Teton County Travel Demand Model

technical
report

prepared for

Teton County, Town of Jackson, and WYDOT

prepared by

Cambridge Systematics, Inc.

July 9, 2019

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date

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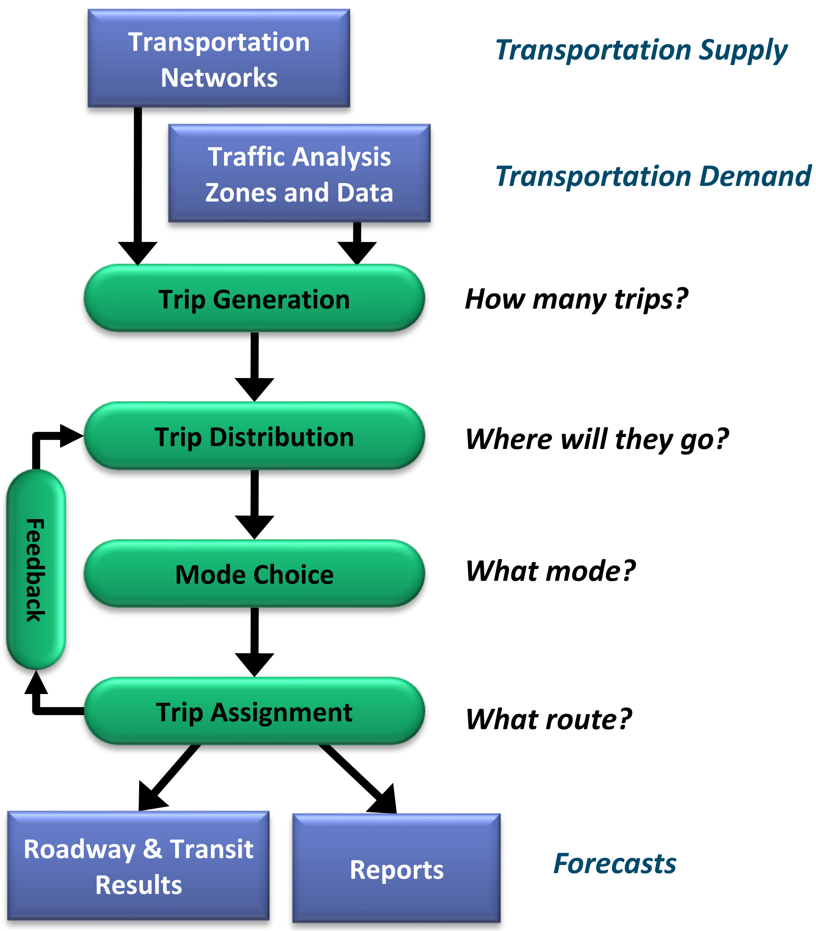
1.0 Introduction

The Teton County Travel Demand Model (TCTDM) is a tool that can aid in planning for transportation improvements by estimating existing travel and forecasting future year scenarios. The TCTDM is a four-step model, as illustrated in **Figure 1.1**, that estimates trip generation, trip distribution, mode choice, and trip assignment for residents, commuters, visitors, and trucks that travel to, from, through, and within the Teton County model area. This document summarizes the inputs to the model as well as its structure and assumptions.

Figure 1.1 Four Step Model Process



2.0 Model Inputs

A wealth of data is used as input to the model in order to explain travel in the region. This includes information on people, households, schools, and employment (socioeconomic data); road, non-motorized, and transit networks (transportation supply); and other characteristics of the region.

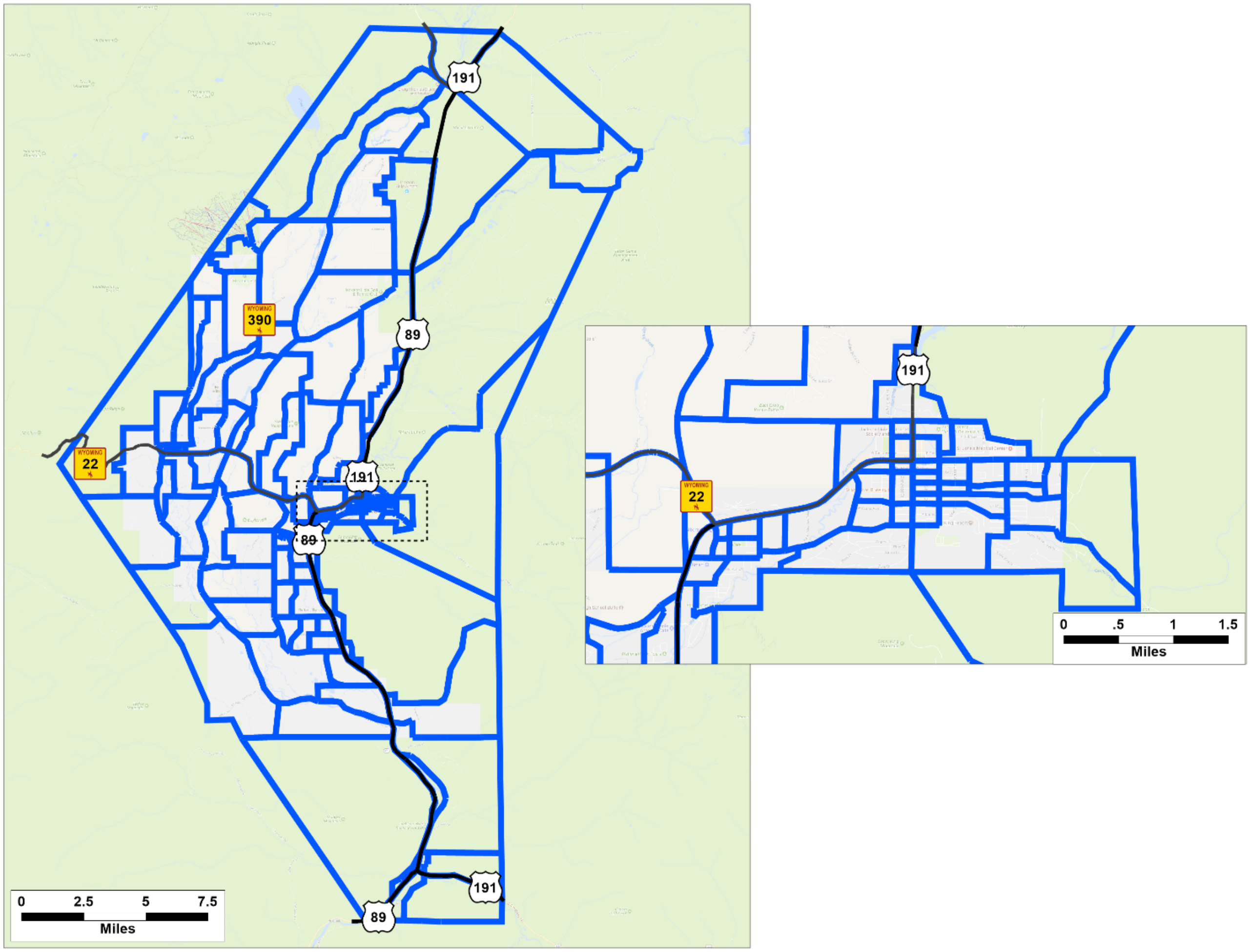
Each of these model inputs represent something that the model is “sensitive” to; meaning, the model can produce estimates that change based on changes to the inputs. For example, the roadway network is an input to the model. Adding capacity to a roadway, removing capacity from a roadway, or building a new connection can be evaluated by the model, which will produce an estimate of the number of people and vehicles using that facility. The model can also evaluate changes in transit service, the non-motorized network, and changes in socioeconomic data. If a change in input assumptions produces a reduction in congestion, the model will estimate updated travel speeds that may be faster than in the baseline (i.e., pre-change) scenario.

2.1 Zone System

The model divides Teton County geographically into zones, called Traffic Analysis Zones (TAZs). These TAZs contain information about the people that live, work, and go to school in these zones. In addition, information about lodging and visitor activities are included in the TAZ dataset. The TAZs for the TCTDM were defined to provide a fine enough level of detail to analyze impacts of changes to transportation network or TAZ inputs.

The Teton County zone system consists of 129 zones internal to the model area, as shown in **Figure 2.1**. During the development of the TAZs, considerations for zone boundaries included physical boundaries, Census block boundaries, the transportation network, past efforts at defining TAZs, and level of development/activity in the zone. The Teton County Transportation Advisory Committee (TAC) reviewed initial versions of the TAZ structure and provided feedback and comments that led to further refinement of the final set of TAZs.

Figure 2.1 Teton County TAZ System



2.2 TAZ Data

TAZ data includes socioeconomic data (SED) inputs to the model include a zonal properties file, which contains information about the population, households, lodging, employment, and school enrollment in each TAZ. The model also requires other data at the TAZ level, including area type and parking cost information. **Table 2.1** lists the required TAZ inputs for the model.

Table 2.1 Input Socioeconomic Data

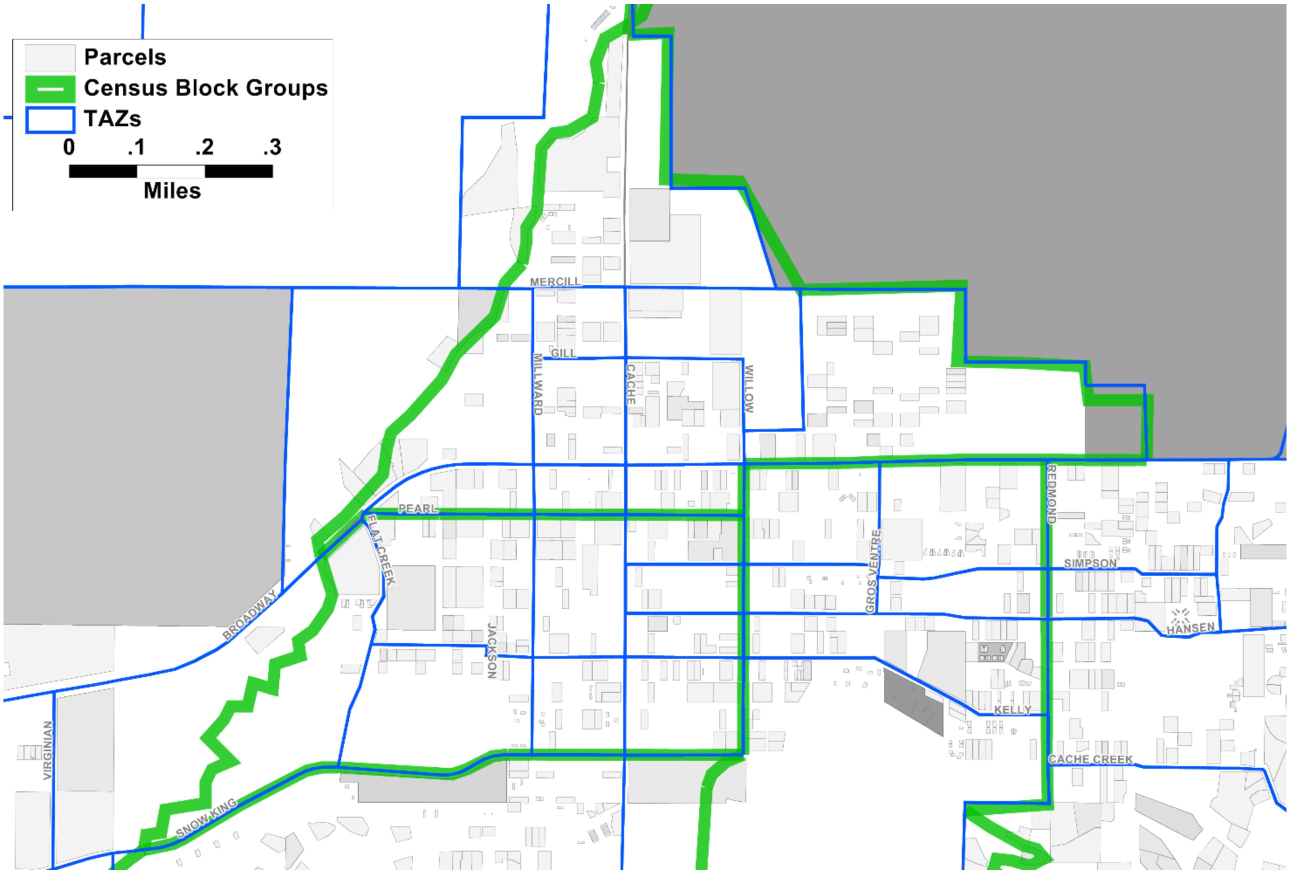
Category	Description
Households	Total number of households in each TAZ.
Household Characteristics	Average household size, average number of workers per household, and median household income.
Lodging Units	Total number of lodging units.
Total Employment by Season	Total employment for summer, winter, and off-peak.
Employment by Type by Season	Employment for summer, winter, and off-peak categorized into the following employment types: • Eating/drinking, • Hotel/lodging, • Office, • Retail, and • Basic/industrial.
Total K12 Enrollment	K-12 school enrollment for summer, winter, and off-peak.
Area Type	TAZ characteristics of central business district (CBD), CBD fringe, urban, suburban/exurban, and rural.
Parking Cost	Parking cost in dollars for the summer, winter, and off-peak seasons.

