TMIP How-To: Create Travelshed TAZs

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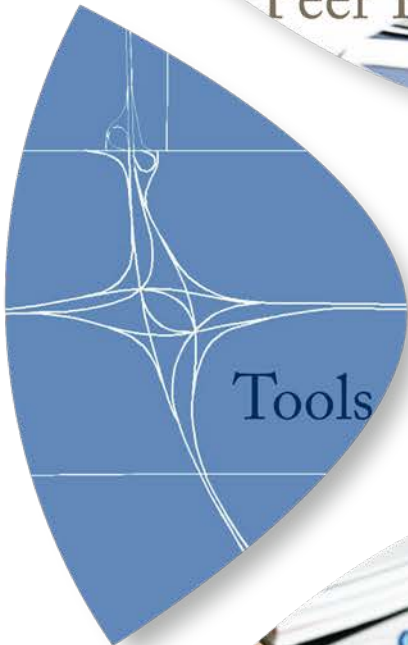
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1. Report No. FHWA-HEP-16-023	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle TMIP How-To: Create Travelshed TAZs		5. Report Date April 10, 2015	
		6. Performing Organization Code	
7. Authors Vincent L. Bernardin, Ph.D., Erich Rentz, Brian Grady		8. Performing Organization Report No.	
9. Performing Organization Name and Address RSG 2709 Washington Ave., Ste. 9 Evansville, IN 47714		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. DTFH61-12-D-00013, T-12002	
12. Sponsoring Agency Name and Address United States Department of Transportation Federal Highway Administration 1200 New Jersey Ave. SE Washington, DC 20590		13. Type of Report and Period Covered September 2013 – September 2015	
		14. Sponsoring Agency Code HEPP-30	
15. Supplementary Notes The project was managed by COR for Federal Highway Administration, Sarah Sun who provides technical oversight.			

16. Abstract

This How-to report shares why and how TAZs were developed for the new Tennessee statewide model using a travelshed paradigm rather than traditional network-based boundaries. Using travelsheds to define TAZs results in a clearer relationship between the zones and the underlying roadway network with less ambiguity around the placement of loading points, makes zonal walkability in urban areas and area type in rural areas much clearer and naturally takes into account other boundaries and barriers to travel. The webinar will overview both the advantages and the challenges of this alternative approach as well as detailed information on the GIS intensive process to develop travelshed zones to support others who might be interested in adopting the approach for their region.

17. Key Words Travelsheds, traffic analysis zones, TAZs		18. Distribution Statement		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified	21. No. of Pages 24	22. Price N/A

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1.0 Executive Summary

Developing travelshed TAZs is an alternative approach to TAZ delineation which treats road facilities and their catchment areas as akin to rivers and their basins in a hydrological system. Low capacity roads funnel traffic to high capacity facilities in a similar fashion to streams converging to form rivers. Rivers' catchment areas are defined as watersheds and in the same light transportation facilities can view their catchment areas as travelsheds. With this view, transportation models can divide their model areas into TAZ that follow the travelshed concept rather than historically traditional TAZ delineation methods.

The development and application of travelshed TAZ arose in response to shortfalls associated with traditional TAZ architectures. The most significant advantage of the travelshed TAZ architecture is the relationship between each zone and the underlying roadway system which can simplify the placement of centroid connectors. Travelshed TAZ also allow more reasonable and accurate assessment of walkability measures in urban areas and area type in rural areas. In designing a TAZ network one does not have to choose between entirely following the travelshed or traditional TAZ methods; it is possible to develop zone systems with a mix of traditional and travelshed TAZ.

The case study for this report is the development of the 2014 version of the Tennessee statewide model. TAZs were developed by aggregating MPO zones in the urban areas and census blocks in the rural areas. Developing travelshed zones for Tennessee was a three-step process. First, a common boundary polygon layer was produced that reflected a common set of boundary constraints to be honored in the final TAZ network. Second, a custom toolbox was developed to automate the creation of a first-cut of the travelshed TAZ boundaries that divided each common boundary polygon into travelsheds. The third and final step was to manually review and revise the output from the automated process.

In the first step, the development of the common boundary layer ensured the inclusion of specific travel and developmental barriers within the final TAZ system. The common boundary layer thus included line representations of rivers, railroads, ridgelines, limited access highways, census designated place boundaries, national and state park boundaries, wildlife management areas, and county boundaries. The next stage of the process was to generate a first cut of the Statewide TAZ using an automated process.

In the second step, several out-of-the-box methods were investigated to test whether they could automate the development of the statewide TAZ network. None of the methods explored produced satisfactory results. A set of tools was created using Esri's ArcGIS platform to facilitate and automate the generation of travelshed TAZ that: prepared source data, identified travelsheds, and generated an output polygon TAZ layer. Once the initial rough cut of the statewide TAZ network had been created, a team of analysts worked county by county adjusting the tool inputs and making manual adjustments to its outputs.

While it is difficult to relate and evaluate how well the TAZ performed without an alternative set of TAZ for comparison, the validation statistics from the Version Two Tennessee statewide model paint a very good picture for the model as a whole and thus, indirectly, the zone system. The best approach to TAZ delineation may be to blend methods together to capture the varying characteristics of a model region. This means that in practice one does not have to construct a TAZ system fully comprised of travelshed TAZ or fully comprised of traditional network-based TAZ. Examining closely the region to be modeled should reveal cases for each method. Adding this alternative approach to the transportation modeler's toolkit will facilitate the examination, and re-examination, of model regions and provide new and potentially better methods to support travel modeling and forecasting.

2.0 Introduction

Transportation models delineate their modeled areas in Traffic Analysis Zones (TAZ) to model trip productions and attractions or activity locations. The delineation of these zones requires considering factors that contribute to creating physical and psychological barriers to travel. Traditionally, TAZ are largely defined by network boundaries. Examples of traditional TAZ structures can be viewed in Figure 1.

