossing each screenline are summed. The summation of each future screenline is divided by the corresponding base screenline summation. This provides the growth rate for the different areas cut by the screenlines.

New Links

The main use of screenlines is to determine the future design hour volume of links that exist only in one scenario. This comes up when a new route is added to a scenario. This can occur with both future no-build and build alternative scenarios.

Example 6-21 Post-Processing – Use of Screenlines

For example, assume a roadway network in the future no-build year had two north-south links at Main Street and Elm Street, but a build alternative added a new north-south link at Oak Street for a total of three north-south links. The analyst has the model outputs for the scenarios with and without the new connection and the future no-build DHV diagram (without the connection).

1. Draw a screenline across Main and Elm Streets in the future no-build model scenario, and sum up the future no-build model volumes for each street as well as the total north-south future model volume.

Future No-Build Model Scenario

Main Street Total = 450 + 400 = 850 vph
Elm Street Total = 300 + 350 = 650 vph
Total North-South Volume = 850 + 650 = 1500 vph

2. Draw a screenline across Main, Elm and (new) Oak Streets in the build alternative scenario and sum up the build alternative model volumes for each street as well as the total north-south build alternative model volume. Calculate the street (link) splits and directional (northbound and southbound) splits for all three streets.

Build Alternative Model Scenario
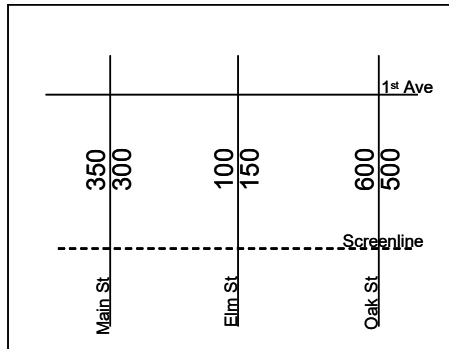
Main Street Total = 350 + 300 = 650 vph
Elm Street Total = 100 + 150 = 250 vph
Oak Street Total = 600 + 500 = 1100 vph
Total North-South Volume = 650 + 250 = 2000 vph

Note: in this example, the build alternative scenario pulls in 33% more traffic (2000 vph vs. 1500 vph) than the future no-build model scenario. This is a result of previously diverting traffic returning to the route that it wants to use. In this case the analyst must use the build alternative model scenario to create the future design hour volumes. If the difference was less than 10%, then the analyst could use the future no-build volume distributed on the build network.

Link Split Calculation:
Main Street split = 650/2000 = 0.325 (32.5%)
Elm Street split = 250/2000 = 0.125 (12.5%)
Oak Street split = 1100/2000 = 0.55 (55%)

Directional Splits Calculation:
Northbound Main Street = 300/650 = 0.46
Southbound Main Street = 1 – 0.46 = 0.54
Northbound Elm Street = 150/250 = 0.60
Southbound Elm Street = 1 – 0.60 = 0.40
Northbound Oak Street = 500/1100 = 0.45
Southbound Oak Street = 1 – 0.45 = 0.55

3. Draw a screenline across Main and Elm Streets in the future DHV diagram, and sum up the total future DHV volumes for each street as well as the total future north-south DHV volume.

Future No-Build DHV
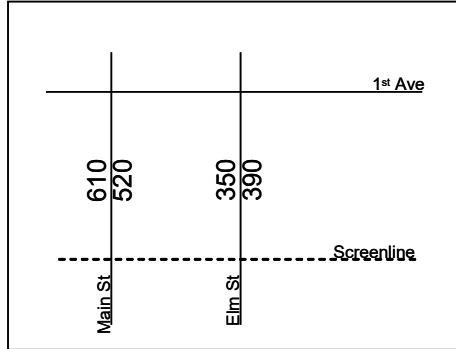
       Main Street Total = 610 + 520 = 1130 vph
       Elm Street Total = 350 + 390 = 740 vph
       Total North-South Volume = 1870 vph

4. Calculate the total north-south build alternative DHV by creating a ratio by dividing the build alternative screenline grand total (Main/Elm/Oak Streets) by the future screenline grand total (Main/Elm Streets) and then multiplying this ratio with the future DHV screenline total (Main/Elm Streets).

