Washington State Department of Transportation

Washington State

Multimodal Permeability Pilot

August 2021

Contents

Introduction

In 2018 the Federal Highway Administration (FHWA) released *the Guidebook for Measuring Multimodal Connectivity* (MMC Guidebook). The Guidebook explored methods for describing bicyclist and pedestrian networks. FHWA defined networks as, “accessible, interconnected pedestrian and/or bicyclist transportation facilities that allow all users to safely and conveniently get where they want to go”. Such networks can be objectively described in terms of density, directness, access to destinations, facility quality, and network completeness.

The MMC Guidebook discusses how jurisdictions can integrate multimodal network connectivity analysis into the active transportation planning process. The guide outlines a five-step process (Figure 1) and illustrates the application of that process in five case studies, summarized in the appendices. In late 2018, FHWA called for additional pilot projects to apply their systematic connectivity planning process in the hopes of showing how the methodology can lead to better data driven planning outcomes.

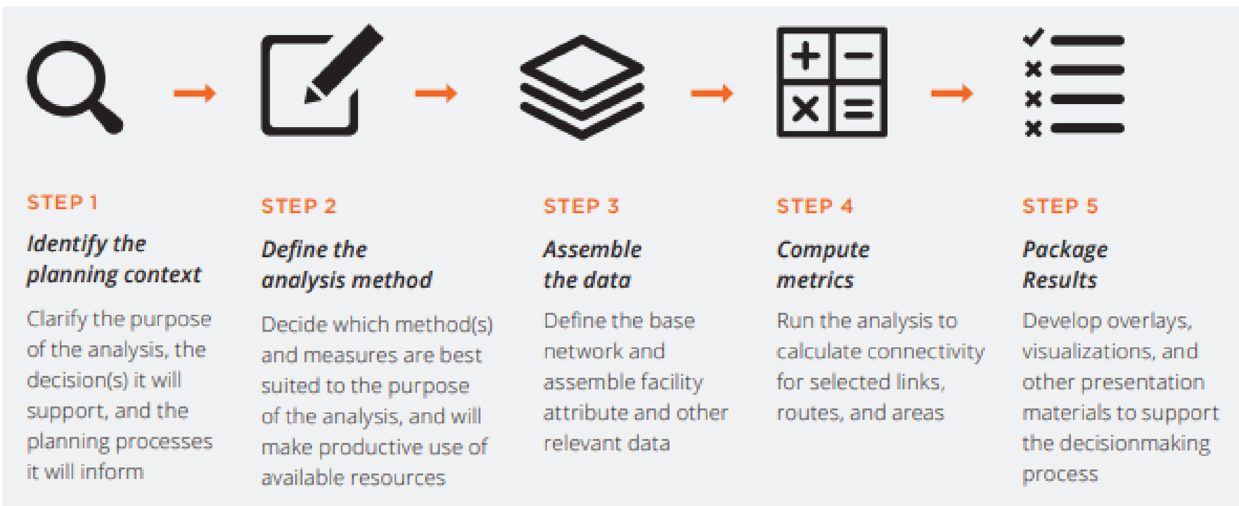

Figure 1. Five-step connectivity analysis

Multimodal network connectivity analysis was piloted in Washington State during 2019 and 2020; this report documents the process and findings of work completed. The Multimodal Permeability Pilot (MPP) was undertaken concurrent to the development of the Washington State Department of Transportation (WSDOT) [Active Transportation Plan 2020 and Beyond – Part 1] (ATP). Although an independent study with distinct methodology, the ATP used a variety of tools to explore how the state roadway network aligns with bicyclist and pedestrian needs. The parallel data analysis activities of the ATP and MPP were complementary.

Background and Planning Context (Step 1)

WSDOT has a primary goal of safety for all modes across the state transportation network. WSDOT’s strategic plan envisions a transportation system where “Washington travelers have a safe, sustainable, and integrated multimodal transportation system.”[1] Similarly, the agency’s

[1] WSDOT. Strategic Plan. Information collected on: 01/30/2020. https://www.wsdot.wa.gov/about/secretary/strategic-plan/

mission is to "…provide safe, reliable, and cost-effective transportation options to improve communities and economic vitality for people and businesses."[2] This includes providing safe and comfortable routes for pedestrians and bicyclists, some of the most vulnerable road users.

Ease of use of a transportation system is especially important for pedestrians and bicyclists, as their trips are often shorter than those made in vehicles or on public transit and entail greater physical effort and exposure to environmental conditions. A state route system, which typically sees higher speeds, traffic volumes, and pavement widths than local streets, can sometimes act as a significant transportation network barrier for pedestrians and bicyclists.

Highway Permeability

This study developed a tool to assess the permeability of major roadways within the State of Washington. Biologists often talk about cell membranes as being permeable to water, because they have passage ways that let water through. With respect to this study's focus on transportation, permeability refers to the ability to get under, over, or through a roadway barrier. To illustrate this concept, consider a river. A deep river can act as a barrier to travel when bridges, boats or other means of crossing are not available. The act of building a bridge makes the barrier permeable to a person who wants to travel across the barrier. The more bridges or other crossing points that are available, the greater the permeability of the river. A major roadway with high travel speeds or traffic volumes can act similarly for people who walk and bike. More intersections or other crossing facilities (such as bridges and tunnels) and more local roadway connections to those intersections increases permeability of major roadways. Permeability is not the sole consideration, however, as some crossing opportunities are poorly suited to active travel due to traffic conditions or a lack of facilities for vulnerable users. Moreover, the number of intersections present affects travel efficiency for motorized traffic, and other crossing treatments (e.g., pedestrian bridges) present additional tradeoffs to consider.

Assessing permeability of major roadways can help identify and prioritize areas in need of new or improved crossings for pedestrians and bicyclists. Higher densities of destinations (employment, schools, services, etc.) or the presence of key destinations such as multimodal hubs (airports, transit stations, ferry terminals, etc.) create a higher priority for increased permeability. Even where levels of walking and biking activity are relatively low, the presence of destinations is generally associated with latent demand for active transportation. Additionally, there is a need to develop equitable transportation options for those without access to a motor vehicle or even transit. People with disabilities, in particular, may be more affected by low highway permeability if they must go out of their way to reach a crossing. Using quantitative methods to identify potential (or latent) demand for crossing opportunities can help support project proposals to improve transportation networks for pedestrians and bicyclists.