Figure 1: Traditional TAZ Network Examples
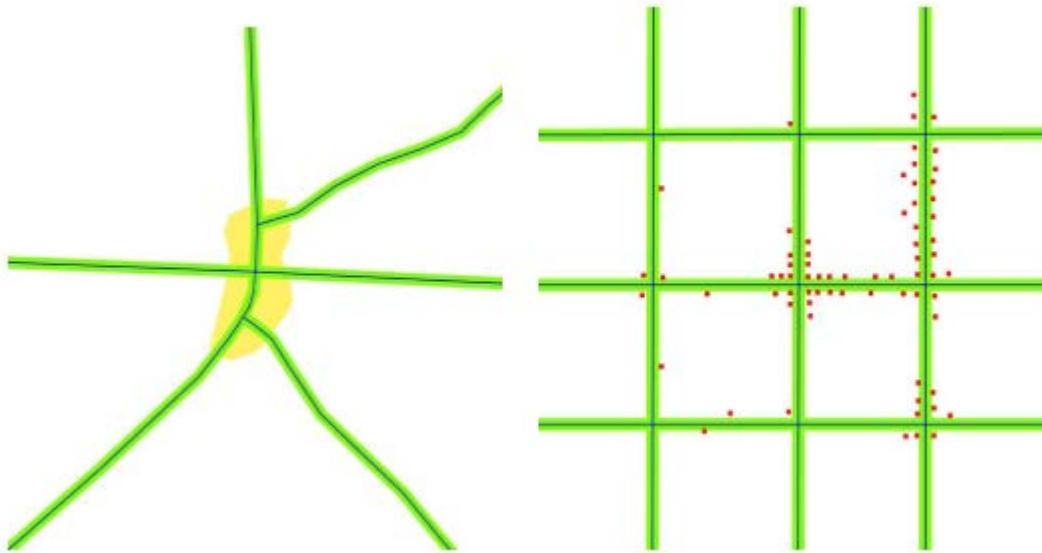
However, it seems counter-intuitive to consider roads as travel barriers when their primary purpose is to facilitate travel. An alternative approach to TAZ delineation is to view road facilities and their catchment areas as akin to rivers and their basins in a hydrological system. Low capacity roads funnel traffic to high capacity facilities in a similar fashion to streams converging to form rivers. Rivers' catchment areas are defined as watersheds and in the same light transportation facilities can view their catchment areas as travelsheds. With this view, transportation models can divide their model areas into TAZ that follow the travelshed concept rather than historically traditional TAZ delineation methods. Examples of travelshed TAZ systems can be viewed in Figure 2.
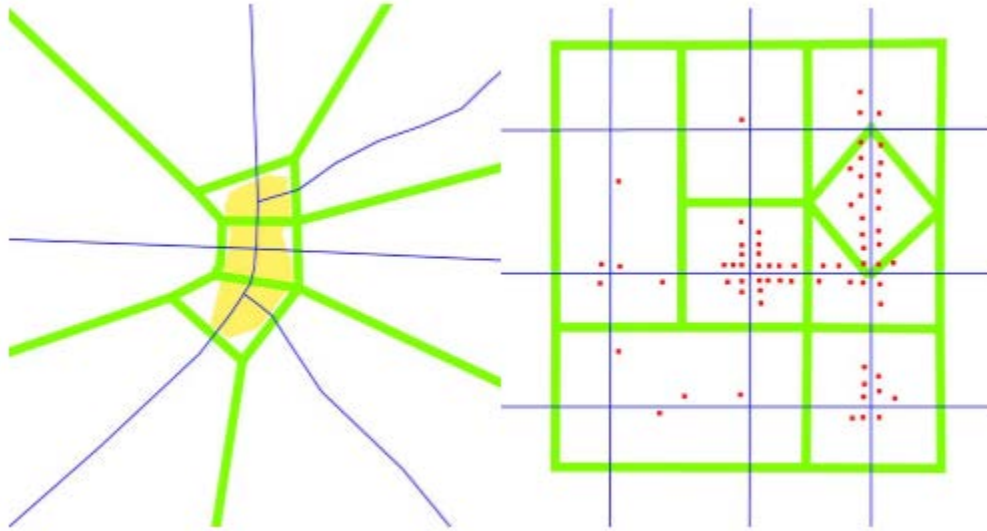
This report will discuss how to develop travelshed TAZ by using the development of Tennessee's Statewide TAZ system as an example.

2.1 Traditional vs. Travelshed TAZ

The development and application of travelshed TAZ arose in response to shortfalls associated with traditional TAZ architectures. The first issue with traditional TAZ architectures stems from the fact that opposite sides of the same street are often parts of different TAZ. This design can make certain analyses, such as walkability assessments, difficult at the zonal level. For instance, some zones will have one boundary that is very walkable because it runs parallel to a sidewalk lined with storefronts while another boundary of the TAZ has no sidewalk coverage and is not walkable at all. How can these spatial characteristics be generalized into zonal features? If the spatial characteristics within a zone vary so widely, it is worth reconsidering whether they should form a single zone.

Another problem with traditional TAZ delineation methods stems from the way small towns are divided in statewide and large regional models. Often, as illustrated in Figure 3, small towns or small urbanized areas wind up in the corner of several otherwise rural zones. This division dilutes the urban area among otherwise rural zones thereby losing the urban character of the area.

**Figure 3: Rural TAZ Splitting Small Urban Areas**
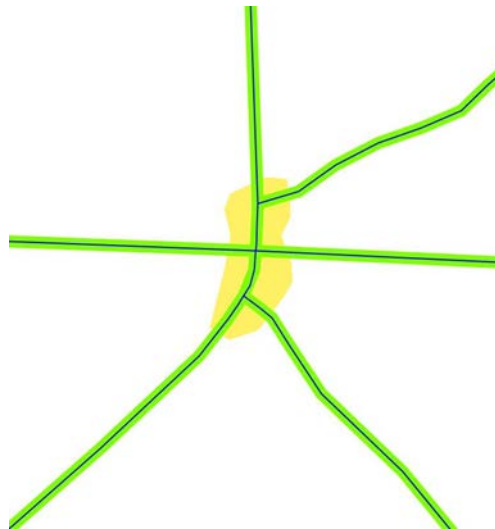
As an alternative, the idea for the "travelshed" is borrowed from hydrology. A watershed is an area that drains into a specific stream or river and thus a travelshed is an area that "drains" traffic onto a specific arterial or highway. Travelsheds identify how corridors accumulate traffic from a model's study area. This alternative approach to TAZ architecture explicitly addresses the loading and unloading of the transportation network and thus dissects the model region into TAZ by identifying natural spatial breaks between network loading patterns.

Travelshed TAZ, as a concept, has been receiving increased attention. For modeling walking and biking, websites like walkshed.org are evidence of this increased attention. Although the vast majority of models within the U.S. employ traditional TAZ architectures, implementations such as those by the Portland MPO, Iowa DOT, and Tennessee DOT are examples where the travelshed approach has been adopted. The Portland MPO this method for their travel demand model as early as 20 years ago. Statewide models are slowly moving in the direction of travelshed zones as well, with the Indiana and Iowa statewide models revising their zone systems around small towns. These adjustments are recognition that in the context of statewide modeling, the traditional TAZ architecture can pose significant challenges.

The travelshed TAZ concept can be implemented using various different geometric approaches. Examples of different travelshed TAZ geometries can be seen in Figure 4 and Figure 5. For instance, one way that travelshed TAZ architectures can be constructed is by offsetting the transportation grid as in Figure 4.

Figure 4: Travelshed TAZ Example - Offset from Transportation Grid
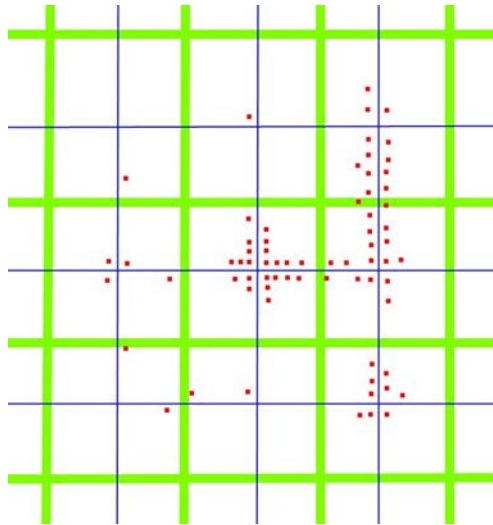
There are several advantages to this architecture. For instance, business geocoding becomes easier because one does not have to worry about a geocoded business falling on the wrong side of the street or on the street centerline itself. When a model shifts away from the traditional TAZ network system, that problem goes away because both sides of the street are part of the same zone. Further, to the extent that there often is a conglomeration of businesses around the intersection of arterials, it makes sense to group those destinations rather than split them across zones. Another example of the travelshed TAZ concept can be seen in Figure 5.

Figure 5: Travelshed TAZ Example: Block Faces
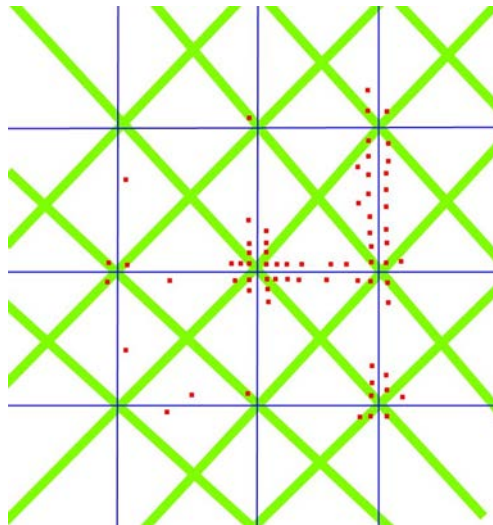
Notice that for the most part each block face becomes a zone. In some cases, like in micro and traffic simulation, modelers already employ this approach. This approach can often become challenging at a regional scale as it will lead to a much larger number of zones. However, the clear benefit of this approach is that there is no ambiguity as to where the network loads and where the centroid connector should be placed. These examples are by no means exhaustive. There are various ways to employ the travelshed TAZ method and these are but a few examples of how travelshed TAZ can be shaped.