2.2.1 Socioeconomic Data Development Methodology

Teton County provided parcel-level data, which includes information on numbers of households (by housing type), lodging units, zoning information, and floor area by industry type. The American Community Survey (ACS) is a rolling survey administered by the US Census Bureau that collects demographic data from a sample of households throughout the US. Information obtained from ACS includes household characteristics such as number of vehicles and number of workers per household, but is only available at the Census block group level. The geographic size of TAZs mostly falls somewhere in between the finer-detailed parcel data and the larger Census block group levels, as shown by the example in **Figure 2.2**. Because of this difference in spatial detail, the following approach was used to allocate household characteristics to the fine-grained distribution of households.

- ACS Census block group properties were assigned to individual parcels. Where a single parcel was contained in multiple block groups, properties of the applicable block groups were averaged and assigned to that parcel.
- Parcel-level data was then aggregated to the TAZ level.

Figure 2.2 Spatial Detail of Socioeconomic Data Sources



2.2.2 Population and Household Data

Two data sources were used to develop the population and household data: parcel-level data provided by Teton County and 2016 ACS data. ACS data provided TAZ-level household properties, including average household size, average number of workers per household, and average number of vehicles per households. **Table 2.2** lists all the data used to calculate household and population portions of the model's socioeconomic data.

Table 2.2 Population and Household Data Sources

Input Data Field Name	Description	Sources of Data
TOT_HH	Total Number of Households	Teton County
Avg_HH_Size	Average Household Size	ACS Table B25010 (Average Household Size)
Avg_Wrkrs_per_HH	Average number of workers per household	ACS Table B23025 (Total Workers)
Median_Income	Median Household Income (in 2016 dollars)	ACS Table B19013 (Median Household Income)
n/a	Total Population	ACS Table B01003 (Total Population)
n/a	Total Population in Group Quarters	ACS Table B26001 (Population in Group Quarters)
n/a	Total Households	ACS Table B25002 (Number of Housing Units, Occupied and Vacant)

2.2.3 Lodging Data

Information on number of lodging units and vacancy data was provided by Teton County and the JH Chamber of Commerce and used directly in the model. Teton County parcel data indicated the number of lodging units in each parcel. Parcel-level lodging information was aggregated to TAZs for input to the model. While the parcel data separated lodging by commercial (e.g., hotels motels and lodges) and other (e.g., bed and breakfasts and short term rentals), the model does not distinguish between the two types of lodging.

2.2.4 Employment Data

The model is structured to account for three distinct seasons in Teton County: summer, winter, and off-peak. To account for the differences in these three seasons, employment data input to the model reflect the added jobs during the summer and winter that support the increased activity during these seasons.

Two data sources were used to compute employment by season by industry.

- Parcel data (provided by Teton County) for total floor area by industry and total number of lodging rooms
- Total full-time employees by season per 1,000 square feet of floor area by land use and employees per hotel/lodging room (published in the 2013 Employee Generation by Land Use Study), as shown in **Table 2.3**.

The rates identified in **Table 2.3** were multiplied by commercial and industrial square footage by parcel as provided by Teton County. The resulting parcel-based employment data for each of the three seasons was then aggregated to TAZs for input to the model. As a reasonableness check, parcel-based employment totals were compared to Census LEHD data as shown in **Table 2.4**.

Table 2.3 Seasonal Employment by Industry

	Full-time Employees (per 1,000 square feet or hotel/lodging room)		
Industry	**Year Round**	**Summer Season**	**Winter Season**
Retail	1.202	2.636	1.916
Eating/Drinking Places	3.911	2.422	0.378
Office	1.598	0.228	0.102
Industrial	0.71	0.198	0.027
Hotel/Lodging	0.487	0.471	0.329

Source: Teton County and Town of Jackson Employee Generation by Land Use Study, August 2013.

Table 2.4 Modeled and Census LEHD Employment

Season / Quarter	LEHD Employment*	Modeled Employment
Winter (Quarter 1)	16,216	16,752
Spring (Quarter 2)	13,533	11,883
Summer (Quarter 3)	18,060	20,010
Fall (Quarter 4)	14,028	11,883

Source: CS analysis of Teton County parcel data and LEHD estimate of stable jobs, defined as the number of jobs held on both the first and last day of the quarter with the same employer.

2.2.5 Airport Employment

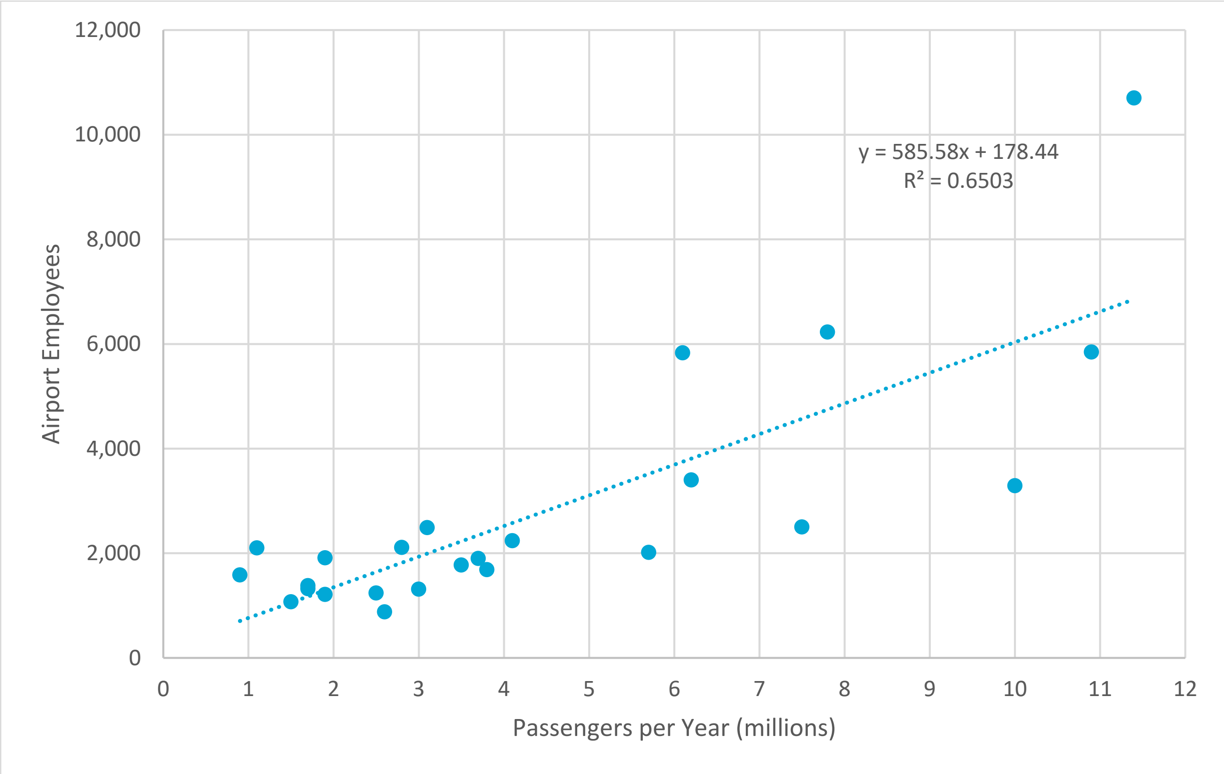
Employment data for the Jackson Hole Airport was sought from airport management, but was not readily available. The number of employees for use in the model was estimated using the number of passenger enplanements and a regression analysis based on data for employment per passenger at small- and medium-sized US airports.

Employment data was compiled in an economic impact study commissioned for the Sacramento County Airport System, published in 2011.[1] The relationship between airport passengers and airport employment is demonstrated by the regression analysis shown in **Figure 2.3**.

Load factor reports from the Jackson Hole Airport provided the passenger enplanement and deplanement counts by month for 2017 and the yearly total for 2016. Passenger levels for the summer, winter, and off-peak seasons were used to calculate seasonal airport employment, as the passenger traffic at the Jackson Hole airport varies by season significantly. Adjusting for seasonal variations and using the regression shown in **Figure 2.3** results in total airport employment of 598 for the winter, 799 for the summer, and 364 in the shoulder seasons.

[1] Economic Impact Study, Sacramento County Airport System. https://sacramento.aero/download.php?f=/SCAS_Economic_Impact_Study.pdf. Retrieved on June 21, 2018.

Figure 2.3 Airport Employees by Yearly Passengers



2.2.6 Parking Costs

For the base year model, the only parking costs in the model are at Teton Village during the winter season. The model is set up to test implementation of parking costs in other zones. Parking costs can be separated into all-day costs such as those paid by employees in an area, and short term parking costs, such as those paid by residents and visitors patronizing businesses in an area.