[2] WSDOT. Strategic Plan. Information collected on: 01/30/2020. https://www.wsdot.wa.gov/about/secretary/strategic-plan/

Active Traveler Tolerance for Out of Direction Travel

Major roadways, such as downtown main streets and rural highways lined with amenities, provide numerous benefits to communities. They typically provide direct and efficient routes of travel for multiple travel modes. However, crossing major roadways, especially in more rural areas, can be particularly challenging for pedestrians, bicyclists, and other vulnerable users. Sometimes people will travel out of their way to cross at designated crossings, or crossings they perceive as safer and less stressful. But there is a limit as to how far a pedestrian or bicyclist will travel out of their way to reach a destination. For example, bicyclists will travel an average of 10 to 25 percent farther on a given trip to utilize safe routes and crossings.[3] Pedestrians are less inclined to go out of their way to reach more comfortable crossing facilities. Broach, 2016, found that "to avoid an additional unsignalized arterial crossing, a pedestrian would be willing to go over 70 meters (230 feet) farther via an alternate path." In general Broach noted that pedestrians appear to have a lower tolerance for out-of-direction travel when compared to bicyclists. A pedestrian’s tolerance also decreases when they are travelling with another person.[4] Trips on travel routes that take pedestrians and bicyclists far out of their way likely won’t be made at all. For people without other travel mode options, there is a concern that low permeability conditions could restrict access to basic needs such as food or healthcare. These conditions can also result in people crossing at inappropriate locations to continue more directly toward their destination.

Measuring Out of Direction Travel: Route Directness Index

Out of direction travel can be quantified as a Route Directness Index (RDI), with high RDIs being less desirable than low ones. RDI is a way of comparing the *out-of-direction travel* for different routes rather than just comparing the travel distances of those routes. Clearly, the physical distance for any given walking or bicycling trip is important to consider, and longer distance trips between destinations may not be reasonable for all travelers. RDI tells a different story, however. A high RDI (more out-of-direction travel) means the available routes are not working well for active travelers. If travel distances are long for a given trip, but the RDI is low, there is not much that can be done to serve the travel need short of providing other travel options such as transit. But, when the RDI is high, there may be ways to reduce travel distances between destinations. Even with a relatively short trip, a high RDI may affect the perceived utility of that trip and indicate the need for more direct connections between destinations.

In order to explore application of the RDI to the state highway system, it is necessary to consider both actual trip distances and a user’s willingness and likelihood of deviating from a direct travel path. According to the National Household Travel Survey (NHTS), the majority of walking trips made for any purpose are less than one mile while bicycling trips are less than three miles.[5] Based on the survey results and using the route deviation tolerance noted

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[3] Mineta Transportation Institute. 2012. Low Stress Bicycling and Network Connectivity.

[4] Broach, J.P. 2016. Travel Mode Choice Framework Incorporating Realistic Bike and Walk Routes. Portland State University.

[5] Federal Highway Administration. 2017. National Household Travel Survey (NHTS). Retrieved from: https://nhts.ornl.gov/

previously, a bicyclist is unlikely to add more than .75 miles (25 percent) to a three-mile trip and a pedestrian is unlikely to add more than 230 feet (4 percent) to a one-mile trip. If a longer detour is required, it is likely that many potential trips are not completed via active transportation. However, this logic does not account for trips made out of necessity (e.g., travel to a job or to health care appointments, or made walking/bicycling because no other modes are available).

Study Threshold for Route Directness Index

RDI is a ratio that compares the straight-line (crow-flies) distance between two points to the actual distance imposed by the roadway network. The lowest RDI is 1 because a trip between those points can be made directly along an existing roadway. The actual methodology analyzed hypothetical trips where the start and end points were about a quarter mile apart relative to a straight line. In such a situation, an RDI of 2 would mean the trip is twice the distance it might otherwise be, or about one-half mile. Although one-half mile is not particularly far, the RDI is independent of the actual distance. We might start further down the road and if the RDI remained a 2 our trip distance would be twice as long as it could have been. The RDI thus measures the real or perceived burden or travel cost incurred by a person walking or bicycling. An RDI of 2 was selected as the threshold where that travel cost makes it increasingly unlikely that an active travel trip would be completed. The "design vehicle" when selecting that threshold was a walking pedestrian. Selecting an RDI of 2 was an attempt to balance observed travel behavior and the realities of existing crossing opportunities along the state highway system. In addition, since this analysis used about a quarter-mile spacing between test destinations, an RDI of 2 corresponds to the one-half mile maximum distance transit planners assume a pedestrian will be willing to walk to catch a bus or train.[6] So with respect to multimodal trips, RDIs greater than 2 might make transit less attractive.

Note that an RDI of 2 does not reflect WSDOT policy at this point; rather, it is a study threshold based on a set of assumptions about the utility and appeal of active travel trips. The threshold is a useful comparison value to keep in mind when reviewing the *Results and Overlay* and *Applications to Decision-Making* sections of this report that follow the methodology discussion.

Application and Case Example – The Walla Walla Valley MPO/SRTPO

The MPP included a regional case study. Applying the study methods to a small region provided a reasonable geographic scale for testing and refining analysis and reporting methods. This pilot project focused on the Walla Walla Valley MPO and the larger Sub-Regional Transportation Planning Organization (SRTPO) boundary areas in southern Washington (Figure 2). The two organizations are collectively referred to as the Walla Walla Valley Metropolitan Planning Organization and Sub-Regional Transportation Planning Organization (WWVMPOSRTPO). This report will use Walla Walla Valley MPO/SRTPO or Walla Walla Valley to refer to the organization or jurisdictional region managed by the WWVMPOSRTPO.

[6] Federal Highway Administration. 2013. Pedestrian Safety Guide for Transit, Chapter 4: Actions to Increase the Safety of Pedestrians Accessing Transit. https://safety.fhwa.dot.gov/ped_bike/ped_transit/ped_transguide/ch4.cfm

The Walla Walla Valley MPO/SRTPO recently completed a comprehensive trails plan for multiuse trails in the Blue Mountain Region. This extensive planning effort occurred over several years and involved fourteen stakeholder groups, including representatives from local jurisdictions, state, and federal partners. Although focused on recreational trail opportunities, it also considered connectivity to existing and proposed trails from locations throughout the region. In many cases, these connections rely on routes through cities and towns, leveraging local bicycling and walking network improvements. According to the 2015 study, Economic Analysis of Outdoor Recreation in Washington State, and two follow-up studies released in 2020, outdoor recreation revenues make significant contributions to Washington's economy and access to recreation is itself a function of the transportation network.

A major problem identified through the Blue Mountain Region Trails Plan, and consistently echoed in active transportation plans across the state, is the barrier created by state-owned roadways for bicyclists and pedestrians trying to make local connections. While opportunities exist to improve segments of roadway or trail to accommodate active transportation, the presence of a state highway can introduce crossing issues that interrupt connectivity or reduce the safety and appeal of a given facility. Active transportation facilities may need to be extended to reach an available crossing and that crossing might still be a high-stress element on an otherwise low-stress facility.[7] Without appropriate connections, recreational opportunities are impaired, but an even more pressing concern is that communities may be cut off from key services, employment/education opportunities, or other vital resources along with safe opportunities for physical activity.