2.2 Advantages to the Travelshed TAZ Development Process

The examples in the previous section detail some advantages of the travelshed TAZ architecture as opposed to the traditional architecture. The biggest advantage of the travelshed TAZ architecture is the clear relationship between each zone and the underlying roadway system. Specifically, if a model uses travelshed TAZ architecture, it is very easy to determine where the network loads, and thus where to attach centroid connectors within the model. A common dilemma in constructing a traditional, grid-based TAZ network architecture is determining where to attach centroid connectors. For instance, in a traditional TAZ architecture many TAZ are bounded by four different roads, each road being a plausible loading point for traffic, and thus a logical candidate for a centroid connector. The travelshed TAZ architecture removes this ambiguity. The zones in travelshed TAZ architectures are designed to have traffic load and unload at their centers, making it easier to place centroid connectors, and thereby reducing the total number of centroid connectors needed. The second biggest advantage of the travelshed TAZ model is that the architecture suppresses the variation of roadway coverage per zone. This helps to promote the homogeneity of zone characteristics and promotes the division of area types (such as urban vs. rural) and other characteristics such as walkability between zones.

While the benefits of the travelshed TAZ architecture are many, it should be noted that in designing a TAZ system one does not have to choose between entirely following the travelshed or traditional TAZ methods; it is possible to develop zone systems with a mix of traditional and travelshed TAZ. The best approach may be to blend methods together to capture the varying characteristics of a model region. Examining closely the region to be modeled may reveal cases for each method. The point of this report is not to advocate the sole application of the travelshed TAZ concept for every transportation model. Rather, this report will enumerate an alternative method to allow modelers to look outside the default network-based zone boundary architecture and promote a closer examination of the spatial variation of a model area. Just as there are many cases where it makes sense for TAZ to follow network boundaries, there are also many cases where it does not make sense for them to follow network boundaries. Adding this alternative approach to the transportation modeler's toolkit will facilitate the examination, and re-examination, of model regions and provide new and potentially better methods to support travel modeling and forecasting.

2.3 Disadvantages to the Travelshed TAZ Development Process

There are limitations to the current approaches to develop travelshed TAZ architectures. One issue with the travelshed TAZ approach is the use of census geographies to create zones. Transportation models often use aggregations of census blocks, or block groups, to create TAZ. However, the census geographies do not necessarily follow the alignments required to delineate travelsheds. This is because census geographies are often delineated using road network boundaries. For traditional TAZ development this does not pose an issue but for the travelshed delineation methods, this can pose challenges. In some areas, the census blocks are small enough that they can still be combined to represent travelsheds appropriately, but this is not always the case.

Addressing the limitations of census boundaries is not impossible, but can take additional time and effort. The travelshed TAZ development approach can take more effort. Developing traditional TAZ can be straightforward: take model area's transportation network, convert the lines to polygons, divide exceedingly big polygons, aggregate really small polygons, and viola: a traditional TAZ network. It takes more thought and effort to develop travelshed TAZs. For some, this can be seen as a limiting factor. However, it must be noted that there are significant benefits to taking the time and effort up front to scrutinize the development of the TAZ system. The

benefits of developing a detailed travelshed system architecture can outweigh the initial effort in the long run by requiring less effort for validation in the end.

2.4 Case Study Introduction: Tennessee Statewide Model

The case study for this report is the development of the 2014 version of the Tennessee statewide model. The previous Tennessee statewide model was developed in 2005, and the model's network can be seen in Figure 6.
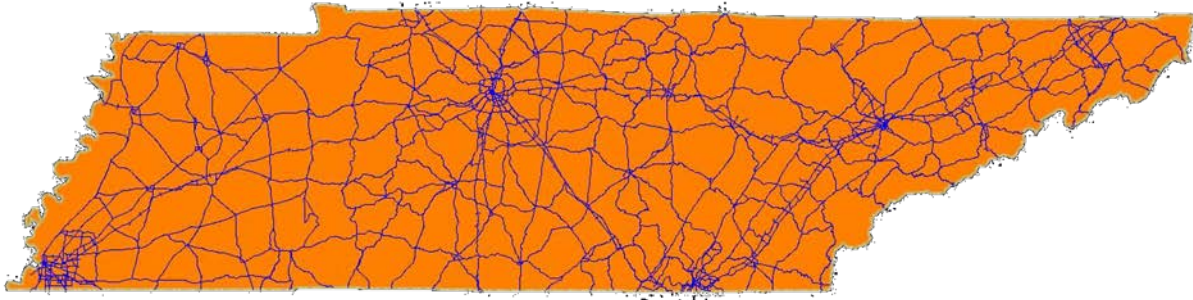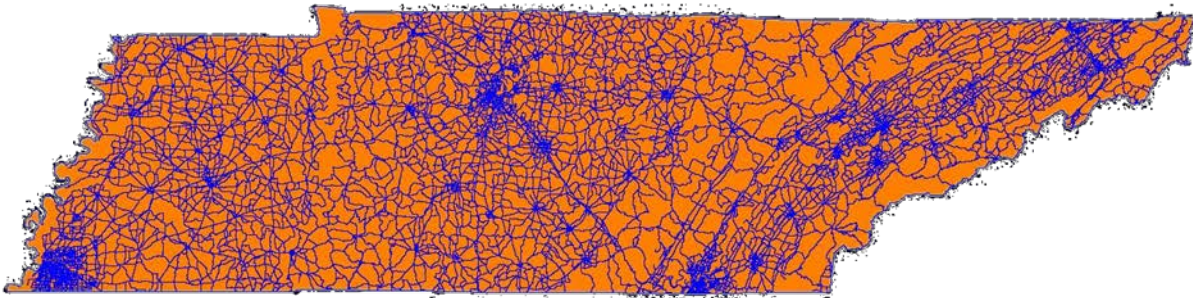
Figure 6: Tennessee Statewide Model Version 1, 2005, TAZ

Figure 7: Tennessee Statewide Model Version 2, 2014, TAZ

The 2014 version of the model, shown in Figure 7, tripled the modeled road lane miles in the model, thus adding the need for additional zonal resolution. In order to support the significant, additional network coverage, the question of how to design the zone system naturally arose. In order to avoid the future problem of having to revise a traditional TAZ architecture to add resolution in rural areas around small towns, it was decided that a travelshed TAZ approach should be adopted from the outset. This method was adjusted and limited for the MPO areas to promote consistency with the MPO models. To promote this consistency between statewide and MPO models, the statewide model TAZ in the MPO areas were developed as aggregations of MPO TAZ. The way that they were aggregated did consider and make use of travelshed concepts, but the underlying structure of the MPO TAZ limited the degree to which the resulting zones exhibited travelshed characteristics. On the rural side, the ability to determine area types and represent small towns distinctly was of the most importance. This case study will outline how, in the rural areas, a travelshed approach was used to develop TAZ built from census blocks. The idea behind using census blocks being that they would give adequate spatial resolution to develop travelshed zone boundaries while eliminating the need to overlay and disaggregate block level census data for the final zone network.

3.0 How-To for Developing Travelshed Zones

Developing travelshed zones for Tennessee was a three-step process. First, a common boundary polygon layer was produced that reflected a common set of boundary constraints to be honored in the final TAZ system. Second, a custom toolbox was developed to automate the creation of a first cut of the travelshed TAZ boundaries that divided each common boundary polygon into travelsheds. The third and final step was to manually review and revise the output from the automated process. The following sections outline the detail of each one of these three steps.