2.2.7 Area Type

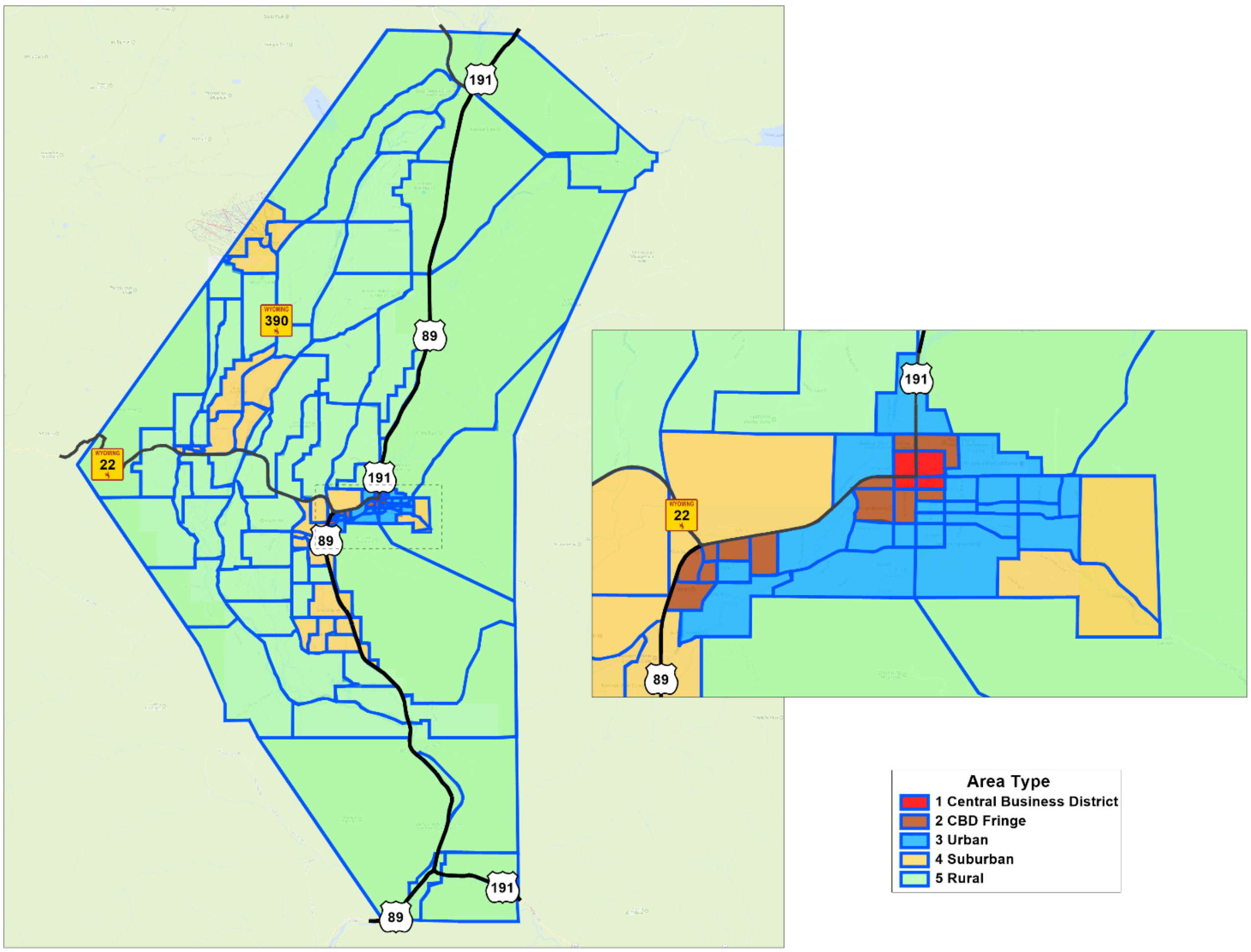
Area type is an attribute assigned to each TAZ and is based on the activity level and character of the zone. Terminal times, link speeds, roadway capacity, and volume-delay characteristics are dependent on area type. Area type is first defined at the TAZ level based on socioeconomic characteristics and then transferred to the roadway network. **Table 2.5** lists the area types included in the model and their definitions, with area type definitions for existing conditions shown in **Figure 2.4**.

Table 2.5 Area Type Definitions

Area Type Number	Area Type
1	Central Business District (CBD)
2	CBD Fringe

Area Type Number	Area Type
3	Urban
4	Suburban / Exurban
5	Rural

Figure 2.4 Area Type Map



2.3 Transportation Networks

The TCTDM represents the transportation system using a GIS-based representation of roadway, bicycle, and transit facilities within the county.

2.3.1 Roadway and Bicycle Network

The roadway and bicycle network is one element of the transportation supply for Teton County. The roadway network is a series of links (segments) and nodes (zones and connections between links) represented spatially. Links and nodes include a number of properties, as listed in **Table 2.6** and **Table 2.7**. Each link in the network is assigned a facility type. For roadway links, facility type is used along with the speed limit and number of lanes to determine free flow speed and link capacity. Facility types are defined in **Table 2.8** and described below.

- **Freeway** – Freeways are divided, restricted access facilities with no direct land access and no at-grade crossings or intersections. Freeways are intended to provide the highest degree of mobility serving higher traffic volumes and longer-length trips. Teton County does not feature any freeways, with the closest freeway being I-15.
- **Highway** – For the purpose of this model, highway facilities are defined as higher speed facilities with limited access. Highways in the Teton County model area include US-89 north of Jackson, US-89 between Hwy 22 and Hoback Junction, and short sections of US-191 and US-89 south of Hoback Junction.
- **Ramp** – Ramps provide connections between freeways and other non-freeway roadway facilities. Teton County does not feature any ramp facilities.
- **Principal Arterial** – Principal arterials permit traffic flow through and within urbanized areas and between major destinations. These facilities usually receive priority at signalized intersections and have limited driveway access. Principal arterials in the Teton County model area include a portion of Highway 89 through Jackson (i.e., portions of Cache and Broadway) and State Highway 22 between Jackson and Teton Pass.
- **Minor Arterial** – Minor arterials collect and distribute traffic from principal arterials and highways to streets of lower classification and, in some cases, allow traffic to directly access destinations. The TCTDM represents short sections of High School Road and South Park Loop Road as minor arterials, as well as portions of Maple Way and Snow King Ave.
- **Collector Street** – Collectors provide for land access and traffic circulation within and between residential neighborhoods and commercial and industrial areas. They distribute traffic movements from these areas to arterial streets. The Teton County model distinguishes between major and minor collectors, with major collectors having a higher potential to serve through movements or having higher travel speeds.
- **Centroid Connector** – These facilities are the means by which the trip and other data at the traffic analysis zone (TAZ) level are attached to the street system. Centroid connectors are an approximate representation of local streets, which are not included in the travel model.
- **Transit Links** – The model allows for two types of transit links. Transit local links are local streets used by buses. These links are not used by the traffic model but are included to allow proper representation of bus routes. Transit only links are links designated exclusively for transit use. Such links do not currently exist in Teton County, but may be useful for testing of concepts such as separate bus lanes or bus rapid transit (BRT).
- **Non-Motorized Links** – The network includes non-motorized links that provide connections not available to autos. These links are available for bicycle and pedestrian use but not motorized vehicles.

The roadway network also includes more detailed information about non-motorized facilities. The bicycle facility type field, defined in **Table 2.9** and shown in **Figure 2.6**, contains information about the type of bicycle facilities available. Bicycle facilities can include roadway links with routes, lanes, or adjacent multi-use paths. The bicycle facility type is also used to define any links where bicycles and/or pedestrians are not allowed to travel.

Table 2.6 Roadway Network Link Properties

Attribute	Values
Length	Link length in miles
Area type (AT)	Based on zonal area type described above
Facility type (FT)	Type of facility, indicating capacity and operational characteristics of the roadway.
Number of lanes	Directional number of through travel lanes
Turn Lane Information	Information about the number and length of left and right turn lanes
Speed limit	Posted speed limit, where available
Truck Prohibition	Identifies links on which trucks are prohibited (if any)
Walk Prohibition	Identifies links on which pedestrian travel is prohibited (if any)
Bike Facility Type (BikeFT)	Type of bicycle facility

Table 2.7 Roadway Network Node Properties

Attribute	Table Header
TAZ	TAZ identifier, to be match with the TAZ data table. Only present for centroid nodes.
PNR	Identifies nodes serving as park and ride nodes for transit
PULSE	Identifies nodes where the transit system uses timed arrivals to facilitate efficient transfers (if any)
Signalized	Identifies signalized intersections

Table 2.8 Facility Type Definitions

Facility Type Number	Facility Type
1	Freeway (not used)
2	Highway
3	Principal Arterial
4	Minor Arterial
5	Major Collector
6	Minor Collector
7	Ramp (not used)
8	Centroid Connector
9	Walk Connector (generated, not present in the input network)
61	Transit Link
62	Non-motorized

Table 2.9 Bicycle Facility Type Definitions

Bicycle Facility Type Number	Bicycle Facility Type
1	Separated multi-use path
2	Bike lane
3	Bike route or sharrow
4	No designation
5	No designation (highway)