       General equation form:

$$\frac{Build\ Alternative\ Model}{Future\ No-Build\ Model} = \frac{Build\ Alternative\ DHV}{Future\ No-Build\ DHV}$$

       Modified equation to solve for the total Build Alternative DHV:

$$Build\ Alternative\ DHV = \frac{Build\ Alternative\ Model}{Future\ No-Build\ Model} \times Future\ No-Build\ DHV$$

       Build Alternative DHV = (2000/1500) x 1870 = 2493 vph

5. Using the Build Alternative DHV (from Step 4) and the link splits (from Step 2), determine the volumes for each of the streets. Oak Street would be calculated by:
       Build Alternative DHV (Oak) = Oak Street split (from Step 2) x Build Alternative DHV total (from Step 4)

       Build Alternative DHV (Oak) = 0.55 x 2493 = 1371 vph
       Build Alternative DHV (Main) = 0.325 x 2493 = 810 vph
       Build Alternative DHV (Elm) = 0.125 x 2493 = 312 vph

6. Compute the directional DHV for each street by applying the directional splits from Step 2 to the DHV totals for each street calculated in Step 5.

Future Build DHV
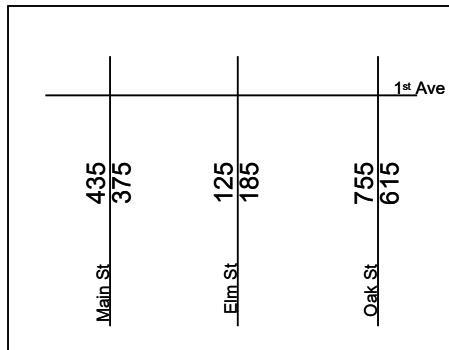
Main Street DHV (NB) = 0.46 x 810 = 373 vph (rounded to 375)
Main Street DHV (SB) = 0.54 x 810 = 437 vph (rounded to 435)

Elm Street DHV (NB) = 0.60 x 312 = 187 vph (rounded to 185)
Elm Street DHV (SB = 0.40 x 312 = 125 vph

Oak Street DHV (NB) = 0.45 x 1371 = 617 vph (rounded to 615)
Oak Street DHV (SB) = 0.55 x 1371 = 754 vph (rounded to 755)

6.12.4 Turn Movements

Once all the link volumes have been determined from the standard or screenline post-processing methods, turn movements need to be calculated for each intersection.

Intersection volumes are represented at the turning movement level. It is important to note that the model is built and calibrated at the link level, not the turn level. Turn movement outputs from the model shall not be used directly in software for analysis. TPAU will not provide turning movement volumes for model requests; as they are typically misused to directly post-process turn movement volumes instead of following the link based post-processing procedure. Turn volumes should be developed from post-processed link volumes according to the procedures below.

Base Year turn movements should follow ground count patterns unless projects or other network differences are present in which case turn percentages are obtained from select-link runs. Future Year Turn movement percentages can be determined from select-link runs.

Future No-Build Turn Volumes

The volume of traffic entering each intersection must balance with the traffic leaving the intersection. If an imbalance exists, then inflow/outflow volumes will need to be balanced proportionally.

Typically the future no-build turning movement volumes are the same as the existing (base) year movements with a growth factor applied. Impacts from other projects should show up in the future no-build model run, and would impact the growth rate or methodology used to calculate the future no-build design volumes.

There are times when another project is expected to impact the travel patterns in the study area, and the turning movements would have to be manually adjusted to reflect this. The turning movement percentages provided by the Future Year No-Build model select link runs can help point out some of these impacts. *(Note: A capacity constrained demand model should indicate the shift in travel patterns and the directional link volumes from the model should be used as a starting point to arrive at a future DHV. Arriving at a post-processed set of volumes requires a method such as described above or in NCHRP 765).* The origin and destination matrix can also be a helpful tool to obtain the distribution of trips between zones. Model runs with and without committed/STIP projects can be run to determine the impacts, if any, from nearby financially constrained future projects. After turn movements have been developed, the network needs to be re-balanced and volumes rounded to obtain Future No Build DHVs.

Future Build Turn Volumes

At this point the directional design hour volumes have been calculated for each link so the intersection approach volumes are known. The volume of traffic entering each intersection should balance with the traffic leaving the intersection. If an imbalance exists, then inflow/outflow volumes will need to be balanced proportionally.