3.1 Developing the Common Boundary Layer

The development of the common boundary layer ensured the inclusion of specific travel and developmental barriers within the final TAZ Network. Actual physical and psychological barriers to travel should to be included in the final TAZ since each zone is meant to represent a place, not two or more distinct places which are actually separated to some degree by a barrier. Barriers will ultimately be incorporated in destination choice models so that their effect on travel can be fully represented. The common boundary layer thus included line representations of rivers, railroads, ridgelines, and limited access highways. These boundaries were determined to be a minimum demarcation that would need to be included in the final TAZ architecture. While the automated travelshed TAZ delineation process often picked up the presence of these boundaries, there were certain situations that would cause a travel barrier to be missed during the travelshed identification process. It was therefore important to make sure that these barriers were identified for inclusion in the final TAZ. Additionally, in order to accurately delineate TAZ for forecasting it was determined that census designated place boundaries, national and state park boundaries, and wildlife management areas should be included in the common boundary layer. This ensured that development was forecasted in areas where development could occur. Finally, there is often a need and desire to summarize statewide model results at the county level so county boundaries were included in the common boundary layer as well.

Figure 8: Common Boundary Layer
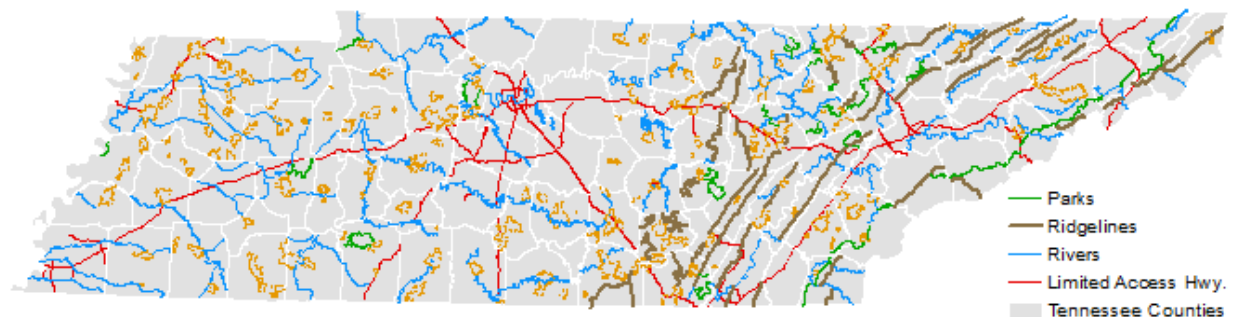
3.1.1 Identifying Common Boundaries: Rivers

**Figure 9: Common Boundary Layer - River Features**
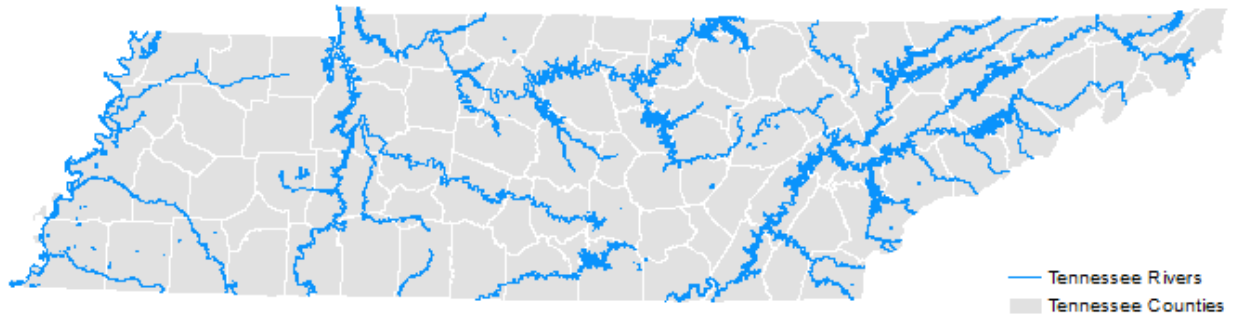
While it may be simple to cognitively appreciate that hydrological features form a barrier to travel, it is much more difficult to identify which hydrological features should be identified as such. There exist a multitude of spatial representations of hydrological features. Some of these representations are coarse and contain major rivers while some of these representations contain every stream and rivulet. The question quickly arises of how to define major waterways and water bodies that actually pose a barrier to travel. Two key criteria were determined to answer this question: is the water feature lengthy enough to form a significant travel barrier? And, was the feature crossed frequently by the road network? Using these two criteria in conjunction highlighted the hydrological features that pose physical barriers to travel. For instance, the example below depicts the road network overlaid on hydrological features. Note the limited network connectivity. River feature examples such as this were included in the common boundary layer.

**Figure 10: Example Rivers Included in Common Boundary Layer**

3.1.2 Identifying Common Boundaries: Ridgelines

Figure 11: Common Boundary Layer - Ridgelines
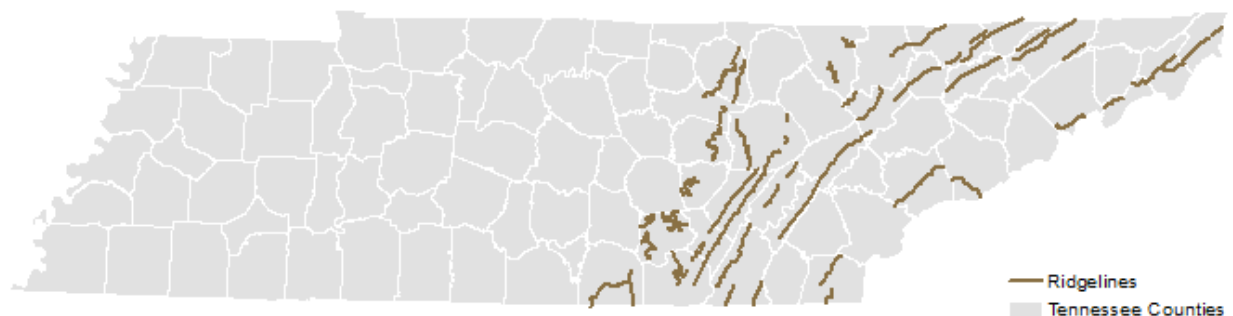
Ridgelines are another travel barrier that cognitively make perfect sense but can be challenging to identify and demarcate. There is was not an all-inclusive ridgeline file for Tennessee so in order to produce ridgelines for the common boundary layer a process was developed to produce spatial representations of ridgelines. A combination of watershed boundaries from the USGS National Hydrography Dataset (NHD) and digital elevation models (DEM) from the National Elevation Dataset (NED) was used to create ridgeline representations. During review it was noted that in reality it was not necessarily just ridgelines that were needed for the common boundary layer, but also extreme slopes. Using a similar approach to the one described for identifying appropriate rivers for inclusion, areas of high slope that were intersected by few streets in the all-streets network were identified as physical barriers to travel. Figure 12 displays example ridgelines included in the common boundary layer.

Figure 12: Example Ridgelines included in the Common Boundary Layer
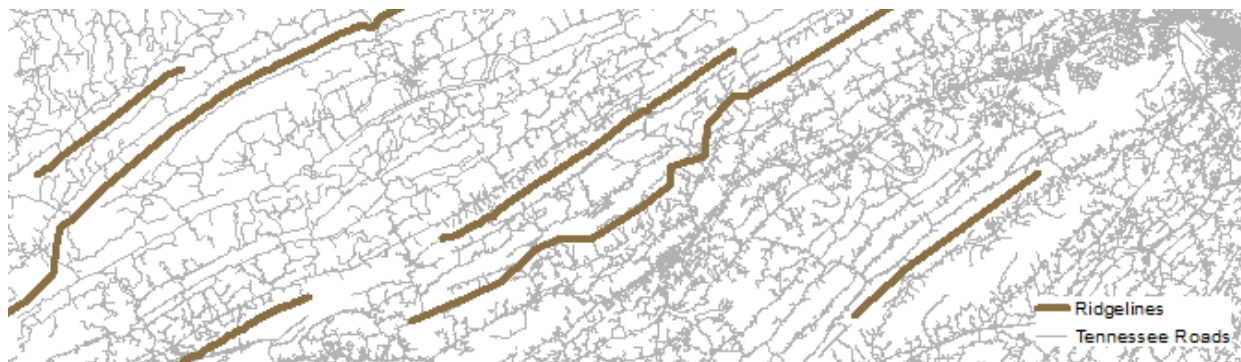
3.1.3 Identifying Common Boundaries: Railroads

Railroads are another potential travel barrier. Obviously, some railroads present more of a physical barrier than others. Railroads can also help to define the psychological boundaries of a travelshed because they can bound individuals' mental maps. In order to define the railroad component of the common boundary layer data sources, both state and national, were combined to define the rail network in within the common boundary layer.