Figure 2.5 Roadway Facility Types

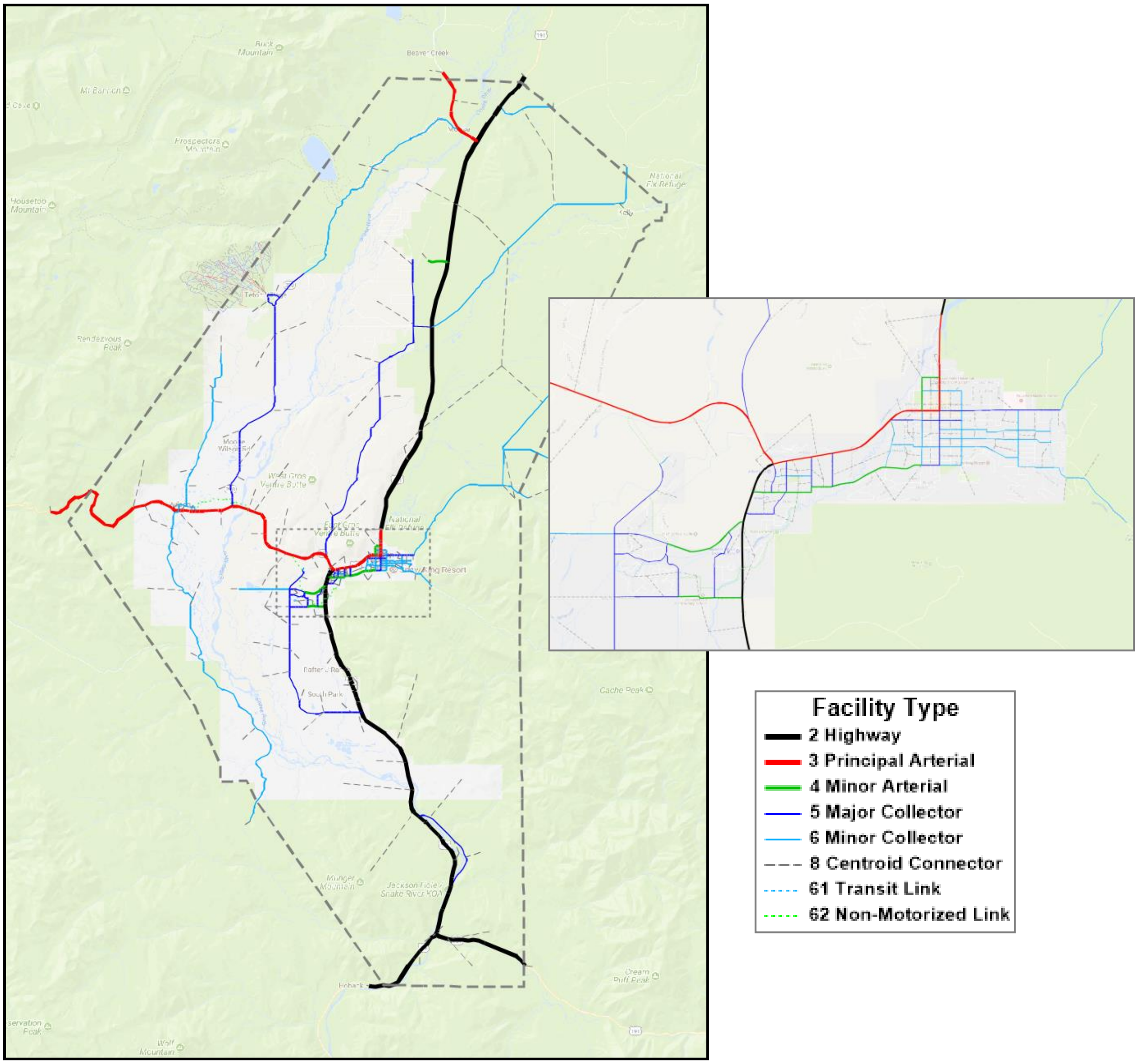
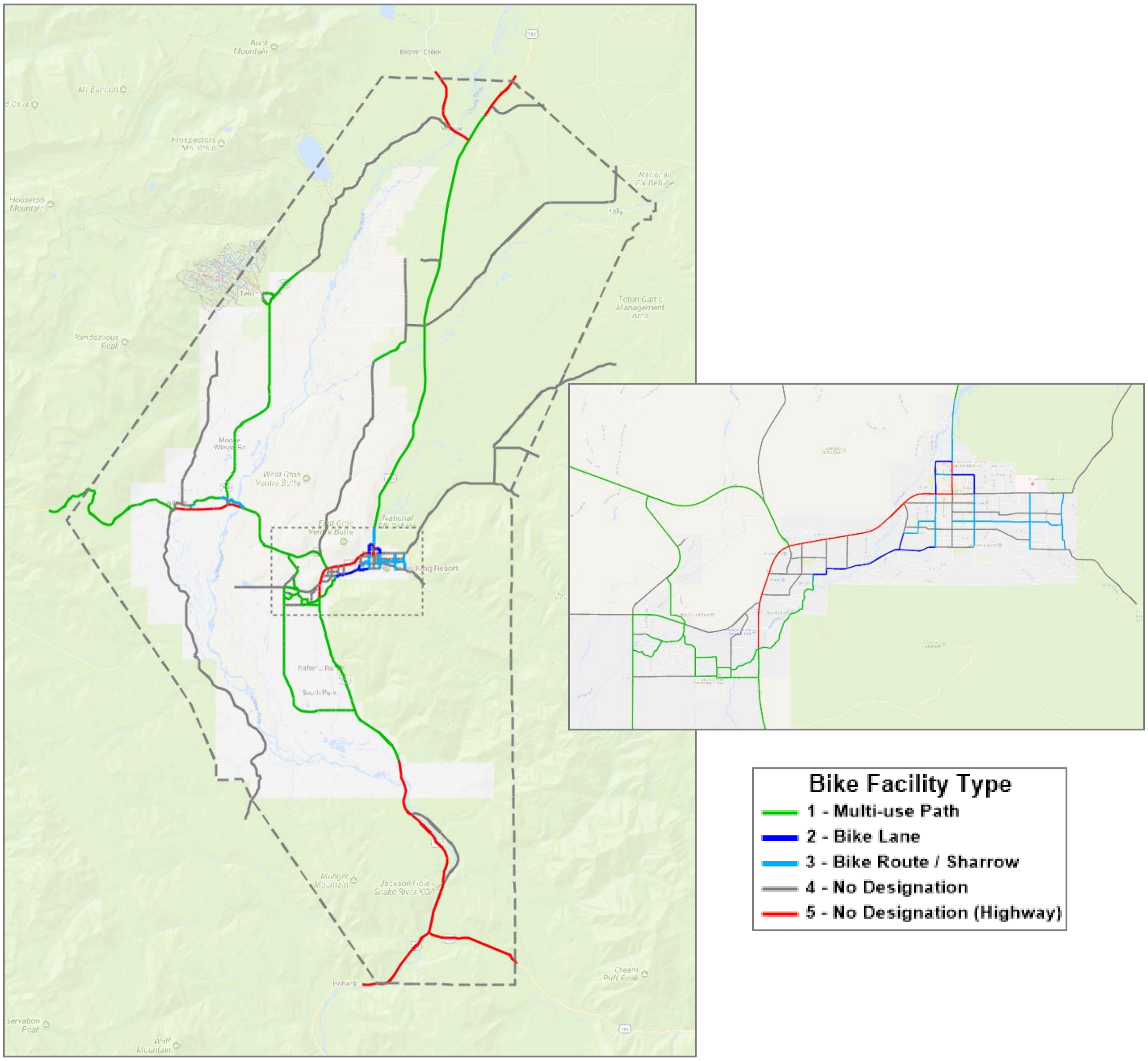


Figure 2.6 Bicycle Facility Types

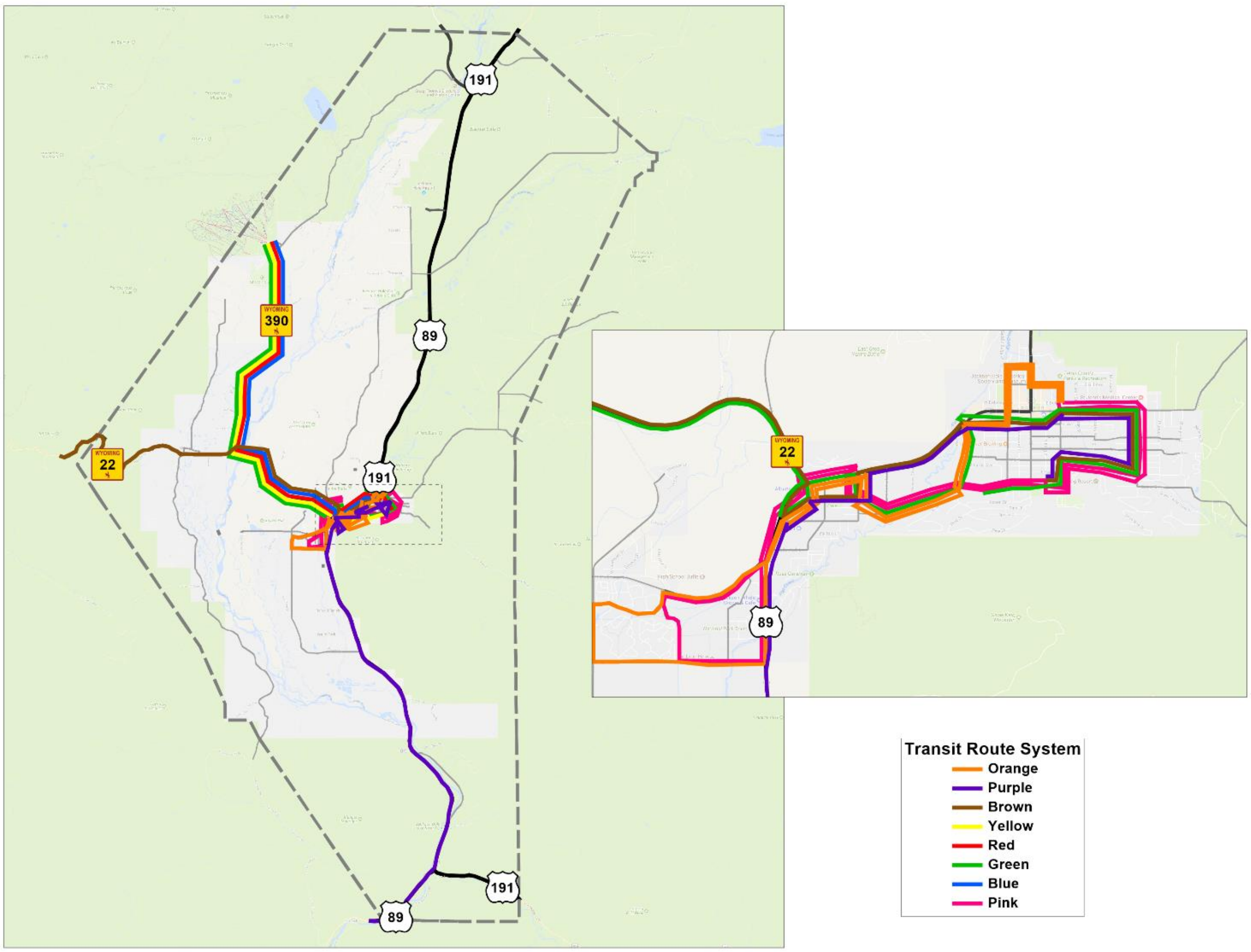


2.3.2 *Transit Route System*

The transit route system represents another element of transportation supply. Transit routes are represented spatially and are related to links and nodes present in the roadway network. Transit vehicles travel along links and can stop at nodes. The link between the transit network and the roadway network allows transit vehicles to be sensitive to roadway congestion and the resulting changes in travel times on the roadways. **Figure 2.7** shows the transit network for the Teton County Model. Each transit route contains attributes describing the route, as listed in **Table 2.10**.

In addition to the route and stop locations for the transit line, there are also a number of properties to define for each route, including headway and type of service, as summarized in **Table 2.10**. Due to the unique fare structure used by the Southern Teton Area Rapid Transit (START) bus system, transit fares are implemented using a zonal fare system. This system has been set up to replicate START fare policy. In addition, because many system riders use monthly or annual passes instead of paying per-ride, the zonal fare system has been adjusted to reflect a mix of cash payments and pass holders.

Figure 2.7 Transit Route System



Note: Routes are shown for the 2017/2018 winter season. The model includes separate assumptions for summer, winter, and off-peak.

Table 2.10 Transit Network Attributes

Attribute	Values
Route Name	Unique descriptive route name
Route ID	Arbitrary route ID
Route Number	Designated route number
Headway	Route headway in minutes for the peak and off-peak time periods, and for the summer, winter, and off-peak seasons. A headway value of -1 indicates that a route does not run in a particular time period or season.

Mode	Transit mode code, allowing for local bus, express bus, and BRT (for alternatives testing)

3.0 Time Periods

Time, in terms of the Teton County Model, has two dimensions – seasonality and time of day. The model can be run to reflect off-peak season conditions as well as peak summer and winter conditions. For all scenarios, the model also represents different times of day. Regardless of season chosen, the TCTDM is modeling average **weekday** trips.

3.1 Seasonality

The TCTDM represents three seasons in Teton County: summer, winter, and off-peak season conditions as defined in **Table 3.1**. Seasonal considerations are addressed through the following factors:

- **Seasonal Demand:** Employment and vacancy rates by vary by season, resulting in changes to activity levels in different parts of the model area. In addition, special generators, external trips, and model parameters such as trip rates vary by season.
- **Seasonal Supply:** The START system provides different service during the winter and summer seasons. Speed limits vary by season in some areas, Teton Pass has a seasonal truck/trailer restriction, and the section of Moose-Wilson Road through Grand Teton National Park is closed in winter. In addition, winter conditions may discourage use of non-motorized modes as compared to the summer and off-peak seasons.

Table 3.1 Season Definitions

Season Name	Season Start	Season End
Summer Peak	Mid-June	August 31
Winter Peak	Mid-December	March 31
Off-peak (spring portion)	Mid-April	Mid-May
Off-peak (fall portion)	October 1	Mid-November

Note: The off-peak season is only modeled once, representing a combination of the fall and spring portions.

3.2 Time of Day

The TCTDM assumes four time periods – AM, mid-day, PM, and night. Trips for each of these periods sum to the daily total. For some model steps including trip distribution and mode choice, the AM and PM peak periods are combined into a peak period, with the mid-day and night time periods are combined into the off-peak period. Based on observed traffic count data, the specific time periods modeled are defined as shown in **Table 3.2**.