Build turning movements are a combination of the known travel pattern changes and the existing turning movements. Model select-link assignments can be used as a starting place. Select-link plots will need to be requested to verify or modify the turning percentages. Developing the build turning movements in some cases is not a straightforward process. It may involve looking at all the possible movements and using the best judgment and knowledge of the area. Changes to turn volumes are also made as the intersection is balanced to hold the link volumes. The link volumes need to be held as much as possible to preserve the future growth ratios and/or differences. After turn movements have been developed, the network needs to be re-balanced and volumes rounded to obtain future Build DHVs.

There are matrix-based programs such as Turns W32 that assign turning volumes based on the link volume. These automate the NCHRP Report 765 Chapter 5 (Fratar volume balancing method) turning movement process, which can save considerable time over a hand calculation. The intersection approach link volumes and the exiting link volumes

are entered. The programs typically assume that more traffic is attracted to the higher volume links and will weight the movements accordingly. The program goes through an iterative process to closely match the data that were entered. Most of these matrix-based programs require that inflows equal outflows for each intersection. If an imbalance exists, then inflow/outflow volumes will need to be balanced proportionally.

Turns W32

Turns W32 is a tool developed by Dowling Associates, Inc., which converts directional link volumes into turn movement volumes at intersections. Prior to use, flows in and out of the intersection must be balanced so that inflows equals outflows.

Exhibit 6-14 Turns W32 Screen
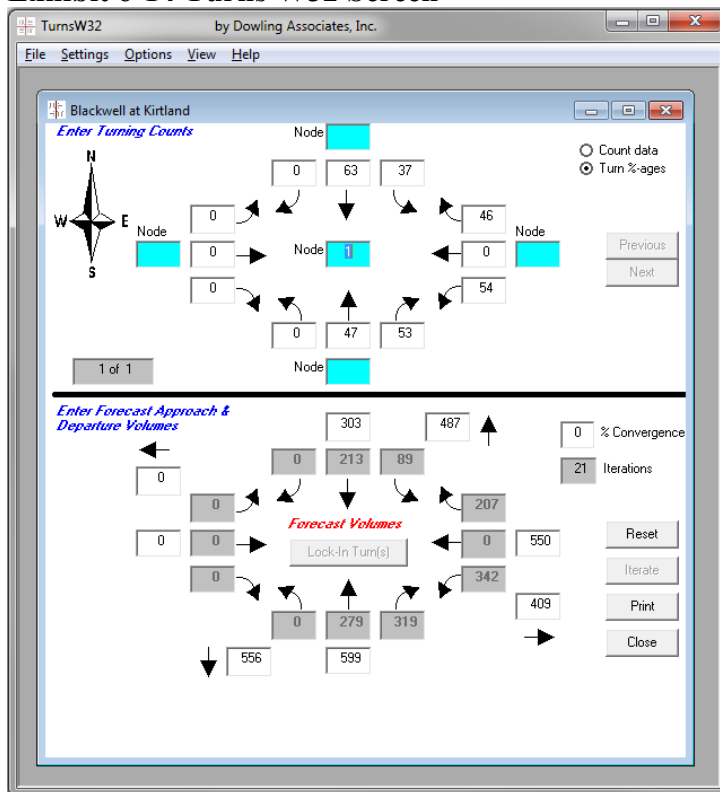
As shown in Exhibit 6-14, turn percentages are input into the upper part of the screen in Turns W32 rather than actual turn movement volumes. Preliminary future link volumes with balanced inflows and outflows are input on the lower part of the screen. The program will not process unbalanced inflows and outflows. The convergence value should be set to 0 percent. This value represents the tolerance between successive iterations. A solution is achieved when the results of iteration differs less from the results of the previous iteration by this value. After iterating, the lower screen displays the preliminary future year turn movements. These turn movements need to be adjusted in the final step, which is to re-balance the network while holding the model link growth values as much as feasible.

Example 6-22 Turns W32

This example is based on the previous post-processing spreadsheet application shown in Exhibit 6-13. It is desired to determine Future Year turn movement volumes at the intersection Blackwell Road at Kirtland Road. In this example, Kirtland at Blackwell Road is a tee-intersection. Future year directional link volumes at the intersection have been previously determined and are shown in the intersection diagram below.