Figure 13: Common Boundary Layer - Railroads
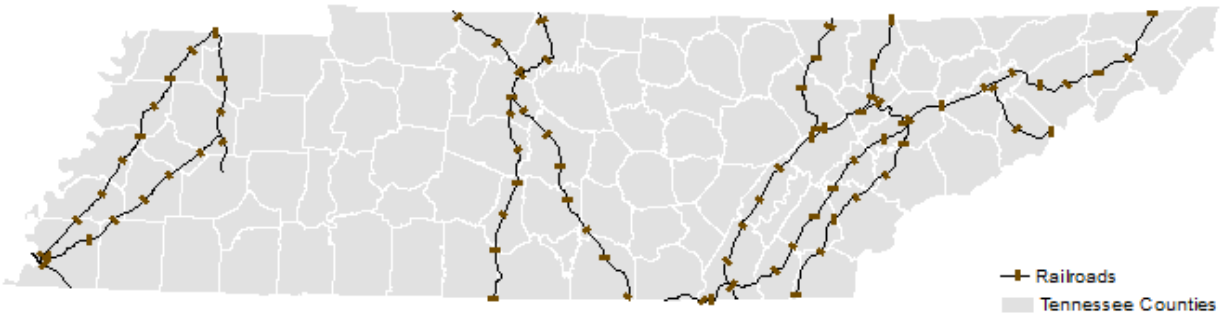
3.1.4 Identifying Common Boundaries: Limited Access Highways

While the travelshed TAZ concept views roads as travel facilitators, some roadways can pose as barriers to travel. In particular, limited access roadways can act as travel barriers and as such need to be included in the common boundary layer. Thinking again about the relationship between a travelshed and the roadway network, nothing loads directly onto the freeway and their characteristic of having few access points means it is appropriate to view these limited access highways as barriers and include them in the common boundary layer. While Interstates are of particular interest, in the statewide context even partially access controlled facilities can be included in the common boundary file. In Tennessee there were some facilities that would have some degree of access control for portions and then would cease being access controlled. In some of these cases limited access roadway sections were deemed too short or non-barriers and were subsequently dropped from the common boundary layer. The roadways included in the common boundary layer can be seen in Figure 14. The interstate system is very clear, but other important facilities like the Natchez Trace Parkway, which is also a national park, are also featured prominently.

Figure 14: Common Boundary Layer - Roadways
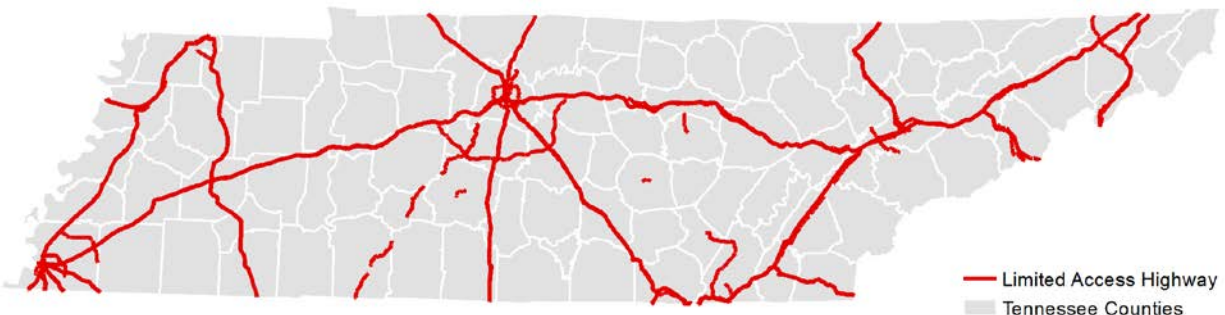
3.1.5 Identifying Common Boundaries: Census Designated Places

Census designated places (CDP) were used to identify small towns and urban clusters in otherwise rural regions. The character of a small town is so different from a purely rural area that it is important to ensure that these areas were highlighted and separated for statewide transportation modeling. CDP with a population greater than 500 persons were selected to be highlighted for inclusion in the common boundary layer. While the boundaries of CDP are not physical barriers, they are a decent proxy for the psychological barrier of travel between small towns and adjacent rural areas. An individual in a small town is more likely to display the same

travel behaviors as neighbors within that area than those outside. Unfortunately, CDP boundaries can be quite irregular in shape. To address this irregularity the CDP boundaries were buffered and then block centroids falling within the buffer were dissolved. Not only did this reduce the irregularity of the CDP boundary shapes, but it also recognized the potential for new development around existing towns. After buffering there were still some CDP with irregular shapes. These CDP were then trimmed of appendages as necessary.

**Figure 15: Common Boundary Layer - Census Designated Places (CDP)**
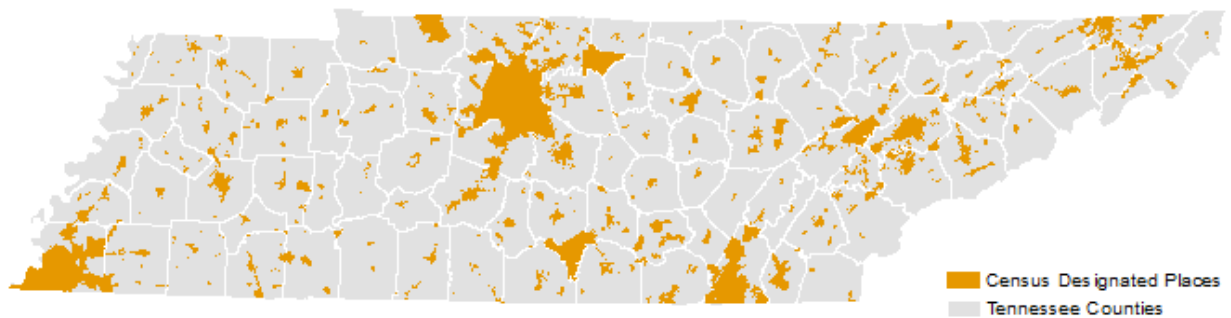
3.1.6 Identifying Common Boundaries: Parks

National parks, major state parks, and wildlife management areas were incorporated into the common boundary layer to ensure that protected undeveloped land was represented as such for forecasting and to ensure that popular destinations are delineated from surrounding rural areas. Gatlinburg is a prime example of the challenge posed by protected land in delineating TAZ. The area contains swaths of highly developed land adjacent to large undeveloped areas. To accurately forecast growth scenarios in this circumstance it is of paramount importance to ensure that growth is forecasted in places where growth is possible and not in the Great Smoky Mountain National Park. Also of importance when considering parks is identifying and delineating unique destinations that are surrounded by otherwise rural areas. These parks are unique in that they represent destinations for non-business, long distance trips where the attraction is not based on number of employees. By distinguishing between park lands and non-park lands alternative measures, like acreage, can be used to estimate trip productions and attractions.