Table 3.2 Time of Day

Time Period	Hours
AM Peak Period	7:00 am – 9:00 am
Mid-day	9:00 am – 3:00 pm
PM Peak Period	3:00 pm – 6:00 pm
Night	6:00 pm – 7:00 am

4.0 Model Components

The TCTDM sequentially models trip generation, trip distribution, mode choice, and trip assignment. A feedback loop passes travel speeds computed in the final trip assignment step back to earlier model steps to ensure consistency between all model steps.

4.1 Trip Generation

Trip generation is the first phase of the four-step travel demand modeling process. It identifies trip ends in the form of productions (the home end of the trip) and attractions (the non-home end of the trip), that correspond to places where activities occur. Socioeconomic data serve as the primary input to this step. Trip generation estimates productions and attractions by trip purpose for each TAZ, then balances trips at the regional level so total productions and attractions are equal. The resulting productions and attractions by trip purpose and TAZ are subsequently used by the Trip Distribution model to estimate zone-to-zone travel patterns.

4.1.1 Trip Purposes

Trip purpose is used in travel models to categorize various types of trips with similar characteristics, such as trip rates, trip length, and mode shares. A separate set of trip generation rates has been developed for each individual trip purpose. The specific trip purposes in the TCTDM are listed below. For commuters, home-based trips have productions outside of the modeling area, but are still segmented into the appropriate trip purposes.

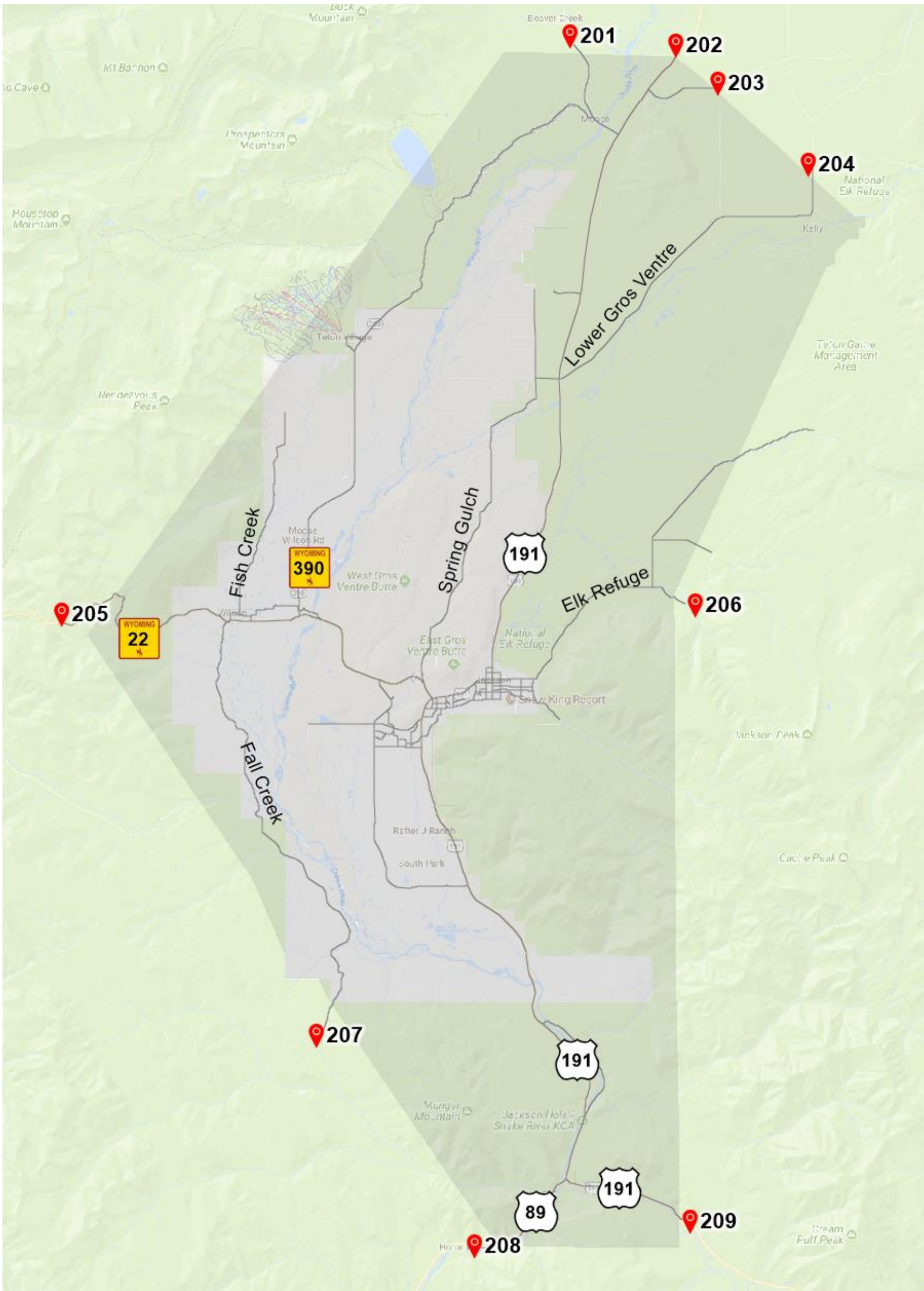
- Trips made by ***residents*** and ***commuters***:
  - ***Home-Based Work (HBW)***: Commute trips between home and work.
  - ***Home-Based Shop (HBS)***: Trips between home and retail locations for the purpose of shopping.
  - **Home-Based School (HBSc):** Trips between home and school by students enrolled in grades K through 12.
  - ***Home-Based Other (HBO)***: All other trips that have one end at home.
  - ***Work-Based Other (WBO)***: Work-related trips without an end at home.
  - ***Other-Based Other (OBO)***: Trips with neither an end at home nor a work-related purpose.

- Trips made by ***visitors***:
  - ***Lodging-Based Other (LBO):*** Trips made by visitors, based at a lodging establishment.
  - ***Visitor Other-Based Other (VOBO):*** Trips made by visitors, not based at a lodging establishment.
- Commercial truck trips:
  - ***Small Truck (MTRK):*** Medium-weight truck trips (FHWA Vehicle classes 5-7)
  - ***Large Truck (HTRK):*** Heavy truck trips (FHWA Vehicle classes 8-12)

4.1.2 External Trips

In addition to internal-internal trips that occur entirely within the modeling area, the model also includes external travel to and from outside of the region. Trips with one end inside the modeling area and the other outside of the area are called Internal-External (IE) and External-Internal (EI) trips. Through trips, or External-External (EE) trips, are those which pass through the modeling area without stopping. External travel is modeled explicitly at the external stations where roadways cross the model boundary. The 9 external stations are shown in **Figure 4.1**.

Figure 4.1 External Stations



External travel is based on traffic counts at or near these external stations, combined with GPS/LBS data that provides an understanding of the type of travel crossing the model boundaries. External trips represent all persons crossing the modeling area boundary – these include visitors to the region, commuters who live outside of the region and work within the region, residents of the region traveling outside of the region, or trucks traveling to or through the region.

4.2 Trip Distribution

Trip distribution is the second phase of the four step travel model. Trip distribution is the process through which trip productions and attractions from the trip generation model are apportioned between all zone pairs.

The TCTDM uses a standard practice gravity model approach that represents the effects of travel time between zones. This model assumes that as the travel time between zones increases, the number of trips between those zones decreases. Conversely, if travel time between zones decreases, the number of trips between those zones increases. Given two options with exactly the same attributes but with one having a destination that can be reached more quickly than the other, it is reasonable to assume that a trip maker would chose the closer destination.

The model calibration process involved the estimation of a number of factors, including *friction factors* that represent the impedance to travel between each zone pair and *K-factors* that account for nuances in travel behavior and the transportation system that are not represented in the set of model inputs.

The results of the trip distribution step are trip table matrices that contains both intrazonal trips (i.e., trips that do not leave the zone) and interzonal trips for all possible pairs of zones.

4.3 Trip Mode Choice

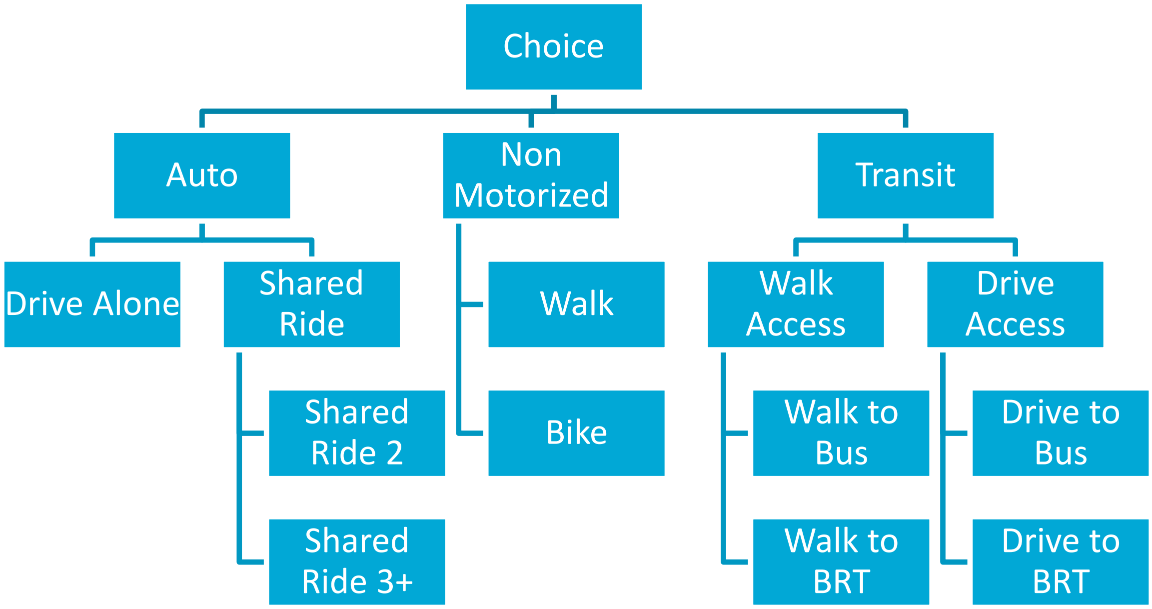
The TCTDM produces and distributes all person trips including non-motorized, auto, and transit trips. The mode choice models separate the person trip tables resulting from trip distribution into the drive alone, shared ride (i.e., carpool), transit (walk access and drive access), and non-motorized (bicycle and walk) modes.

The TCTDM applies a logit-based mode choice model for each internal trip purpose. The logit model is based on the concept of utilities (or disutilities) that describe the characteristics of travel by each mode. The utilities represent the likelihood of taking one mode relative to another. The utility function can be made up of impedance variables such as travel time, transit wait time, and cost as well as locational and socioeconomic variables. Mode choice is evaluated separately for each trip purpose, and the inputs to each of those models depends on its specification, which varies between purposes. In general, inputs to the mode choice model include:

- Socioeconomic data;
- Travel skims (information about the routing choice for each zone-to-zone pair for each mode); and
- Information about the origin and the destination zone.

The choice structure and mode choice options are shown in **Figure 4.2**. The results of the mode choice step are trip table matrices of person trips for each mode.

Figure 4.2 Mode Choice Nested Logit Structure



4.3.1 External Trips

START provides commuter transit service that extends beyond the model boundary. Ridership on these routes is a direct input to the model, and can be modified as a scenario planning tool.