Initial Future Year Directional Link Volumes

Initial Future Volumes
Unbalanced

301	490
0	547
0	412
559	595

The first step is to ensure that the directional link volumes produce equal intersection inflows and outflows at the intersection, and to adjust them if they do not. In this case, the inflows are greater than the outflows. As shown in the table below, the inflows total 1443 and the outflows total 1461. Typically, an average of the two values is used.

In this example, the average of the inflows and outflows is 1452. Individual directional link volumes are then adjusted as follows for the EB outflow.

Initial EB outflow = 412.
Proportion of total outflows = 412 / 1461 = 0.28
Reduction needed = 1461 – 1452 = 9 vph
Adjustment = 0.28 x 9 = 2.5 ~ 3 vph
Adjusted outflow = 412 – 3 = 409

The adjusted intersection inflows and outflows are shown in the table below.

	Initial Future Volume		Adjusted	
	Inflow	Outflow	Inflow	Outflow
EB	0	412	0	409
WB	547	0	550	0
NB	595	490	599	487
SB	301	559	303	556
Total	1443	1461	1452	1452
Average	1452			
Difference	9	-9		

The next step is to determine the initial turn movement percentages. In this example, the Base Year 2008 turn movement percentages are used. These turn percentages are summarized in the table below.

Direction	Movement	2008 30 HV	Movement Percent of Approach Volume
EB	Left	0	NA
EB	Thru	0	NA
EB	Right	0	NA
WB	Left	215	54%
WB	Thru	0	0%
WB	Right	180	46%
NB	Left	0	0%
NB	Thru	220	47%
NB	Right	245	53%
SB	Left	95	37%
SB	Thru	160	63%
SB	Right	0	0%

The final step is to input the balanced directional link volumes and the turn percentages into Turns W32. As shown in Exhibit 6-14, the turn percentages are entered into the upper half of Turns W32, while the balanced directional link volumes are entered into the lower half. The percent Convergence is set to **0%**. Upon selecting Iterate, the program computes and displays updated turn movement volumes and directional link volumes. The analyst may need to make further adjustments to turn movements as part of re-balancing of the network.

6.12.5 Automated Post-Processing

Certain software tools perform post-processing internally. However, no tool can substitute for the need to manually check results for reasonableness. The analyst should have a good understanding of the internal methodology used in the software.

VISUM has an internal post-processing module. TPAU evaluated VISUM 10.0 by comparing its outputs to the manual method. VISUM provides an acceptable level of post-processing to determine preliminary link volumes. These volumes are sufficient for sketch planning level analysis or as input to further manual post-processing of turn movements for facility level analysis. However, VISUM's internal turn movement post-processor was found to be inconsistent with the manual procedure since it does not balance intersection inflows and outflows prior to determining turn movements. For facility level analysis VISUM internally post-processed link volumes can be used if turn movements are post-processed manually.

There are other proprietary products from consultants (JRHMoves from JRH Engineering and Furness from CH2MHill) that have been evaluated and found to be consistent with NCHRP 765 for links and turn moves.

6.13 Forecasting Truck Volumes for Pavement Design

Because pavement design is based on the number of axle-loadings experienced on the roadway, heavy vehicle information needs to be furnished in a specific format. The pavement designer will contact the project traffic analyst for this truck information. The Pavement Services Unit (PSU) does all of the pavement designs for all ODOT projects, unless consulted out. Most of these projects are small operational improvements, pavement preservation or bridge replacement projects.

Pavement design volume requests either are at a scoping or project-specific level. All scoping-level requests are done internally by the PSU. A project-level request will need to be done by the project traffic analyst who could be a region project analyst, a consultant, or a TPAU analyst. These requests should be routed through the Transportation Systems Monitoring Unit (TSMU). TSMU will then forward the request to the appropriate project leader and then from there to the project analyst.

Requests of heavy vehicle volumes are e-mailed by PSU. These requests should include the project name, project limits, project type (scoping or project-level) highway name, and route number. They should also include any special needs such as breakouts on one-way facilities.   In addition, the analyst should discuss factors that may influence the outputs and therefore the design with the pavement design staff involving the pavement designer. The discussions can help clarify the level and precision of the data required which may streamline the process.