The desired outcome of the MPP was to establish methods for identifying locations where:

1. Low-stress state highway crossing frequency is limited or nonexistent;
2. Parallel facilities leading to low-stress crossings are challenging or indirect; and
3. Installation of a new crossing could enhance network connectivity.

Of particular interest was identification of those locations that were closer to community destinations and also methods that WSDOT could use to define proximity to destinations along the state system.

Further, as WSDOT updates the ATP, the agency seeks to identify opportunities to better inform existing conditions analysis, project selection, and ultimately, application of the Practical Solutions framework in development of an integrated, multimodal transportation system. Described in more detail in subsequent sections of this report, the Practical Solutions framework relies on a data-driven process to refine project selection and design. By establishing a process to better define the effects of state highways on local networks, opportunities for improving crossings or avoiding removal of existing crossing opportunities may be identified through a systematic methodology that can be used across the state.

[7] Level of Traffic Stress (LTS) is a method that assigns a numeric score to a roadway or intersection that is used to represent the travel experience of a bicyclist or pedestrian. Level 1 is typically considered low stress and suitable for a child user's attention while Level 4 is considered high stress and uncomfortable for most adult users.

Case Study Setting

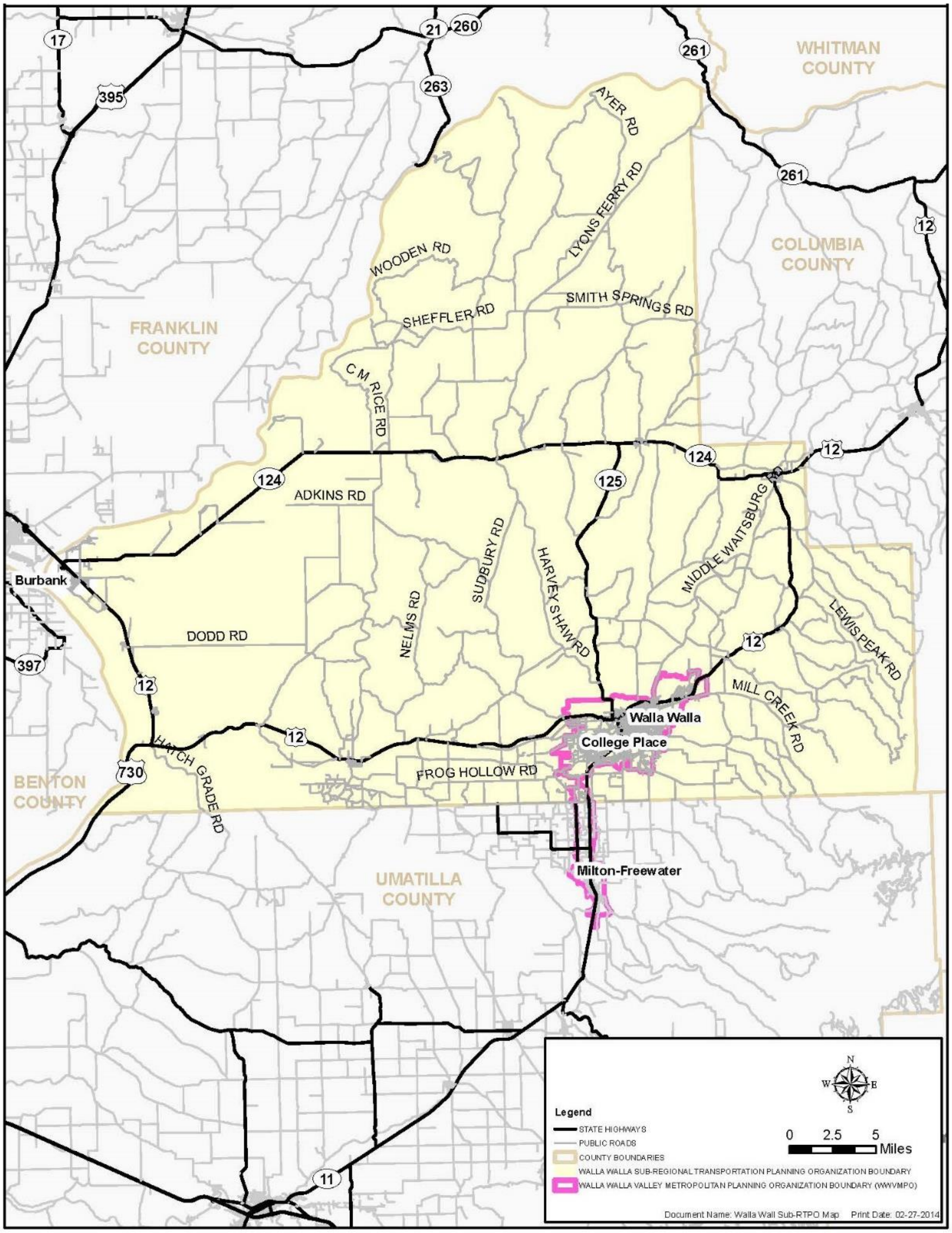

Figure 2. Walla Walla Valley Sub-Regional Transportation Planning Organization boundary and Metropolitan Planning Organization boundary. This map shows the larger Walla Walla County and Walla Walla Valley SRTPO valley in gold and the Walla Walla Valley MPO boundary as a thick pink line. While the MPO boundary includes roadways in Oregon, the MPP focused exclusively on roadways in Washington State.

The Walla Walla Valley MPO/SRTPO is located in southeastern Washington State within WSDOT's South Central Region and includes Walla Walla and Columbia counties in Washington and a portion of Umatilla County in Oregon. Roadways in Oregon were excluded from this analysis due to discrepancies in available GIS data. Land use patterns vary widely across the study area, ranging from the more urbanized City of Walla Walla, to smaller population centers like Eureka, Prescott and Waitsburg. Rural areas of the region are characterized by farm and grazing land. The Walla Walla Valley SRTPO/MPO was established in 2013 to facilitate regional transportation planning. There were 65,000 MPO residents in 2016 and the region was forecasted to grow to nearly 75,000 residents by the year 2040.

Selected Analysis Method (Step 2)

FHWA's MCC Guidebook discusses several network connectivity analysis tools. A Level of Traffic Stress tool was used to inform development of the ATP and to complement it, the analysis tool selected for the MPP was the Route Directness Index (RDI). RDI compares the straight-line distance between two points to the actual distance a person would be required to travel using the available roadway network. This concept is illustrated in Figure 3 where the straight-line distance between home and school is one mile, but the zigzagging roadway requires four miles of travel. In this example, the ratio of roadway network distance to straight line distance is four to one, and RDI = 4.0.