3.1.7 Identifying Common Boundaries: Counties

Counties boundaries were include in the common boundary layer to facilitate socioeconomic data creation and to facilitate model summarization. Socioeconomic data, current and forecasted, is more reliable at a county level than at more disaggregate geographies. Respecting county boundaries therefore provided fixed control totals for the generation of socioeconomic data at the disaggregated TAZ level. On a pragmatic note, respecting county boundaries also promoted modularity and allowed for subsequent steps to be broken into smaller pieces. Dividing the TAZ delineation task at the county level significantly decreased the run time for automated tools, decreased the effort for analyst revision, and decreased file transfer and manipulation times.
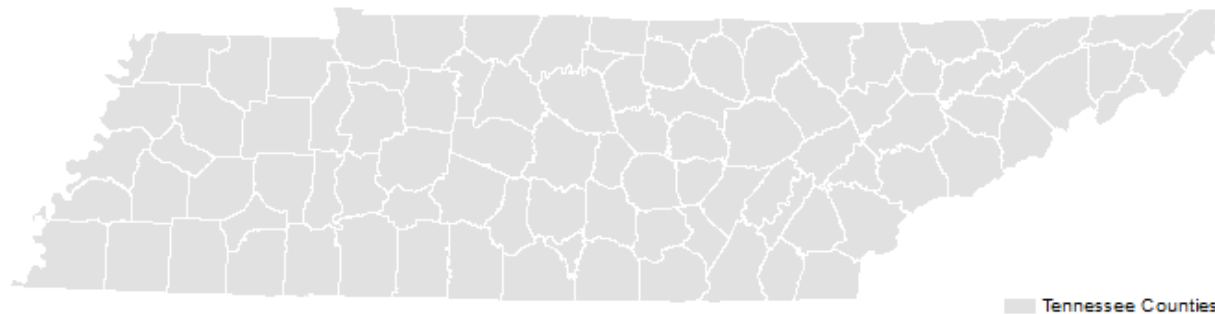
3.1.8 Combining Common Boundaries to Produce Common Boundary Polygons

The ultimate goal of the common boundary work was to create a polygon layer, with coverage for the entire state of Tennessee, which represented a first and rough cut of the boundaries that the final TAZ would honor. While some of the common boundary layers are more commonly perceived and represented as polygons, in order to create a final polygon layer all of the common boundaries need to be combined as line representations before they could be converted to polygon representations. The steps are as follows: 1.) convert individual common boundary files from polygons to lines as necessary; 2.) merge common boundary line files into one final line layer; 3.) review the line layer to remove dangling lines and parallel lines in close proximity; 4.) convert the reviewed line layer to polygon. Excepting the line layer review, these steps were very straight forward. The review was more arduous for a couple of reasons. First, there were many dangling lines that needed to be connected or dropped to form true polygons. Second, it was important to eliminate close parallel lines from different layers. For instance, railroads often run parallel to rivers (for obvious reasons) but the 20 to 30 foot gap between the line representing a river and the line representing a railroad does not need to be represented as a polygon and thus one of these line representations needed to be removed. The review process ensured that the final common boundary polygon layer was an accurate representation of what were deemed to be the lowest common denominator of boundaries the final TAZ network to honor.

3.2 Automated Delineation

The next stage of the process was to generate a first cut of the Statewide TAZ using an automated process. The common boundary layer split the state into 700 polygons of varying size. However, the target number of TAZ was 3,000 to 3,500 so those 700 common boundary layer polygons needed to undergo substantial splitting. Several out-of-the-box methods were investigated to test whether they could automate the development of the statewide TAZ system. None of the methods explored produced satisfactory results. It was determined that an automated solution would need to be produced from scratch in order to create a first cut of the statewide TAZ. A set of tools was created using Esri's ArcGIS platform to facilitate and automate the generation of travelshed TAZ. At the highest level, the set of tools followed the following workflow:

1) Prepare source data.

2) Identify travelsheds.

3) Generate output polygon TAZ layer.

These steps are enumerated in detail in the following section.

3.2.1 Prepare Source Data

The algorithms that were developed to create travelsheds required three spatial inputs: traffic counts, census blocks or MPO model TAZ, and the common boundary layer. Traffic counts were obtained from Tennessee's TRIMS Traffic layer which contained imputed AADT values for all the links in the model network. Census block boundaries were obtained from TIGER while socio-economic data was obtained from the decennial census, American Community Survey, the Bureau of Economic Analysis (BEA), InfoGroup USA, and Longitudinal Employer-Household Dynamics (LEHD). MPO model TAZ were obtained from each of Tennessee's ten MPOs. For a sense of scale, Tennessee's ten MPOs had a total of 8,000 TAZ while the state is comprised of more than 240,000 census blocks.

To promote consistency between the statewide model TAZs and the MPO model TAZs the statewide TAZ development process was split into two parts: MPO and Non-MPO. In the state's rural areas travelsheds were defined based on aggregations of blocks while in the MPO areas travelsheds were defined based on aggregations of MPO model TAZ. This difference meant that the two processes (MPO and rural TAZ development) occurred in parallel with that single wrinkle. This report outlines the development of the rural, Non-MPO TAZ. Figure 17 displays the MPO regions of the state in color and the Non-MPO regions of the state in gray.

Figure 17: Tennessee's MPO and Non-MPO Areas
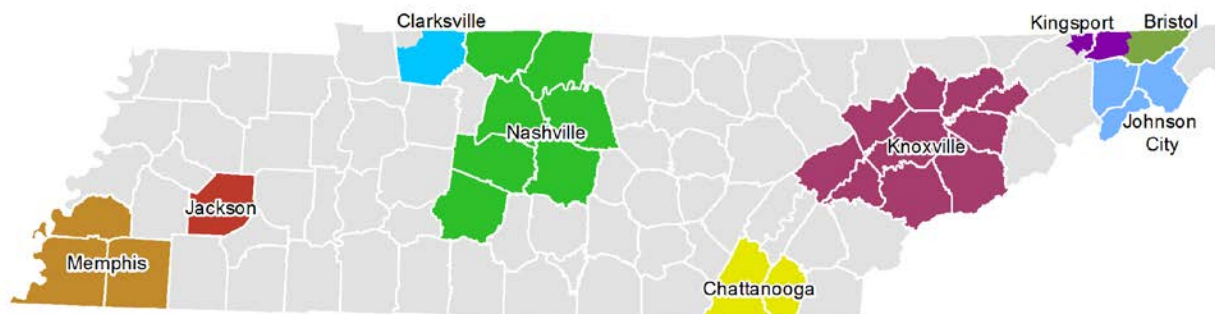
To promote parallelization of the process the datasets were divided by county. This meant that geoprocessing could occur simultaneously on multiple computers, thus greatly reducing computational duration of the automated steps. This division also facilitated the subsequent manual revision process. Limiting the manual review process to a county at a time allowed multiple individuals to work simultaneously on the task, while also limiting the burden of the review process.

3.2.2 Identify Travelsheds

The identification of travelsheds in the Non-MPO areas was a three step process: identify a target TAZ count for each common boundary polygon, identify travel corridors within each common boundary polygon based on the target TAZ count, and then assign census block centroids to each corridor. The division of these steps into three separate algorithms facilitated the application of a priori knowledge where appropriate. For instance, based on the shape, location, or network composition of a common boundary polygon an analyst might know to add or subtract from the target zone count. Disaggregating the process and maximizing the modularity of the toolset promoted the use of analyst knowledge and judgment to help in the TAZ development process.

Population and area were used to calculate the appropriate target TAZ count by common boundary polygon. The algorithm for this step utilized an expert system to quantify the

appropriate TAZ count by common boundary polygon. The basic logic behind the algorithm boils down to the following:

Figure 18: TAZ Count Allocation Logic

As alluded to previously, the target TAZ counts were a guideline and not a strict rule. Setting a target TAZ count allowed the next step to have a logical target based on palpable information and helped to limit later revisions when area and population targets were enforced.

The next step was to identify the corridors upon which the final travelshed would be based. These corridors were the primary facilities within each common boundary polygon. In the travelshed/hydrology parlance, the corridors should be conceptualized as akin to rivers within a hydrological system. To highlight corridors in an automated fashion an algorithm was developed to select traffic count links from the TRIMS traffic layer based on the maximum AADT for each route. The number of selections was based on the target TAZ count as highlighted by the initial step. Interstates and other limited access facilities were excluded from the corridor selection. Limited access facilities are already represented by the common boundary layer and are not the type of corridor that this process was trying to highlight.