Responses are typically transmitted via e-mails with a spreadsheet-formatted attachment showing: current and 20 year future Average Daily Traffic (ADT), a 20-year growth factor, and the current heavy vehicle volume by class (see Exhibit 6-16). If one-way ADT is requested, state direction and intersection leg, if applicable.

General information and special considerations

General truck growth rates are assumed to mirror the overall growth rate on a segment as calculated by methods described previously in this chapter. Vehicle classification specific growth rates are not available due to the lack of commodity and routing information. The trucking industry introduces new products, with different axle configurations, which have insufficient highway count data.

Before reporting out any data, the analyst should verify that there are no special considerations that need to be accounted for such as having count information that may reflect an average and not a typical vehicle mix. Sometimes a specific generator may not be directly accounted for that might require splitting a segment. Other considerations might include:
- Variations in vehicle classifications that are not accounted for such as vehicles with drop-axles that change the vehicle classification or the different configuration for a logging truck – 5-axle loaded logging trucks versus a 3-axle when the empty trailer is piggy-backed.
- Having a count taken in the summer on a route that services a local school, so it is missing the school bus volumes.
- Heavy generators such as mills, industrial areas, distribution centers, truck stops, or intermodal transfer facilities
- Periodic users, such as material/construction sites, logging or agricultural

The Federal Vehicle Classifications are shown in Exhibit 6-15. All vehicles are classified into one of the 13 categories. For example, class 6 is described as 3-axle, single unit which can be reported out as shown in Exhibit 6-16 with the information including the number of axles and trailers of each class. The truck volumes are also shown.

Exhibit 6-15 Federal Vehicle Classifications
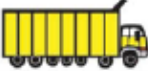
Class		Class	
Class 1 Motorcycles		**Class 7** Four or more axle, single unit	
Class 2 Passenger cars			
		Class 8 Four or less axle, single trailer	
Class 3 Four tire, single unit			
		Class 9 5-Axle tractor semitrailer	
Class 4 Buses		**Class 10** Six or more axle, single trailer	
		Class 11 Five or less axle, multi trailer	
Class 5 Two axle, six tire, single unit		**Class 12** Six axle, multi-trailer	
		Class 13 Seven or more axle, multi-trailer	
Class 6 Three axle, single unit		8 axle B-train double	
		10 axle resource hauling double	
		Triple trailer combination	

Exhibit 6-16 Example Response Spreadsheet Attachment

Project	Hwy 500 (OR 795) MP 77 - MP 83			
				Count
Class	Descript.	# Axles	# Trailers	2010 Vol
4	buses			18
5	2ax	2		40
6	3ax	3		25
7	4ax	4		2
8	4ax trl	4	1	0
9	5ax trl	5	1	12
10	6ax trl	6	1	4
11	5ax dbl trl	5	2	2
12	6ax dbl trl	6	2	0
13	7ax dbl trl	7	2	0
			Total Trucks	103
Future Volume Tables 2010 AADT = 3000, 2030 AADT = 200				
			% Trucks 3.43% 20-year growth factor = 1.4	

The percent truck calculation is the total number of trucks divided by the base year AADT. For this exhibit this would be 103 / 3000 = 3.43%. The 20 year growth factor is the future AADT divided by the base year AADT or 4200 / 3000 = 1.4.

Process

To prepare the data, knowledge of the highway characteristics in the area is helpful. While a field investigation is likely not practical, use of the ODOT video log, Transviewer GIS or other mapping aide should be used. There likely is more information readily available for use on state highway segments than on local jurisdiction roadways. The general state highway process takes advantage of currently available formatted outputs. The scoping-level process is used for scoping level requests or simpler projects. The project specific process is more detailed. These requests include intersection or straightaway classification counts and may involve local road segments or state highway segments that need special considerations are applied. A spreadsheet calculator, Heavy Vehicle Pavement Design Spreadsheet, has been developed to streamline the process for both scoping and project level request.