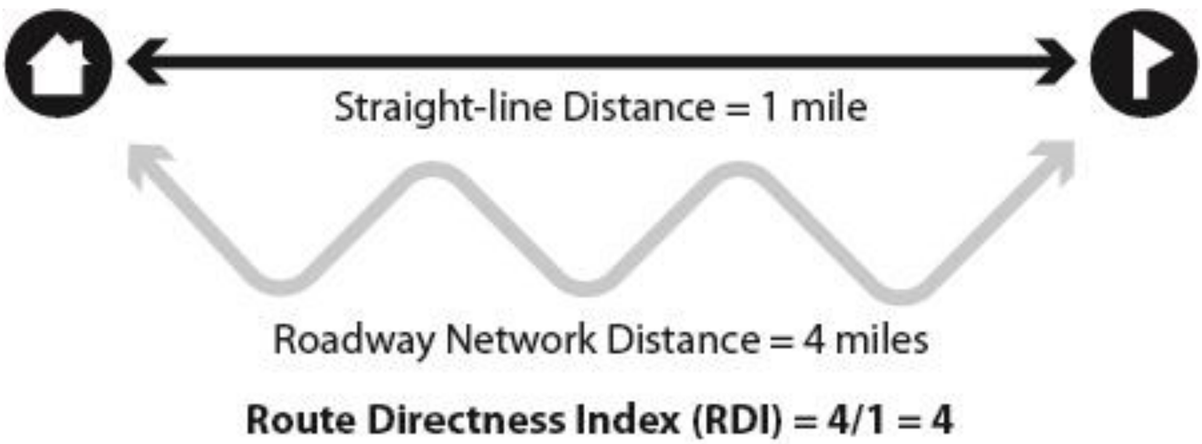

Figure 3. Route Directness Index. An origin and destination point are separated by a straight-line distance of 1 mile. A theoretical roadway network connects the origin and destination, but due to curves in the roadway the network distance is 4 miles. The resulting ratio of roadway network distance to straight-line distance is 4:1, meaning the calculated RDI is 4.

Route Directness Index Applications in Planning

The RDI is a flexible tool that can be used at both the corridor level and network level to describe level of service. RDI can be communicated in a number of ways including maps, tables, charts, and text. When used at the corridor level RDI allows planners to explore the effects of adding a new crossing (e.g., to calculate the number of new users who have access to a given destination based on reduced out-of-direction travel) or map the change in travel time created by closure of a bicyclist or pedestrian crossing (e.g., loss of service created by changes to the roadway network). At the network level, the RDI can be used as a level of service measure that is calculated by computing an average RDI score based on a set of regularly spaced origins and destinations. Example level of service measures might include:

- Average spacing between bicyclist and pedestrian crossing opportunities.
- Average out-of-direction travel required at existing crossing locations.

- Percentage of crossing opportunities that provide a relatively direct crossing opportunity.

The RDI measure can be further analyzed in conjunction with data regarding proximity to destinations and level of traffic stress, both of which are examined later in this report. In terms of benefits and drawbacks, the measure is easy to understand and calculate but it can require substantial technical knowledge to automate calculations across a larger area and interpretation of results can become complicated as the scale of the analysis increases.

The MPP developed a tool to calculate the directness of travel routes from one side of major state roadways to the other, ultimately assessing the permeability of state routes throughout Washington (Figure 4). The methodology utilizes ArcGIS tools, including the Network Analyst extension, to place points (centroids) at equal intervals along the state route system, create origin/destination (offset) points on either side of the state route at each centroid interval, and identify available routes where travel could occur from one offset point to the other. These methods are described in more detail in the next section, *Data Assembly*.

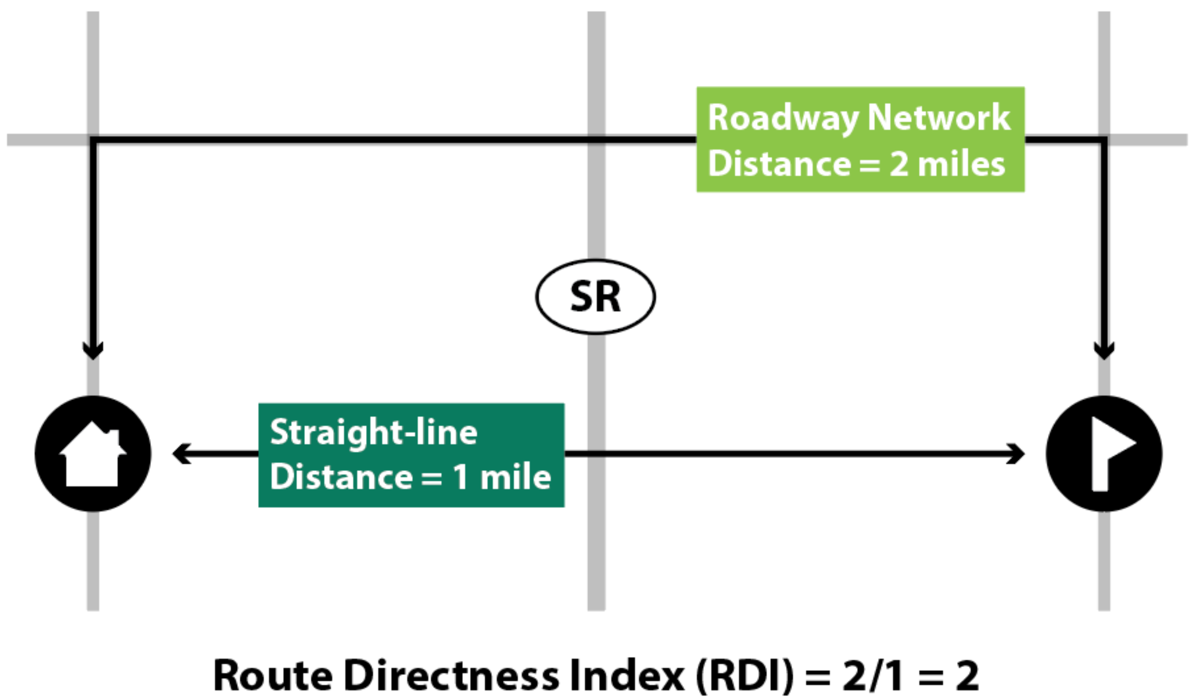

Figure 4. Straight-line distance versus network distance. This origin and destination are separated by a straight-line distance of one mile and a network distance of two miles, resulting in an RDI of 2.

Data Assembly (Step 3)

At the most basic level, the inputs for calculation of an RDI are a roadway network dataset and at least one origin and destination pair. For this project, two transportation networks were assembled and tested: Walla Walla Valley and Washington State.

Walla Walla Valley MPO/RTPO

The following datasets were used to develop the analysis network for Walla Walla Valley:

- **Blue Mountain Region Trails Plan**. A regional trails plan was compiled in 2018 and included the location of existing on-street bicycle facilities and trails.
- **Regional Travel Demand Model.** Walla Walla Valley MPO/RTPO staff provided outputs from their regional model, which included the local roadway network geometry and roadway characteristics.
- **WSDOT Transportation Network Data**. WSDOT data was used to identify which roadways to test for network permeability and to flag roadways where bicycle and pedestrian travel was prohibited.