The final algorithm assigned block centroids to the identified corridor. The algorithm that was developed utilized an iterative buffer approach to tag centroids in a hierarchical fashion. For each common boundary polygon within each county, the algorithm would select the corridor with the highest AADT, buffer around that line representation, tag centroids falling within the buffer, then move to the corridor with the second highest AADT and repeat the process. Once all the corridors were buffered, the process would repeat with an increased buffer size. This would repeat until all centroids were tagged, and then the next common boundary polygon would be considered. Pseudocode for the algorithm can be seen in Figure 19.

**Figure 19: Block Assignment Algorithm**
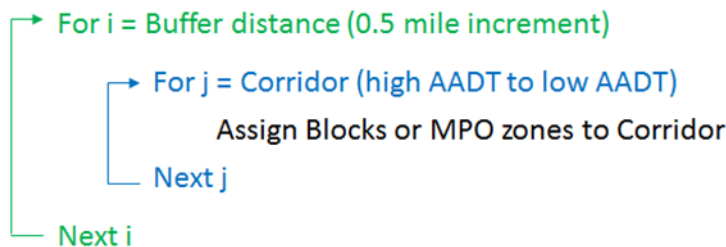
A sample of the travelshed identification process for a single common boundary polygon in Clay County can be seen in Figure 20. The top map shows the selected corridors, the middle map shows the block centroid to corridor assignments and the third map shows the rough travelsheds that have been identified fully automatically. The resulting TAZ geometries need some work, but they exhibit many travelshed qualities.

Figure 20: Sample Travelshed Identification for Clay County
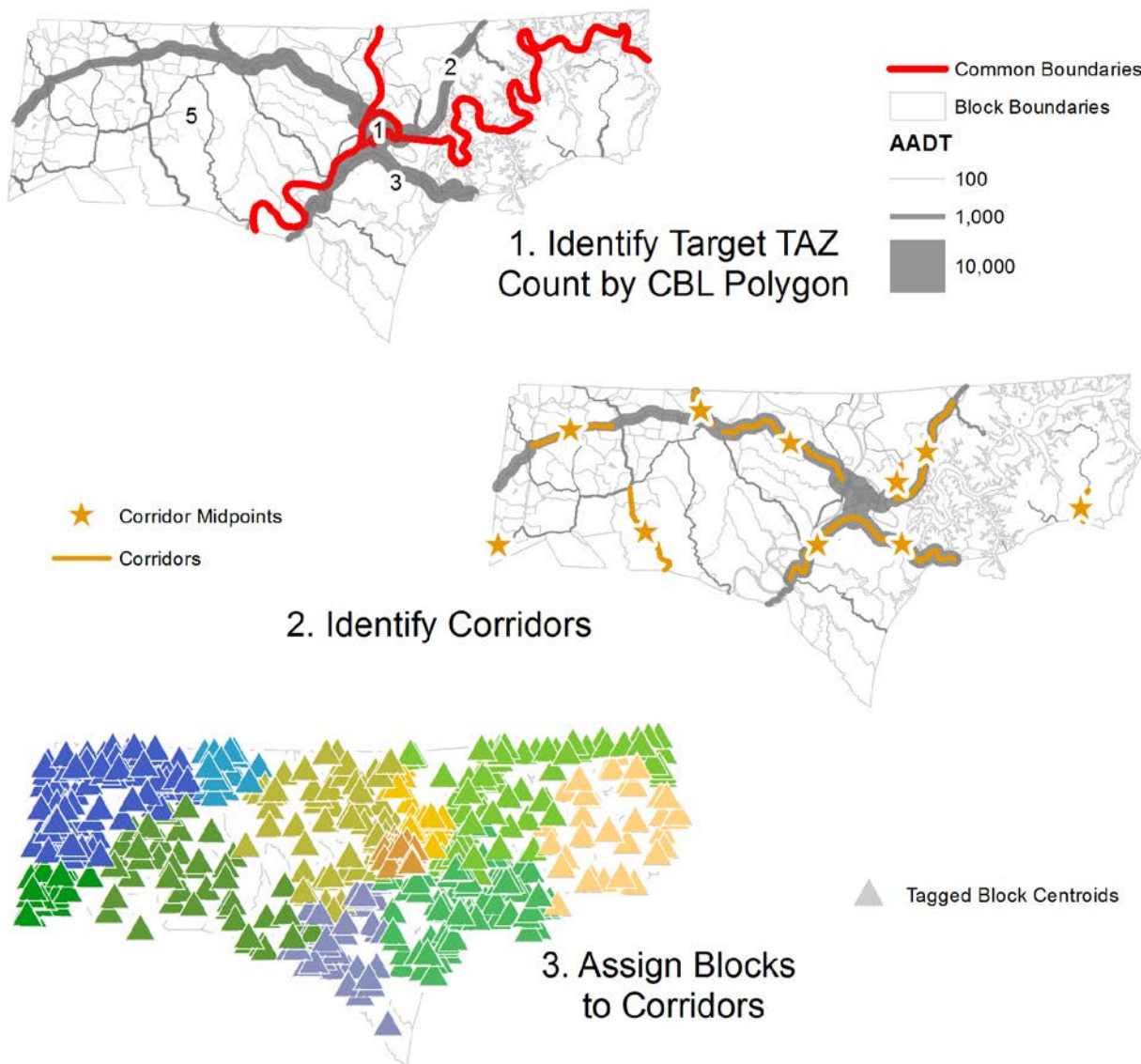
3.2.3 Generate Output Polygon TAZ Layer

Once the block centroids were tagged by corridor, they could be related to their corresponding polygon shapes and aggregated by each corridor's unique identifier to create a first cut of the statewide TAZ. At this point socio-economic data was also aggregated by TAZ. This allowed for an initial series of quality assurance steps to be performed to ensure that the output TAZ followed a few basic conventions to flag TAZ with a population greater than 3,000, to flag TAZ with multipart features, and to flag TAZ that fully surrounded other TAZ. While the conversion of blocks to centroids facilitated the corridor tagging process, the resulting tagged centroids are

difficult to review and grade. Converting the centroids to polygon allows for easier review and brings to light the underlying geometry.

Figure 21: Example Output TAZ, Clay County

Rough TAZ

AADT Source: TRIMS
*AADT is drawn proportionally
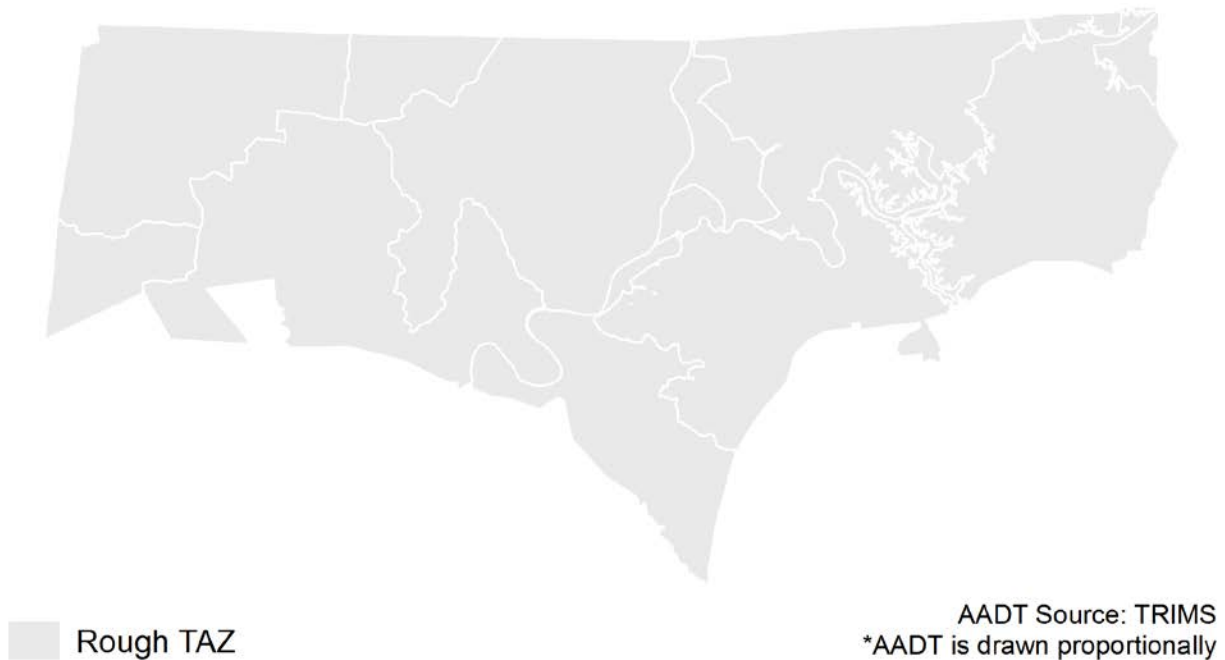
3.3 Manual Review and Revision