6.13.1 Scoping Level

Using the state highway number, milepoint and other locational data, refer to the Traffic Volumes and Vehicle Classification Report available at:

https://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm

This report provides overall and vehicle AADT volumes and vehicle classification by the specified segment. The segments are determined by major intersections and other characteristics. Using this information, enter the following into the output spreadsheet (see Example 6-23) for each identified segment:

- Highway/road name
- Beginning mile point
- Effective date of data
- AADT
- AADT 20-YR
- Volumes for Class 4-13

Example 6-23 Scoping Level Project Forecast

As part of a pavement preservation scoping project process, the section of Highway #7 (US20) from M.P. 40 to M.P. 48, heavy vehicle counts were downloaded from https://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm. The AADT Volume, AADT 20-year Volume, Beginning M.P., and the volumes for Classes 4 through 13 were copied into the Heavy Vehicle Pavement Design Spreadsheet in the Scoping Level tab. The data are shown in the next table and the future forecasted results are shown in the following table.

Project	Hwy 7 (US20) M.P. 40-48			
				Count
Class	Descript.	# Axles	# Trailers	2013 Volume
4	buses	2		22
5	2ax	2		123
6	3ax	3		2
7	4ax	4		0
8	4ax trl	4	1	111
9	5ax trl	5	1	132
10	6ax trl	6	1	29
11	5ax dbl trl	5	2	10
12	6ax dbl trl	6	2	9
13	7ax dbl trl	7 +	2 +	33
			Total Trucks	471
AADTs 2013 ADT = 1200, 2033 ADT = 1300				
			20-year growth factor = 1.08	

Project	Hwy 7 (US20) M.P. 40-48			
				Forecast
Class	Descript.	# Axles	# Trailers	2033 Volume
4	buses	2		24
5	2ax	2		134
6	3ax	3		2
7	4ax	4		0
8	4ax trl	4	1	121
9	5ax trl	5	1	144
10	6ax trl	6	1	32
11	5ax dbl trl	5	2	11
12	6ax dbl trl	6	2	10
13	7ax dbl trl	7 +	2 +	36
			Total Trucks	514

The following example is a relatively simple project level analysis that does not involve local roads or projects with special considerations.

> *While the following example used future forecasts from the Future Volume Tables for the purpose of illustration, the volumes could have just as likely been derived from a cumulative analysis or a post-processed travel demand model. Choice of future forecasting methods is dependent on the study area, the project requirements, and the tools available. See earlier sections in this chapter.*

Example 6-24 Simple Project Level Forecast

As part of a pavement redesign project, a new pavement structure needs to be designed. The pavement engineer on the project first needs to know the heavy vehicle volumes that need to be designed for. The engineer had a 2011 24-hour traffic count available at the project site and recorded the following data from it. The project base year is 2014 with a 2034 future year. The engineer also recorded the 20-year ADT from the Future Volume Tables.

Project	Hwy 2 (US730) M.P. 190 - 195			
Class	Descript.	# Axles	# Trailers	**Count** 2011 Vol
4	buses	2		96
5	2ax	2		475
6	3ax	3		57
7	4ax	4		8
8	4ax trl	4	1	316
9	5ax trl	5	1	724
10	6ax trl	6	1	442
11	5ax dbl trl	5	2	74
12	6ax dbl trl	6	2	38
13	7ax dbl trl	7 +	2 +	245
			Total Trucks	2475
Future Volume Tables 2011 ADT = 2500, 2031 ADT = 2600				
			% Trucks 42.3% 20-year growth factor = 1.04	

The count information and Future Volume Tables' information were entered into the Heavy Vehicle Pavement Design Spreadsheet and the results found recorded from the spreadsheet into the table below.

Project	Hwy 2 (US730) M.P. 190-195			
Class	Descript.	# Axles	# Trailers	**Forecast** 2034 Vol
4	buses	2		101
5	2ax	2		497
6	3ax	3		59
7	4ax	4		8
8	4ax trl	4	1	331
9	5ax trl	5	1	757
10	6ax trl	6	1	463
11	5ax dbl trl	5	2	77
12	6ax dbl trl	6	2	40
13	7ax dbl trl	7 +	2 +	256
			Total Trucks	2589

The Heavy Vehicle Pavement Design Spreadsheet calculator used in this example is shown below.