In order to calculate how a person can move from point A to point B along available roads and trails, different datasets must be integrated similar to the way a variety of datasets have been integrated to enable use of the navigation tools available through Google Maps. Of course, Google's data is proprietary. And unlike Google, public agency transportation data is (or has been) collected using different techniques and stored in a variety of formats. As a result, data from different sources cannot be readily compared or integrated into a single dataset for analysis. For this study, considerable time was spent constructing a routable network dataset, that could look at how a person might move from point A to point B using local or state roads. For Walla Walla Valley, trails data and bicycle facility types were integrated into the roadway network by performing a series of spatial joins and buffering steps in ArcGIS. Data was then visually checked for consistency. Next, the merged dataset was prepared for network analysis using a series of cleaning steps to ensure geometric correctness. Tests were performed to check routing along and across all network links (roads) and to ensure that the nodes connect before calculation of RDI.

The network development effort for Walla Walla Valley, illustrated the level of effort required to manually construct and validate a network dataset containing both state and local roadways. It was determined that applying the same methodology at a statewide analysis scale, using existing WSDOT and local data, would not be feasible. Therefore, other data sources were explored.[8]

Statewide Network

The statewide data analysis network was built on several primary data sources:

- **OpenStreetMap (OSM).** Given the feasibility issues with constructing a statewide network from local data sources, OSM data was selected for the base transportation network. OSM is a continuously updated source of geospatial data that includes transportation networks, in addition to other map features. A case study from CalTrans Highway District 4 in the MMC Guidebook indicated that OSM data was viable source of

[8] WSDOT does maintain an LRS network of state roadways, however, local transportation networks and trails are not included, reducing its viability as an ready to use analysis dataset.

routable network data for a large geographic area. For the MMP, a routable network dataset was created by accessing OSM data using the Python package OSMnx.[9]

- **Level of Traffic Stress (LTS) quality ranking of WSDOT transportation infrastructure.** An LTS analysis of WSDOT owned roadways was completed as part of the ATP planning process (see Appendix B for details). LTS quantifies traffic stress and scores locations by identifying roadway characteristics such as posted speeds, number of lanes, traffic volumes, etc. that are more or less suited to active travel. The GIS analysis of LTS produced a ranking of 1 to 4. In general, LTS 1 facilities, such as crossings, are considered suitable for all ages and abilities. LTS 2 crossings would be acceptable to most people who walk and bike. The ATP planning process defined LTS 3 and 4 to be gaps in the active transportation network. High LTS and RDI scores both have the potential to reduce active travel. This idea is illustrated in Figure 5 that follows this section.
- **WSDOT Transportation Network Data**. WSDOT network data were used to identify roadways to be tested for network permeability. The study was also informed by WSDOT data that identified roadways where bicyclists are prohibited and pedestrian's are likely prohibited.

The network dataset was created by first downloading a statewide OSM transportation network for Washington using OSMnx. To increase processing efficiency, the analysis network was reduced to a one-mile buffer around the state highway system using the GIS clipping function. A final step included transfer of the LTS scores calculated for the state highway system to the analysis network. The tool produces the following three files, which represent the analysis results:

- **Network Distance**: The network distance represents the resulting travel routes between each offset point (offset point illustration in Figure 5). These are the routes a person would take from their start location to their destination using available roadways and using a state highway crossing.
- **Straight-Line Distance**: The straight-line distances represent straight lines between corresponding offset points.
- **Route Directness Index (RDI)**: The RDI values, calculated as the ratio of the shortest path route to the straight-line distance between two points. These values are saved to evenly spaced centroids (the midpoints of each 250 ft segment that was analyzed along the state highways) on the state route network.

The **network distance** and **straight-line distance** work together to calculate the RDI values as illustrated below:

$$\frac{Shortest\ Path\ Route}{Straight\ line\ Distance} = Route\ Directness\ Index\ (RDI)$$

The resulting value identifies how far out of their way a person would need to walk or bike in order to reach their destination.

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[9] Boeing, G. 2017. "OSMnx: New Methods for Acquiring, Constructing, Analyzing, and Visualizing Complex Street Networks."

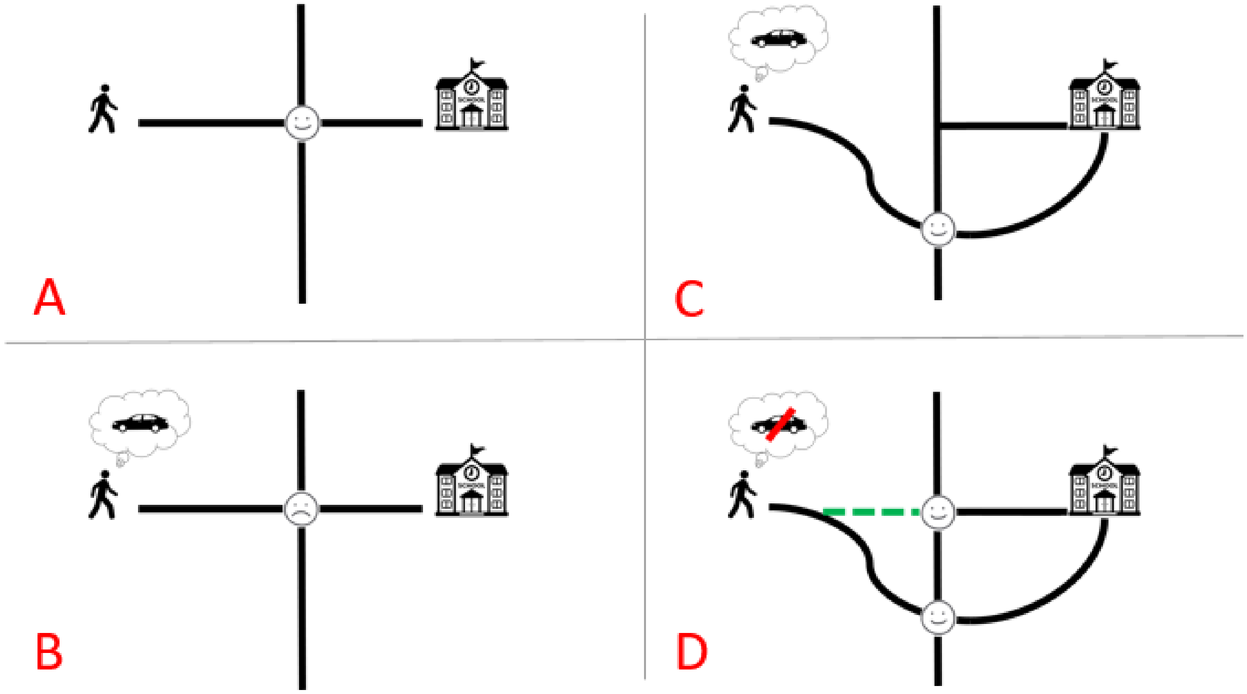

Figure 5 Level of Traffic Stress (LTS) and Route Directness Index (RDI) effects on travel choice. This set of illustrations considers both how direct a pedestrian's trip is to their destination (straight versus winding path) as well as how a crossing on their route is rated for LTS (symbolized by a smiling or frowning face). Illustration A offers the best scenario as it shows a direct route for the person walking between where they are and their destination, and a smiley face indicates that the crossing is low stress. Illustration B also offers a direct route, but the crossing is high stress. In C the route requires out-of-direction travel. In D, a local system link has been constructed to an existing low-stress crossing. Scenarios B and C depicts the pedestrian considering whether to drive instead. Assuming driving is an option, the person would be more likely to use a car when both distances and traffic stress are greater.