Once the initial rough cut of the statewide TAZ network had been created, a team of analysts worked county by county adjusting the tool inputs and making manual adjustments. As mentioned previously, the tools that were developed to automate steps within the travelshed TAZ generation process were flexible to allow for manual adjustments to variables such as TAZ count per common boundary polygon, travelshed corridor identification, corridor preference during block assignment, etc. This meant that the tools were designed to be run, and re-run, based on a user's judgment. Dividing the tools into sub steps also facilitated manual intervention. The process as a whole allowed for the best combination of human judgment and automation. While the algorithms could produce an acceptable product, with the application of manual adjustments the final TAZ network could reflect the travelshed concept and a viable TAZ network.

The main purpose of the manual review process was to check the output TAZ based on the flags created when the final polygon geometry was created. Zones with large areas, high populations, islands, multipart features, or generally irregularly geometry needed to be adjusted. The flags that were generated in the final step of the first run, the fully automated process, were a good starting point for analysts to apply a priori knowledge to determine whether zones needed adjustment, and if so how. In some cases zones wound up being exceedingly large, in area and or population. Other zones had irregular shapes more akin to gerrymandered voting

districts. In some cases, the algorithm had created TAZ with multiple parts. All of these characteristics needed to be visually inspected and addressed.

After the manual review process was completed the TAZ network was reviewed by Tennessee DOT staff, representatives from the 11 MPOs in the state, and staff from the Center for Transportation Research at UT Knoxville. The additional input was considered and some adjustments were made as a result. While a few adjustments were made based on this additional input, by and large the groups reviewing the work were satisfied with the zones.

Figure 22: Example Output TAZ, Clay County

Manual Adjustments
Final TAZ

AADT Source: TRIMS
*AADT is drawn proportionally
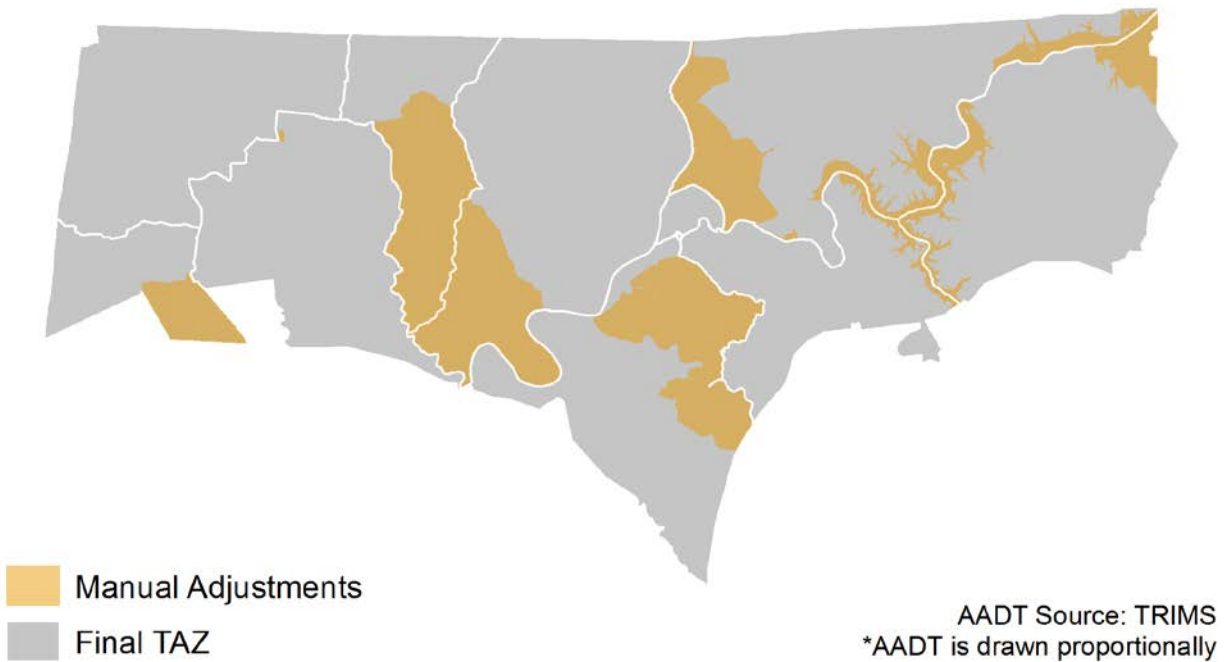
4.0 Conclusions

While it is difficult to relate and evaluate how well the TAZ performed without an alternative set of TAZ for comparison, pointing to the validation statistics from the Version Two Tennessee statewide model paints a very good picture for the model as a whole and thus, indirectly, the zone system. The TAZ are at least part of the reason for this success. NCHRP reported validation statistics for a number of statewide models and the new Tennessee statewide model compared very well in comparison. A breakdown of the model validation statistics can be seen in Table 1.

Table 1: Model Validation Statistics

Volume Range		Number of Count Stations	Percent Error	Correlation Coefficient	MAPE	% RMSE	
						Model	Standard
1	5,000	7,288	10.2	0.69	66.8	91.1	101.4
5,000	10,000	1,943	5.5	0.61	31.1	39.6	56.3
10,000	20,000	1,700	0.8	0.79	21.0	27.8	51.4
20,000	30,000	747	-2.1	0.85	15.9	21.5	35.7
30,000	40,000	318	0.6	0.85	12.0	18.1	32.0
40,000	+	661	-0.1	0.94	11.5	15.6	21.6
Total		12,645	2.1	0.97	47.9	37.0	60.0

One benefit that the Tennessee Statewide Model TAZ development process revealed included the clear representation of small towns in rural areas due to the travelshed TAZ approach. This approach helped to represent origin and destination patterns in rural areas far better than traditional TAZ geometries. Travel in rural areas is from or to these small towns, between small towns, or from a small town to a larger city. The travelshed zone system in the Tennessee statewide model allows for a far superior representation of these origins and destinations than traditional zone systems. This representation is believed to be part of the reason for the Tennessee statewide models performance. Testing this assertion could provide the basis for some fruitful research.

The validation statistics from the Version Two Tennessee statewide model paints a very good picture for the model as a whole and thus, indirectly, the zone system. An alternative set of TAZ could be developed to quantify the direct effects of the travelshed TAZ network, but it is safe to say that the TAZ play a significant role in the model's validation statistics. Automating several of the computationally intensive tasks both facilitated the TAZ delineation process and allowed for the application of analysts' knowledge and judgment at appropriate junctures within that process. There is more effort required to create travelshed zones than to create traditional zones, but this is not necessarily cost prohibitive. Additionally, there are positive externalities to leveraging travelshed zones. While developing the zones may take additional time and effort, that effort can greatly reduce the effort required for creating centroid connectors and validating the model. In the case of the Tennessee's statewide model, more time was spent developing the zone system up front, and the resulting decreased ambiguity in terms of loading points saved substantial time during the validation.

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This report is being distributed through the Travel Model Improvement Program (TMIP).

FHWA-HEP-16-023

Federal Highway Administration