Heavy Vehicle Forecast for Pavement Design Spreadsheet: Project Level Analysis

Project	Name		APM Example				
	Description		Cold Springs Automatic Traffic Recorder,				
	Additional Identification		Sta. 30-002, Hwy No. 2 (US730): 0.24 mile east of Pendleton-Cold Springs				
	Hwy #		36				
	M.P.		193.70				
	Base Year		2014				
	Forecast Year		2034				

Count	TCM # (If available)	480
	Duration	24 hr
	Factor	1.00
	Year	2011

Future Volume Table	Base Year / Future Year	2011		2033
	Base Year AADT		2500	
	Future Year AADT		2600	
	20-yr Growth Rate (per yr.)		0.18%	

Class	Description	# Axles	# Trailers	2011 24 hr Count Volume	2011 24 hr Count Volume	2014 Base Year Volume	2034 Forecasted Volume
4	buses	2		96	96	97	101
5	2ax	2		475	475	478	495
6	3ax	3		57	57	57	59
7	4ax	4		8	8	8	8
8	4ax trl	4	1	316	316	318	330
9	5ax trl	5	1	724	724	728	754
10	6ax trl	6	1	442	442	444	460
11	5ax dbl trl	5	2	74	74	74	77
12	6ax dbl trl	6	2	38	38	38	39
13	7ax dbl trl	7	2	245	245	246	255
13	triples	7 +	2 +	0	0	0	0
Total				2475	2475	2488	2578

6.13.2 Detailed Process for Local Roads or Highway Segments with Special Considerations

A more comprehensive process is required when pavement traffic data are needed for non-state facilities or when special considerations exist. This process should also be used when recent classification counts are available. This process is based on intersection or straightaway classification counts.

Note: Additional classification counts may be necessary for longer preservation projects (or where there are no ATR/AVC's on a particular highway) as counts are not typically obtained for this project type.

Identifying Segments

To determine segments on state highways, use the Traffic Volumes and Vehicle Classification Report available at:

https://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm.

Break roadway into segments if AADT volumes change by more than twenty percent (20%). These initial segments need to be reviewed to see if the truck classifications (4-13) change by more than ten percent (10%). The higher classifications have more impacts of the road surface (since these are the heavier vehicles and/or have multiple axles). Note that the review needs to consider where an absolute number versus the percent change is significant. If there are questions whether a change is significant, the analyst should work with the pavement designer to determine if the segment break is necessary. The analyst needs to put greater importance on changes to the higher classifications. For example, an increase of five triple-trailer trucks (class 13) could cause a 50-100% increase with greater impacts than a 50% increase in delivery/ panel trucks (class 5). When this occurs, the analyst may need to subdivide the segments to better identify the truck volumes.

For local roads, using the count/classification available, determine volumes at different points in the project. Break into sections if volumes change by more than twenty percent (although this changes on a case by case basis) or the project includes more than one highway. While the project may involve only one road, there may be differences in heavy vehicle volumes on each side of a major intersection or urban/rural environment change. A change, such as road classification, may not be reason to split a section, but may be a good place to look for a difference in heavy vehicle volumes. When a count is not available on a specific roadway, counts from similar facilities that serve the same areas may be used as a basis for an educated assumption of the truck percentages.

Count Data

To forecast truck volumes, obtain a 24-hour (less than three years old) full classification count(s) within or near the project. Since truck volumes typically increase overnight as a percent of total vehicles, every attempt should be made to obtain a 24-hour count. If the project has an Automatic Vehicle Classifier (AVC), then those data can be used as a count. Internal staff may look in OTMS. Consultants should contact the TSM staff. If a recent count is not available, and time permits, a full classification count could be requested. Counts on interchange ramps do not have classification data unless specifically requested (such as a freeway to freeway interchange where there are not any ramp terminal intersections), so this is generally obtained from a ramp terminal intersection count.

Determining Classification Volumes

For each intersection count, total the volumes by class for each leg that data are desired. A full classification count is shown in Exhibit 6-17.

Exhibit 6-17 Traffic Count Sheet

Axle Factor Report
10/13/2009 Through 10/13/2009

Intersection ID: 22032009 Date: 10/13/2009
County: Linn Hour: 6:00 AM - 10:00 PM
City: Albany Legs: Burkhart St. (SB), OR99E(Paciifc Blvd.) (WB), Burkhart St. (NB), OR99E(Pacific Blvd.) (EB)
LRS ID: 05800100 Location: Burkhart St. at OR99E(Paciifc Blvd.) and OR99E(Pacific Blvd.)
LRS Location 1.24 Notes: Weather: Clear