Data Assembly Challenges

Data acquisition and assembly presented two primary challenges:

- **Lack of complete bicyclist and pedestrian infrastructure data**. While data for the Walla Walla Valley MPO/SRTPO were available for both bicyclists and pedestrians, these data were not available at the state level. The OSM data used for the statewide transportation network were not maintained or updated systemically with bicyclist and pedestrian infrastructure data. The lack of comprehensive, mode-specific active transportation data precluded an RDI analysis of a statewide bicyclist or pedestrian specific network. Therefore, the statewide data product only considered the regular system of roadways that were well developed and maintained in OSM.
- **Complexity of representing bicyclist and pedestrian transportation networks**. While it is possible to represent bicyclist and motor vehicle networks fairly simply, detailed data were not available to model complex pedestrian routing choice based on multiple intersection legs and marked crossings. The team utilized simplified network geometry representing roadways and intersections as simple lines and nodes and used noted data attributes (e.g., traffic controls) to refine analysis results.

Route Directness Analysis Process

The analysis process for both the Walla Walla Valley MPO/SRTPO and the state followed the same general steps, described below and illustrated in Figure 6. Appendix A provides a more detailed explanation of these methods.[10]

Step 1: Prepare the network dataset that will work for this tool such that roadway and trail connections are accurate, no broken links exist, prohibited roadways are removed, etc.

Step 2: Prepare a data file that includes the roadways to be analyzed and split these roadways into segments of a specified length.

Step 3. Create two offset points (origin and destination points for active transportation trips across the highway) that are offset an equal distance from their associated highway segment.

Step 4: Use GIS to calculate the straight-line distance and network distance (required travel route along the available roads used to complete the trip) between the two points. This step may also include ways to restrict travel based on certain roadway characteristics (e.g., restrict travel along high-stress roadways).

Step 5: Calculate the route directness index (RDI) from the route barrier layer. The barrier layer is that set of highways that must be crossed to reach a destination. RDI is calculated by dividing the network distance by the straight-line distance, with higher RDIs indicating more out of the way travel in order to reach a destination. Once RDIs are computed, the GIS join tool is used to link the data to the roadway network for display and exploration.

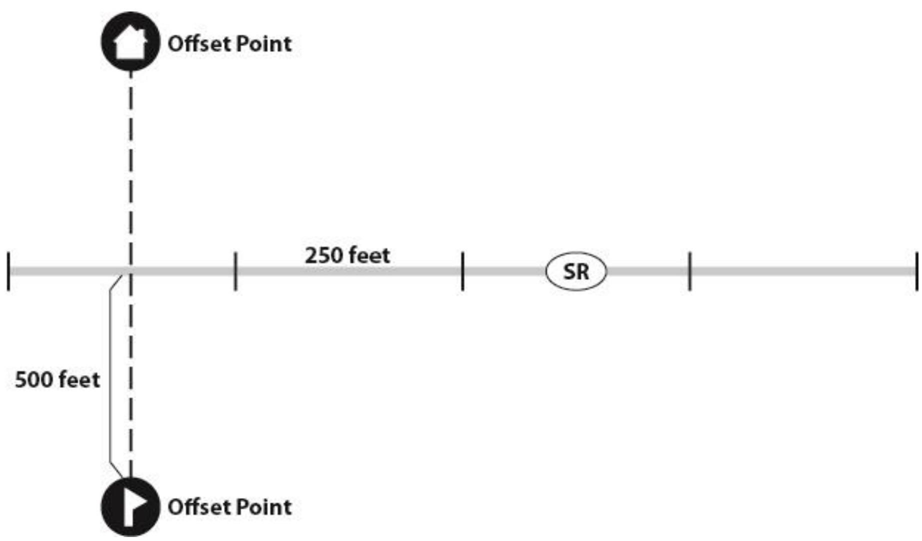

Figure 6. Example of RDI offset points. In this example, a theoretical trip origin and destination are placed every 250 feet along the barrier roadway. An RDI value is calculated when viable origin and destination points are found.

Route Directness Analysis Considerations

The following parameters were tested and refined during development of the analysis process.

[10] A toolbox and accompanying documentation was also created using ESRI ModelBuilder to facilitate future RDI analysis by WSDOT.

Target User: Pedestrian

While the MMP considers both the needs of bicyclists and pedestrians, research shows that bicyclists have a greater tolerance for out-of-direction travel, while the distance deviation tolerated by pedestrians appears to be relatively small.[11] One stated goal of the MPP was to develop metrics for use with the state ATP. Pedestrians were selected as they are more sensitive to out-of-direction travel and focusing on a single set of metrics for this user group covers both transportation modes. The analysis can be made more mode-specific by changing RDI thresholds, average distance between crossing opportunities, etc. Adding LTS quality-rated networks to the analysis was explored as an option, but LTS data were not available for the local network. It was decided that LTS of state route intersections could be used to consider a component of network quality during the data overlay analysis.

Analysis Segment Length

During sensitivity testing, segment lengths of 250, 500, 750 and 1,000 feet were explored. Longer segments resulted in faster data processing but lower accuracy in terms of finding the available intersections. Crossing opportunities were missed in population center areas with shorter blocks. A length of 250 feet was selected for statewide analysis, with the understanding that even at that scale a small number of existing crossings might be missed.

Offset Point Distance and Snapping Distance

During sensitivity testing, multiple offset point distances were considered including 250, 500, 700 and 1,000 feet. These distances were tested to ensure that the origin/destination offset points were not incorrectly associated with the roadway network. A given offset point is rarely directly touching the local network, so a hypothetical pedestrian must "snap to" the nearest local roadway to begin a trip. If an offset point was too far away from the local network the hypothetical pedestrian would not "find" a route that would let them complete a trip. By contrast, if an offset point were too close to the state route, the hypothetical pedestrian would use the state route to complete a trip rather than the available local network. An offset distance of 500 feet was selected as the distance that minimized both potential issues.