4.4 Trip Assignment

Trip assignment is the final phase of the four-step travel model. Trip assignment includes a process where person trips from mode choice are converted into directional vehicle trips by time of day, as well as identification of specific paths taken by vehicle and transit trips. The resulting traffic volumes and transit boarding data are available for each time period (AM, mid-day, PM, and night) as well as for a 24-hour period.

When the model is run with ***speed feedback*** enabled, travel times resulting from traffic assignment are fed back to trip distribution, as shown earlier in **Figure 1.1**. The model is then run iteratively until speeds input to trip distribution are reasonably consistent with speeds resulting from traffic assignment.

4.4.1 Highway Assignment

The Traffic Assignment step loads the travel demand represented by the time of day vehicle trip tables onto the roadway network. Most current travel demand models make use of user equilibrium assignment, which minimizes travel time for all vehicle trips assigned to the network. This is an iterative assignment algorithm that calculates congested travel time as a function of link volume and shifts travelers to the shortest path. As a result, user equilibrium traffic assignment represents traffic diversion from congested links.

The TCTDM considers five different types of vehicles in the traffic assignment step: single occupant vehicles (SOV), shared ride 2 vehicles (SR2), shared ride 3+ vehicles (SR3+), medium trucks, and heavy trucks. After traffic assignment is complete, traffic volumes are available for each individual vehicle class.

The results of the highway assignment are traffic flow tables. The flow tables provide the number of vehicles by vehicle class (SOV, SR2, SR3+, medium trucks, and heavy trucks) and the congested speeds/travel times for each link in the network. Vehicle-miles traveled (VMT) and vehicle-hours traveled (VHT) can also be extracted from the highway assignment; these metrics can also be summarized by facility type and area type.

4.4.2 Transit Assignment

Transit person trips resulting from the mode choice model are assigned to the transit route system. Each trip is assigned from zone centroid to zone centroid using walk or drive access links, transit routes, and walk egress links. The transit assignment step does not include capacity constraint, so increasing transit volumes do not result in diversion of transit trips to other transit service. Transit assignment is also performed in production to attraction format rather than origin to destination format.

Transit assignment results include the total number of boardings at each transit stop, as well as transit volumes on all stop to stop transit route segments. However, transit results are generally best evaluated at the systemwide or route group level. Prior to using the model to support detailed transit corridor studies, a focused transit model calibration and validation effort is recommended.

5.0 Calibration and Validation

The TCTDM has been calibrated and validated to summer peak conditions using a comprehensive set of traffic counts. In addition, the model has been validated for the winter and off-peak seasons using a more limited dataset. Several permanent counters that capture seasonal variations in traffic patterns are located on highways, but winter and off-peak traffic count data are not available outside of these few locations. Therefore, synthesized winter and off-peak traffic counts were developed by adjusting summer counts based on permanent counter data.

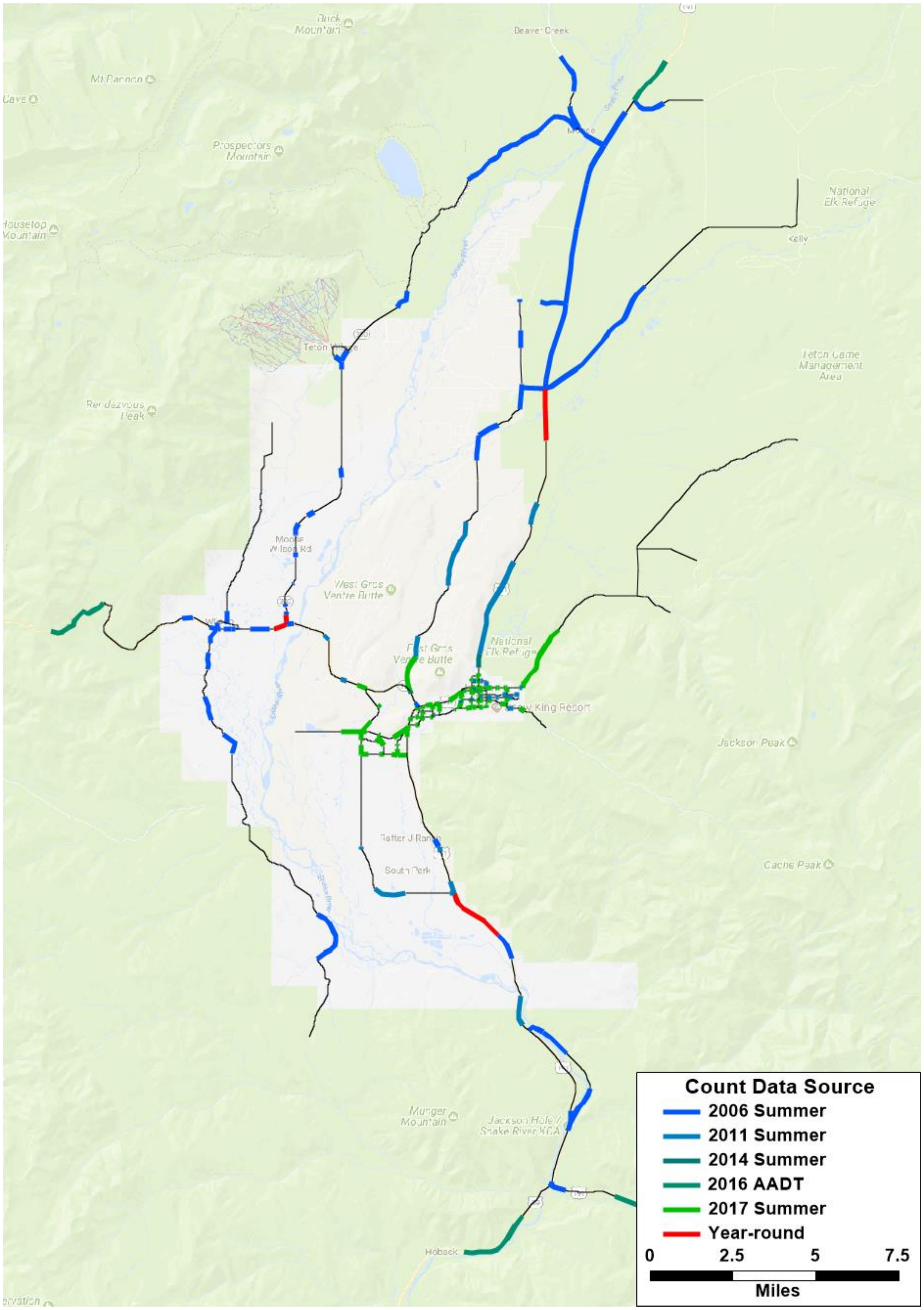
Model calibration was first performed at a valley-wide level, ensuring the model reasonably reproduces the total amount of travel. Validation has also been performed at the facility type level, verifying that the share of traffic is reasonably distributed between highways, arterials, and collectors. Finally, corridor and localized validation was performed to confirm that the model adequately represents detailed traffic patterns. Corridor and localized validation was focused on major corridors, areas that experience significant congestion, and locations where detailed studies are anticipated or ongoing.

5.1 Calibration Data Sources

5.1.1 Traffic Counts

Teton County provided a set of short-duration traffic counts for model calibration and validation. This included counts for locations across the region, conducting during summers of 2017, 2014, 2011, and 2006. Additionally, four permanent count locations with hourly data by year, maintained by WYDOT, were also obtained. **Figure 5.1** shows the locations of these counts.

Figure 5.1 Available Traffic Counts



Summer Count Database

Summer traffic counts ranged in year collected from 2006 to 2017. To determine if any annual adjustment factors were needed, locations with counts for 2017 and older were plotted as shown in **Figure 5.2**, and compared to perfect match (no growth) scenario. This demonstrates that there was little deviation in counts by year compared to 2017 with no clear trend revealing positive or negative growth in traffic volumes. **Figure 5.3** shows the frequency of growth factors (the ratio of the 2017 count to the older count), by year, compared to 2017, which shows a concentration around 1.0 growth factor. On average, 80% of all counts for all years were within 20% of the 2017 count volume.

A separate analysis considered the total counted volumes in 2017 as compared to 2006, 2011, and 2014. This was performed only for locations where a count was available in both 2017 and in the comparison year. As shown in **Table 5.1**, locations with common counts in 2006 and 2017 showed nearly no difference, while 2017 was 5% higher than 2011 but 3% lower than 2014 at common count locations.

Considering these results, no adjustments were made to older counts to reflect 2017 conditions. The most recent counts available were utilized to create a comprehensive set of counts representing 2016 average weekday summer conditions.