Leg	From To	Motorcycle	Car	Lt Truck	Bus	Single Unit Truck			Single Trailer Truck			Multi Trailer Truck			Total All
						2 Axles	3 Axles	4+ Axles	4- Axles	5 Axles	6+ Axles	5- Axles	6 Axles	7+ Axles	
East	East-North	1	1254	291	7	8	1		6	3	1			3	1575
	East-South		341	160	1	10			1	1					514
	East-West	10	6727	1999	59	158	38	2	28	94	68	2		15	9200
	North-East	1	931	299	3	13	1		5	5					1258
	South-East		349	146		6				1					502
	West-East	9	6503	1941	57	145	38	2	38	111	74		1	10	8929
	Total	21	16105	4836	127	340	78	4	78	215	143	2	1	28	21978
	Azle Factor	1	1	1	1	1	1.5	2	2	2.5	3	2.5	3	3.5	0.965
	Vehicle Over	21	16105	4836	127	340	117	8	156	538	429	5	3	98	22783
North	East-North	1	1254	291	7	8	1		6	3	1			3	1575
	North-East	1	931	299	3	13	1		5	5					1258
	North-South	2	1138	427		9	4			1				4	1585
	North-West		34	7											41
	South-North	1	948	367	4	12	1		2	3	1				1339
	West-North		61	25	1	3	1								91
	Total	5	4366	1416	15	45	8	0	13	12	2	0	0	7	5889
	Azle Factor	1	1	1	1	1	1.5	2	2	2.5	3	2.5	3	3.5	0.991
	Vehicle Over	5	4366	1416	15	45	12	0	26	30	6	0	0	24	5945
South	East-South		341	160	1	10			1	1					514
	North-South	2	1138	427		9	4			1				4	1585
	South-East		349	146		6				1					502
	South-North	1	948	367	4	12	1		2	3	1				1339
	South-West		115	36		1									152
	West-South		195	86	1	4									286
	Total	3	3086	1222	6	42	5	0	3	6	1	0	0	4	4378
	Azle Factor	1	1	1	1	1	1.5	2	2	2.5	3	2.5	3	3.5	0.994
	Vehicle Over	3	3086	1222	6	42	8	0	6	15	3	0	0	14	4405
West	East-West	10	6727	1999	59	158	38	2	28	94	68	2		15	9200
	North-West		34	7											41
	South-West		115	36		1									152
	West-East	9	6503	1941	57	145	38	2	38	111	74		1	10	8929
	West-North		61	25	1	3	1								91
	West-South		195	86	1	4									286
	Total	19	13635	4094	118	311	77	4	66	205	142	2	1	25	18699
	Azle Factor	1	1	1	1	1	1.5	2	2	2.5	3	2.5	3	3.5	0.961
	Vehicle Over	19	13635	4094	118	311	116	8	132	512	426	5	3	88	19467

For each leg, there should be a total for each classification (4-13). Note this needs to include both directions (all the "to" and "from") on the approach. This means that at a 4-legged intersection there are six movements to be summed. Once the table is filled out, the columns must be totaled to report the number of trucks by classification. If the manual count is less than 24 hours, an expansion factor (see Exhibit 5-19) needs to be

applied (typically a 1.1 converts a 16-hour count to 24-hour volumes). These classification subtotals are then combined to report the total truck volume(s). The truck total is then divided by the ADT to give the percent trucks. The Heavy Volume Pavement Design Spreadsheet can be used to streamline the individual segment calculations.

Growth Rate

For state highways, record each year and its volume for the road segment from the Future Volume Table (FVT) into the calculation spreadsheet which will compute the growth factor. The analyst will need to review the FVT segments to determine which have appropriate r-squared values and can be averaged together to arrive at a segment growth rate (see Chapter 5).

Off-system growth rates would need to be determined with county or city data (off system data source), such as historical tube counts, travel demand model growth rates, similar facilities or other project information in the area (see Chapter 5). If historical data, state highways with similar characteristics, or a travel demand model does not exist for the particular site, use 2% for rural areas and 1% for urban areas per year.

Appendix 6A – Sample Application of Enhanced Zonal Cumulative Analysis (EZCA)

Appendix 6B – Considering Connected and Automated Vehicles in Future-Year Roadway Capacity Forecasts

Appendix 6C – Supplemental Guidance on Connected and Automated Vehicle Analyses