Results and Overlay (Step 4 and 5)

A variety of metrics were calculated using the results produced by the tool. The following exploratory metrics were calculated:

- **Average RDI**: Defined as the average RDI for a corridor or given area.
- **Average distance between crossing opportunities where RDI is less than two (direct crossings):** This metric calculates the average distance between crossing opportunities where the RDI values are less than two. This value was selected because it is unlikely

[11] Broach, J.P. 2016. Travel Mode Choice Framework Incorporating Realistic Bike and Walk Routes. Portland State University.

that trips where the RDI is significantly greater will be completed by most active transportation users unless the trip is relatively short or they have no other option. An RDI value of two means that a pedestrian or bicyclist would have to travel 100% farther than the straight-line distance between their start and endpoints.

- **Average RDI by intersection LTS**: This metric calculates the average RDI value by intersection LTS; it answers the question of whether low-stress or high-stress crossings are more or less direct. Ideally, the lowest stress crossings would also be the most direct.

Table 1 compares preliminary results for the Walla Walla Valley MPO/SRTPO region with state data. The average RDI for Walla Walla MPO/SRTPO is 3.55 and statewide is 7.66. This means that the average trip involving a state roadway crossing in the MPO/SRTPO is over three times the straight-line distance. Looking statewide, that average trip to cross a highway is over seven times the straight-line distance. Stated another way, crossing state highways for both the Walla Walla Valley and Statewide networks involves substantial out-of-direction travel for a person walking or biking. Therefore, it is likely that many potential active travel trips are never initiated.

A second metric, the average distance between direct crossings where the RDI is less than 2, is about one-half mile within the MPO/SRTPO. This metric was developed to consider the current spacing of crossing opportunities that afford a relatively direct crossing opportunity and are therefore more likely to be used. Based on this assessment, these higher potential demand crossings in the MPO/SRTPO are slightly further apart than the state average of about one-third mile.

When considering the statewide average RDI by intersection LTS, all the RDI values were high. Interestingly, high-stress intersections of LTS 3 and 4 afforded somewhat more direct crossings on average versus LTS 2 intersections on a statewide scale. It is possible that some number of LTS 2 intersections have very large RDIs that skew the results. It is concerning, however, if LTS 2 crossings are generally harder to reach, since these facilities are those that most users would find acceptable. LTS 1 crossings (e.g., bicyclist/ pedestrian bridges) do not show up for either the statewide or regional analysis. They are relatively rare on the state system, so even though they are likely to be associated with relatively direct crossings between areas with many destinations, their contribution to pedestrian networks is less pronounced. At the MPO/RTPO regional level the intersections show less variation of RDI between the different LTS levels and a relatively encouraging result of 1.97 for LTS 2 crossings. These results are explored in more detail in Figures 6 through 8. While the regional findings provide a general understanding of overall conditions, the statewide values were determined to have only limited use as they lack granularity and consider many locations where crossings are not a high priority due to a lack of proximate destinations. For this reason, additional summary analysis (beyond that summarized in Table 1) at the statewide scale was not completed.

Table 1: Walla Walla Valley MPO/SRTPO and statewide summary metrics, showing proximity to existing origins and destinations.

	WALLA WALLA MPO/SRTPO	STATEWIDE
Average RDI	3.55	7.66
Average distance between crossing opportunities where RDI < 2	2,752 FT	1,869 FT*
Average RDI by intersection LTS	LTS 1: N/A LTS 2: 1.97 LTS 3: 2.63 LTS 4: 3.40	LTS 1: N/A LTS 2: 11.07 LTS 3: 8.07 LTS 4: 6.79

*Analysis included a calculation of the average distance between all crossing opportunities

Walla Walla Valley MPO/SRTPO Region Results

Figure 7 provides an assessment of results in the Walla Walla Valley MPO/SRTPO and describes crossings with RDI values less than two, and crossings with RDI values greater than or equal to two. Figure 7 illustrate more crossing opportunities (both short and long travel routes) in more dense areas of the region; the region has long stretches of roadway without crossings of any type such as Highway 24 between Burbank and Eureka.

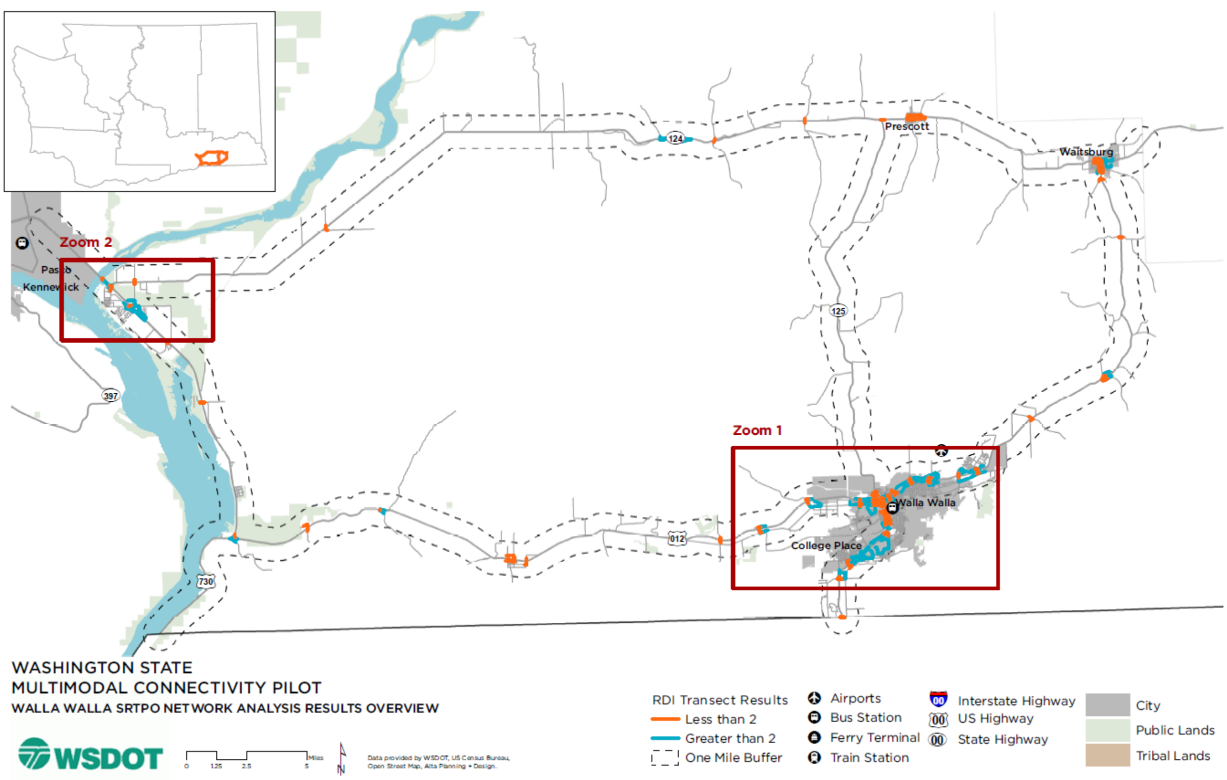

Figure 7. The Walla Walla Valley MPO/SRTPO regional RDI results. Crossing opportunities within proximity to existing destinations shown in orange and blue. Orange corresponds to an RDI of less than 2 and blue an RDI of greater than 2. Crossing

opportunities where RDI values are less than two are often found in areas with more dense, compact road networks. Note zooms 1 and 2 are described in Figures 8 and 9, respectively.