Figure 5.2 Comparison of 2017 Counts to Older Counts

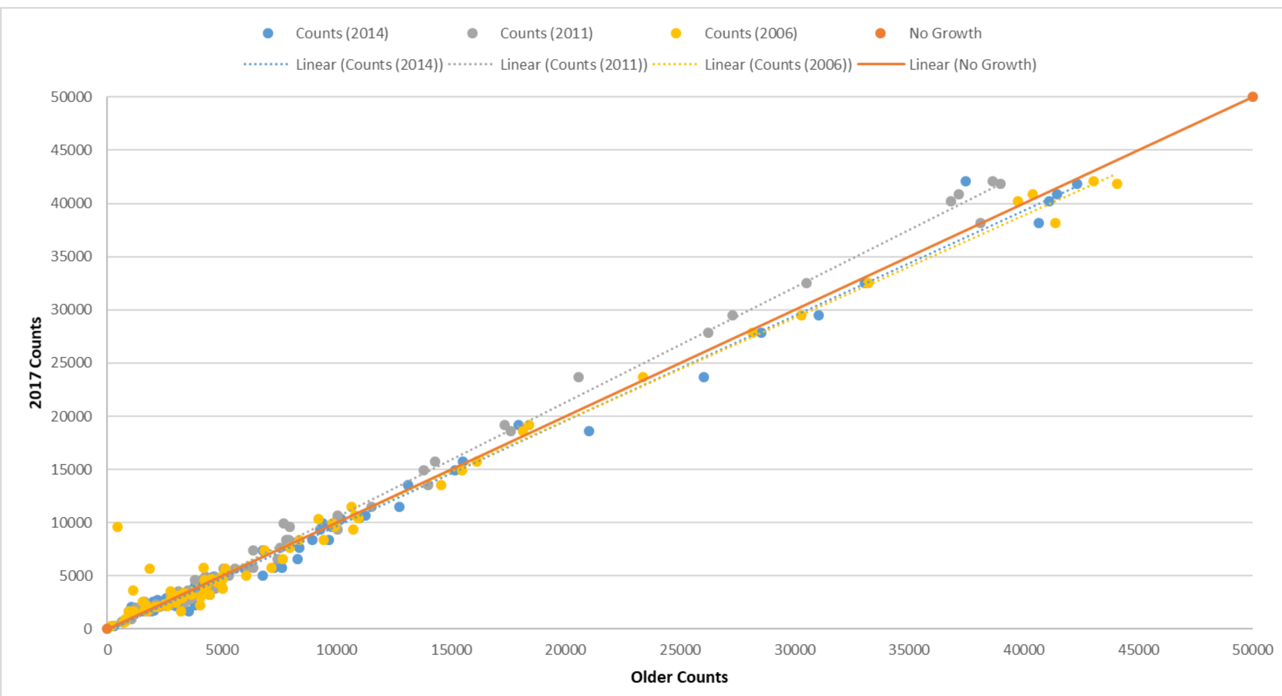


Figure 5.3 Frequency of Count Growth Factors by Year

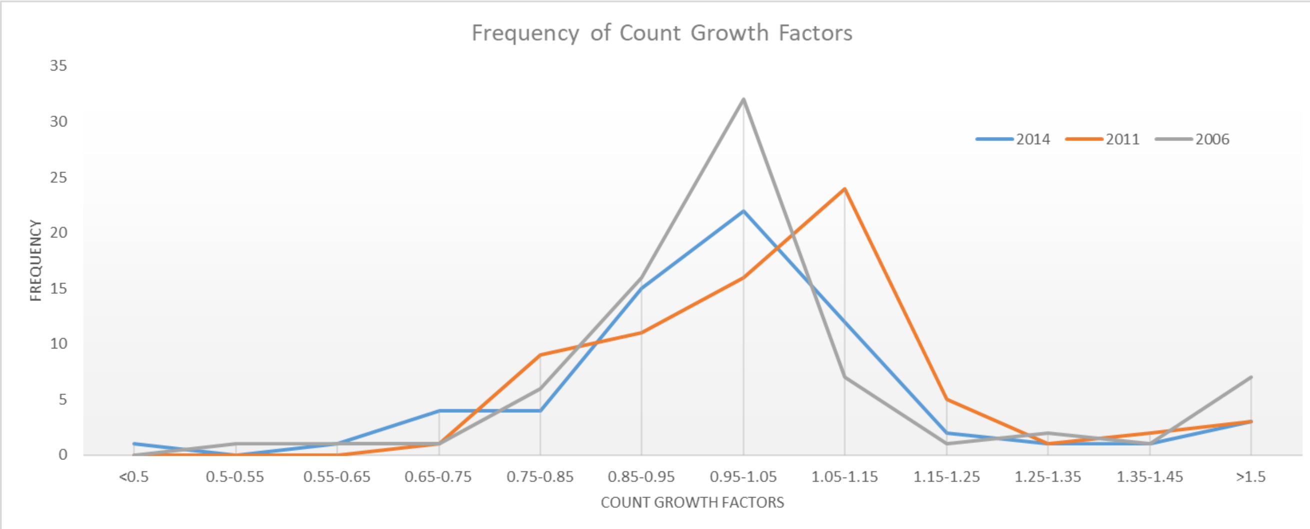


Table 5.1 Overall Change in Counts by Year

Year	2017 Counts	Older Counts	Growth Factor
2014	630,425	652,294	0.97
2011	642,708	614,317	1.05
2006	664,474	665,990	1.00

Note: Count totals reflect the sum of all traffic volumes where counts were available for both 2017 and the comparison year.

Seasonal Adjustments to Counts

All traffic counts were available for summer; however, only four locations provided year-round counts (WYDOT permanent count locations):

- US 26/89/189/191, south of Jackson at MP 148.7;
- WY 390, north of WY 22;
- US 26/89/189/191, south of Kelly; and
- WY 22, west of WY 390.

Additionally, the Teton Village Area Transportation Demand Management (TDM) Report for 2016 Winter and Summer Seasons provided count data for winter and summer near Teton Village. Seasonal adjustment factors were calculated by comparing the counts in the winter and shoulder seasons to the summer counts. **Table 5.2** summarizes the resultant seasonal adjustment factors by the count location.

It was observed that Teton Village winter counts are lower than summer, counterintuitive to initial expectations at a ski resort. This adjustment factor is based on the TDM Report data, which also shows a higher auto occupancy rate and much higher transit mode share in winter., resulting total winter counts being lower than summer counts. After discussion with the TAC, it was confirmed that the overall activity on Hwy 390/Moose Wilson corridor is higher during the summer than the winter, but the winter experiences higher peak conditions at the start and end of the ski day.

Table 5.2 Seasonal Adjustment Factors based on permanent count locations

Location	Winter / Summer	Shoulder / Summer
US 26/89/189/191, south of Jackson at MP 148.7	0.56	0.68
WY 390, north of WY 22	0.78	0.64
US 26/89/189/191, south of Kelly	0.38	0.45
WY 22, west of WY 390	0.68	0.70
Teton Village	0.73	n/a/

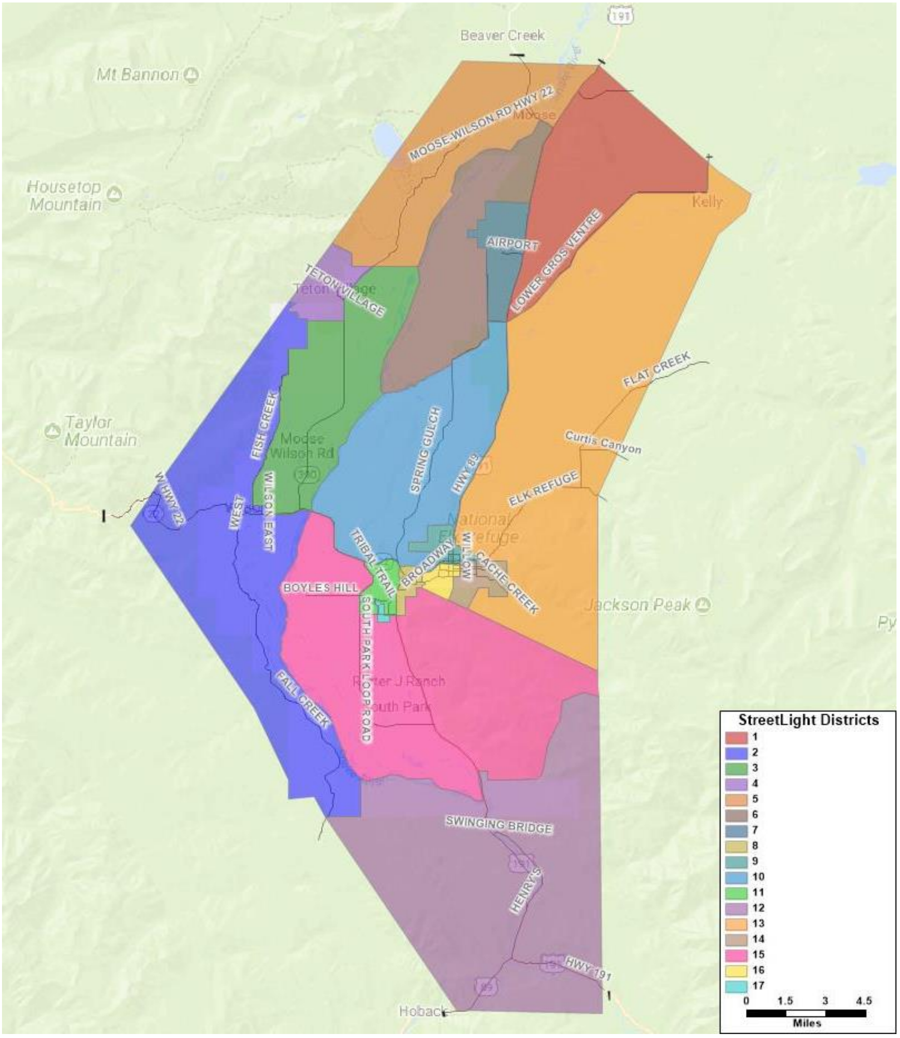
Because of variation in tourism by season, single adjustment factors cannot be universally applied. Tourist activities and travel are concentrated to certain areas, in varying degrees. For example, traffic on Hwy 191 north of Jackson is much lower during the winter due to little winter tourism north of the region as most of Yellowstone and Teton National Parks are closed or difficult to access during the winter. However, there is significant activity at Teton Village during the winter for ski season. Furthermore, the available traffic count data do not adequately represent activity levels within the urbanized portion of Jackson.

A second analysis utilized StreetLight Data (see below in 5.1.2) to determine relative activity in each district for the summer, winter, and shoulder seasons. The resultant seasonal factors are documented in the next section.

5.1.2 StreetLight Data

StreetLight uses anonymized Navigation-GPS data and Location-based Services (LBS) data from smartphone apps to track travel behavior. Using contextual information such as census and parcel data, Streetlight expands the sample and adjusts for sample biases to produce a trip origin and destination matrix that can be compared to modeled trips for calibration or validation purposes. The modeling area includes seventeen StreetLight zones, as shown in **Figure 5.4**. these zones are aggregations of the TCTDM TAZ structure, but keep enough detail to accurately show travel patterns in the study area. Additional pass-through zones are included at the external stations.

Figure 5.4 StreetLight Districts



Two types of StreetLight data were used for this project: 1) Navigation-GPS data to evaluate commercial truck activity, and 2) LBS data to evaluate personal travel. Furthermore, two sets of LBS data were utilized for this project.

- LBS data segmented by traveler type: Resident, Commuter, and Visitor (determined by probable home locations, based on time spent and where the device is in the evenings).
  - Residents: probable home location is in the model region.
  - Commuters: probable home location is outside the model region but nearby.
  - Visitors: probable home location is outside of the model region.
- LBS data segmented by trip purpose (home-based work, home-based other, and non-home-based)

StreetLight data does not include a total number of trips, rather it provides a relative index for each type of travel. LBS and GPS provide the indices for travel to/from all StreetLight districts and those passing through external gates. However, the two sets of data are not directly comparable and require different scaling factors for comparison. Origin-destination trip tables based on StreetLight data are primarily useful in better understanding seasonal variations in activity levels, and for calibrating the trip distribution model.

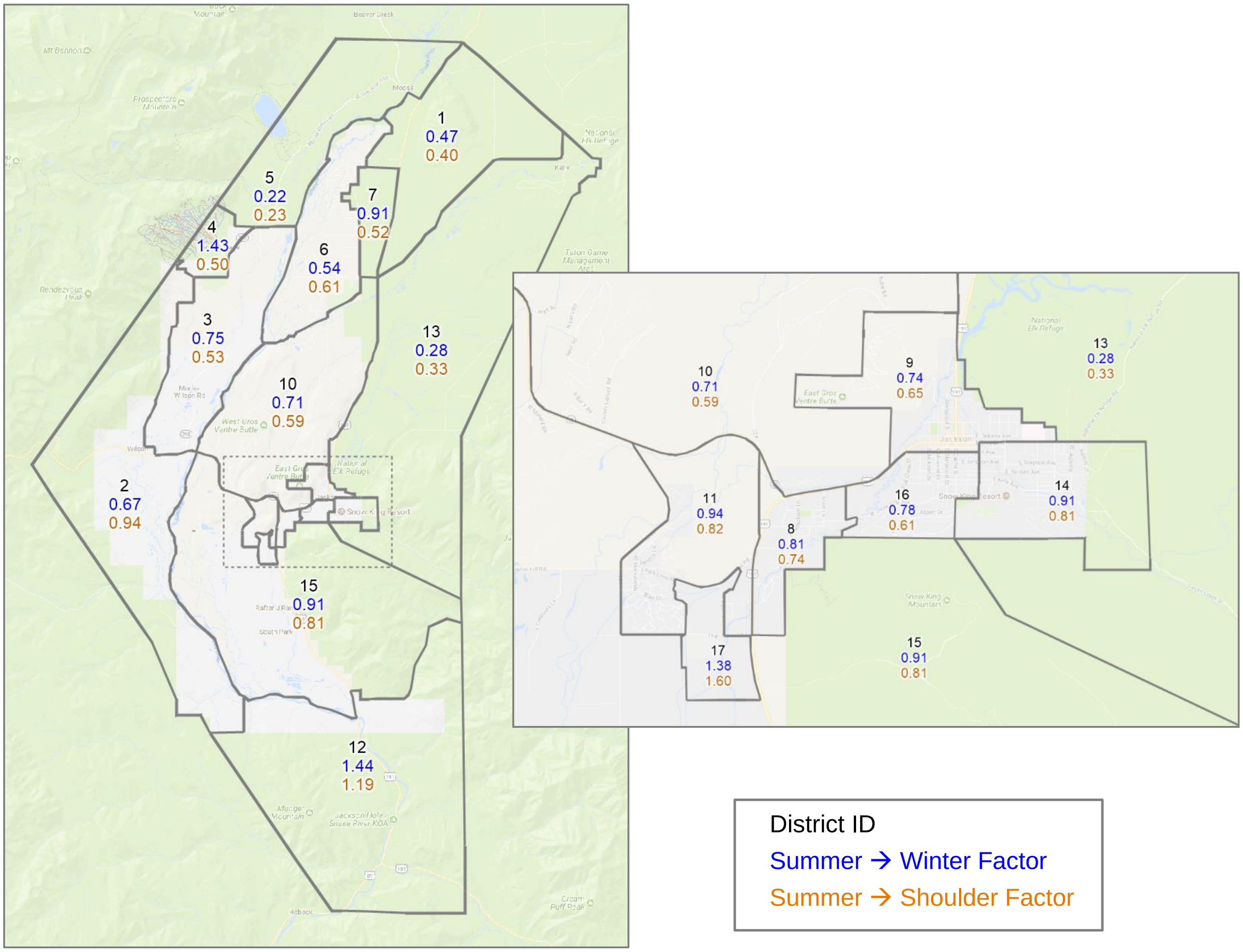
Seasonal Factors

StreetLight data was analyzed for each of the three model time periods, producing the summer to winter and summer to shoulder adjustment factors for each district. These resulting factors are shown in **Figure 5.5**. Some concerns were identified when comparing StreetLight seasonal factors with seasonal factors based on count data, as listed below.

- StreetLight shows higher winter activity at Teton Village than reflected in the counts. This is likely due to increased activity within Teton Village, including non-motorized trips. However, counts show fewer vehicles to/from Teton Village.
- StreetLight shows higher winter activity in the southernmost district than reflected in the counts. It appears that limited cell phone coverage led to a very small sample size south of Jackson, invalidating the seasonal factors obtained for this district.

Based on the above concerns, the sample sizes for each district were reviewed more closely. This review showed very small sample sizes for more rural districts, suggesting that seasonal factors based on StreetLight data are most appropriate for the more urbanized portions of Teton County. Permanent traffic counters are a more appropriate traffic count adjustment source for rural areas, and the Teton Village TDM Report provides more reasonable seasonal adjustment data for Teton Village.

Figure 5.5 Seasonality Factors based on StreetLight Data



5.2 Model Validation

5.2.1 Highway Assignment Validation

Roadway volumes resulting from traffic assignment were compared to traffic count data. This process ensured the model is reasonably representing observed traffic volumes. Traffic count data was provided by WYDOT, Teton County, and The Town of Jackson, allowing a direct comparison of model results to traffic count data. Travel model results were compared to traffic count data using a variety of techniques that include both regional comparisons and inspection of individual link values.

Overall Activity Level

Overall vehicle trip activity was validated by comparing model results to count data on all links with available count data. This has been summarized as the ratio of total model volume to total count volume on all links with available traffic count data. These statistics were reviewed by facility type as shown in **Table 5.3**.

Table 5.3 Activity Level by Facility Type

Facility Type	Number of Links with Counts	Volume to Count Ratio
Highway	28	1.03
Principal Arterial	26	1.01
Minor Arterial	14	0.86
Major Collector	65	0.96
Minor Collector	50	1.08
All Links	**183**	**1.00**

Measures of Error

While the model should accurately represent the overall level of activity, it is also important to verify the model has an acceptably low level of error on individual links. It is expected that the model will not perfectly reproduce count volumes on every link, but the level of error should be monitored. The plot shown in **Figure 5.6** demonstrates the ability of the model to match individual traffic count data points and notes the resulting R-squared value. **Table 5.4** lists root mean square error (RMSE) and % RMSE values for each facility type. General guidelines suggest that % RMSE should be near or below 40 percent, with values below 30 percent for high volume facility types such as highways. The TCTDM achieves a % RMSE of 40% or better on all facility types except minor collectors. The model achieves an overall % RMSE of just over 25%.

The RMSE and % RMSE metrics represents the error between model results and observed values on average throughout the valley. In model application, individual traffic count data, TAZ loading details, and other considerations must be taken into account to fully understand the margin of error for a specific segment or corridor.

Figure 5.6 Model Volume and Count Comparison

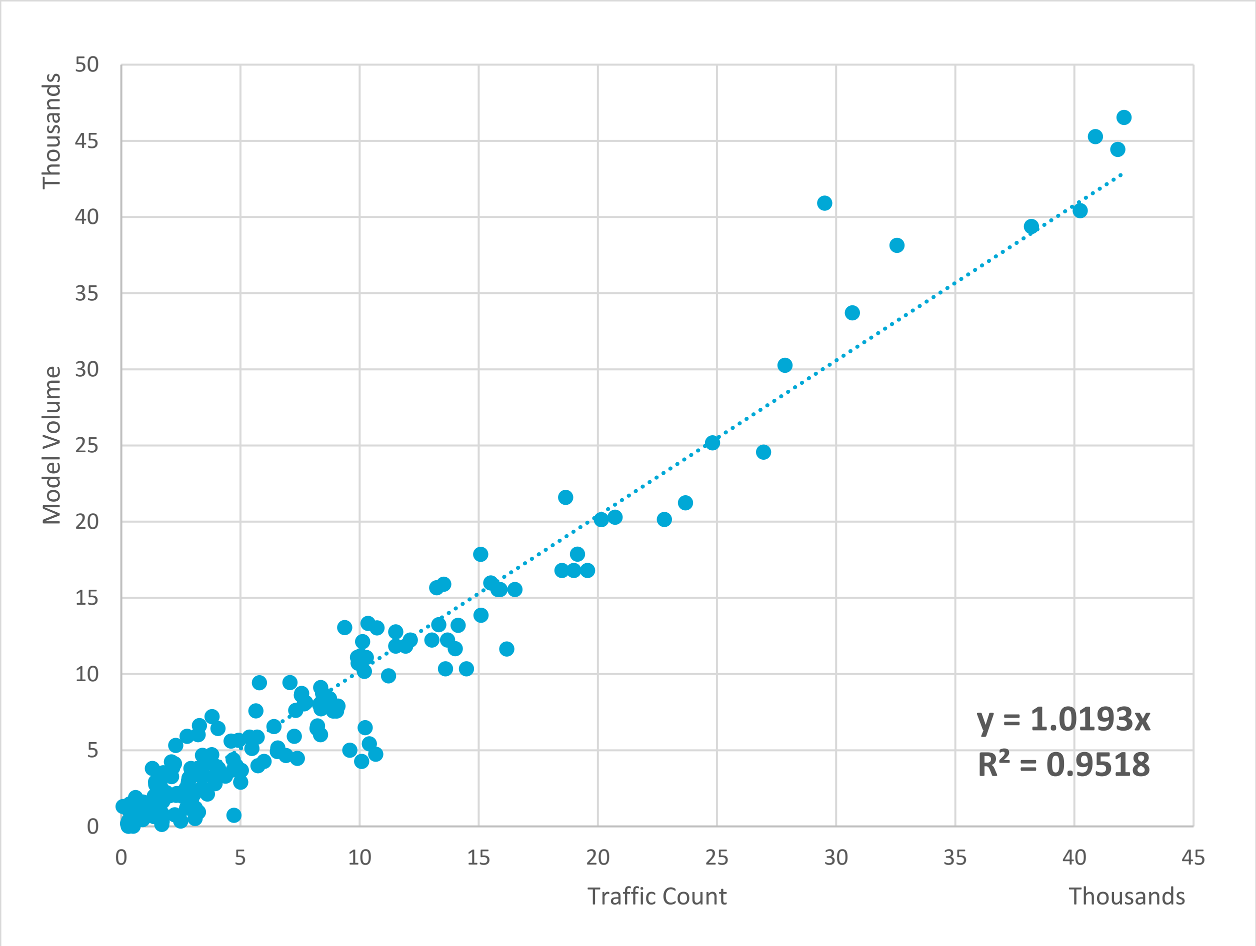


Table 5.4 Root Mean Square Error by Facility Type

Facility Type	Number of Links with Counts	RMSE	% RMSE
Highway	28	3,181	20.8%
Principal Arterial	26	2,390	13.2%
Minor Arterial	14	2,889	37.2%
Major Collector	65	1,539	31.0%
Minor Collector	50	1,262	53.8%
All Links	**183**	**2,036**	**25.7%**

Table 5.5 Root Mean Square Error by Volume Group

Volume Group	Links	RMSE	% RMSE
0 - 1,000	16	656	130.9%
1,000 - 5,000	79	1409	53.2%
5,000 - 10,000	37	1745	23.2%
10,000 - 20,000	36	2597	19.1%
20,000 - 30,000	8	4663	19.0%
30,000 and up	7	3978	10.4%
All Links	**183**	**2036**	**25.7%**

Winter Validation

In addition to summer peak seasons, the model can be run for the peak winter season and the off-peak season. Because traffic count data for these time periods are limited, the seasonal validation statistics are less meaningful. A validation exercise was conducted for the winter peak season using the limited seasonal counter data along with factored summer counts. The VMT resulting from the winter peak model is about 70% of the total summer peak VMT. Approximate validation statistics are shown in **Table 5.6**.

Table 5.6 Winter Validation Statistics

Facility Type	Number of Links with Counts	Volume to Count Ratio	RMSE	% RMSE
Highway	28	1.16	2,770	29.9%
Principal Arterial	25	1.07	2,919	21.2%
Minor Arterial	14	0.86	2,255	37.5%
Major Collector	65	0.99	1,381	36.3%
Minor Collector	49	1.13	1,011	55.5%
All Links	**181**	**1.06**	**1,899**	**33.6%**

Note: Winter validation statistics rely on an approximate count factoring approach developed using available data sources.

5.2.2 Transit Assignment Validation

Transit assignment results include the total number of boardings at each transit stop, as well as transit volumes on all stop to stop transit route segments. However, transit assignment in the Teton County Model is validated at the system level, with some consideration given to route level validation. Individual stop and segment values have not been validated to observed conditions. Prior to using the model to support detailed transit corridor studies, a focused transit model calibration and validation effort is recommended.

As shown in **Table 5.7**, the overall number of boardings is within 3 percent of observed values, or 68 total trips. Validation on each route is within 100 trips of observed values.

Table 5.7 Transit Validation by Route and System

Route	Observed	Modeled	Difference	% Diff
Town Shuttle	1,844	1,864	20	1.1%
Teton Valley	134	207	74	55%
Star Valley	128	178	50	39%
Teton Village	666	590	-75	-11%
Total	**2,772**	**2,840**	**68**	**2.5%**

5.2.3 Winter Transit Validation

Teton County experiences considerably higher overall transit ridership in the winter months the in the summer. As shown in **Table 5.8**, Transit results for the winter peak model are within 10% of observed values and are reasonably close to observed values at the route level.

Table 5.8 Winter Transit Validation by Route and System

Route	Observed	Modeled	Diff	% Diff
Town Shuttle	1,367	993	-374	-27.4%
Teton Valley	135	173	38	28%
Star Valley	144	185	41	28%
Teton Village	2,852	2,710	-142	-5%
Total	**4,499**	**4,061**	**-438**	**-9.7%**