City Level Results

Figure 8 is an enlargement of Figure 7 (zoom 1), centered on the City of Walla Walla. Crossing opportunities where RDI values are less than two are often found in areas with more dense, compact road networks, in this case where State Routes 12 and 125 are close together in downtown Walla Walla. This type of analysis at the city scale can help identify areas that may be in need of new or improved crossings. It will be especially important to identify destinations that demonstrate travel need to assist with future planning efforts for new or improved state route crossings for pedestrians and bicyclists.

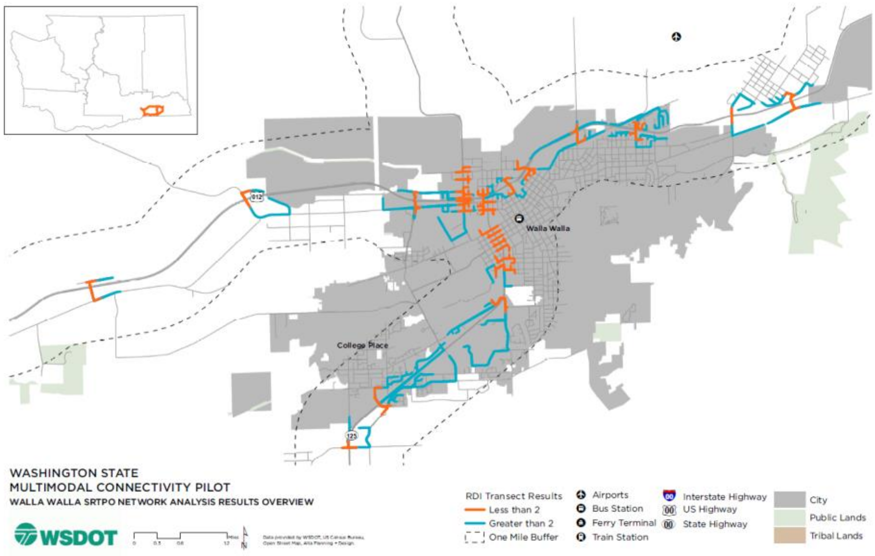

Figure 8. City of Walla Walla RDI results (Zoom 1, from map in figure 7). The map shows crossing opportunities with an RDI of less than 2 as orange and greater than 2 as blue. Crossing opportunities where RDI values are less than two are often found in areas with more dense, compact road networks.

Figure 9 is an enlargement of Figure 7 (zoom 2), centered on Burbank. Compared to Walla Walla, there appear to be far fewer state route crossing opportunities (both long and short crossings) in Burbank, which is consistent with a lower density area. A lack of crossing opportunities does not necessarily indicate a problem that needs to be addressed. In the Burbank area context, it may not be critical to add new crossings if the area lacks specific destinations that warrant such improvements. The RDI analysis provides a general corridor level analysis indicating where crossing improvements may be warranted, but planning, local knowledge, and engineering judgement in support of multimodal safety and mobility should be used to screen and refine the results of the analysis.

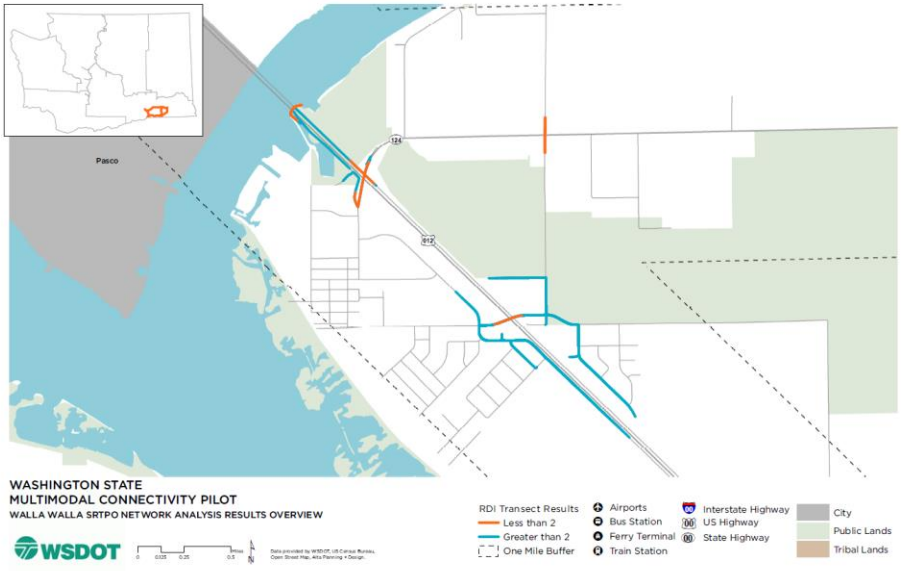

Figure 9. City of Burbank RDI results (Zoom 2, from map in Figure 7). The map shows crossing opportunities with an RDI of less than 2 as orange and greater than 2 as blue. Crossing opportunities where RDI values are less than two are often found in areas with more dense, compact road networks.

State Route Level Results

Results were broken out by state route to explore the utility of route-by-route comparisons. Table 2 lists these results and Figure 10 illustrates state routes in the Walla Walla Valley region. Route 730 affords the most direct crossings, though they are far apart and high stress. The average RDI of Route 125 is high, requiring more out-of-direction travel, but the crossings are frequently spaced and comfortable for most users. It was determined that route-by-route analysis is useful for comparative purposes but requires integration of land use or proximity to destinations to further increase their planning value.

Table 2: The Walla Walla Valley MPO/SRTPO state route metrics comparing average RDI, crossing distance between locations where RDI is less than 2 and average RDI by LTS.

	ROUTE 12	ROUTE 124	ROUTE 125	ROUTE 125SP	ROUTE 730
Average RDI	3.54	2.99	3.79	4.37	2.44
Average distance between crossing opportunities where RDI < 2	2,068 FT	6,558 FT	2,151 FT	974 FT	11,224 FT
Average RDI by crossing LTS	LTS 1: N/A LTS 2: 2.25 LTS 3: 3.27 LTS 4: 2.49	LTS 1: N/A LTS 2: 1.23 LTS 3: 1.47 LTS 4: 5.82	LTS 1: N/A LTS 2: N/A LTS 3: 1.38 LTS 4: 4.54	LTS 1: N/A LTS 2: N/A LTS 3: 4.37 LTS 4: N/A	LTS 1: N/A LTS 2: N/A LTS 3: N/A LTS 4: 2.44

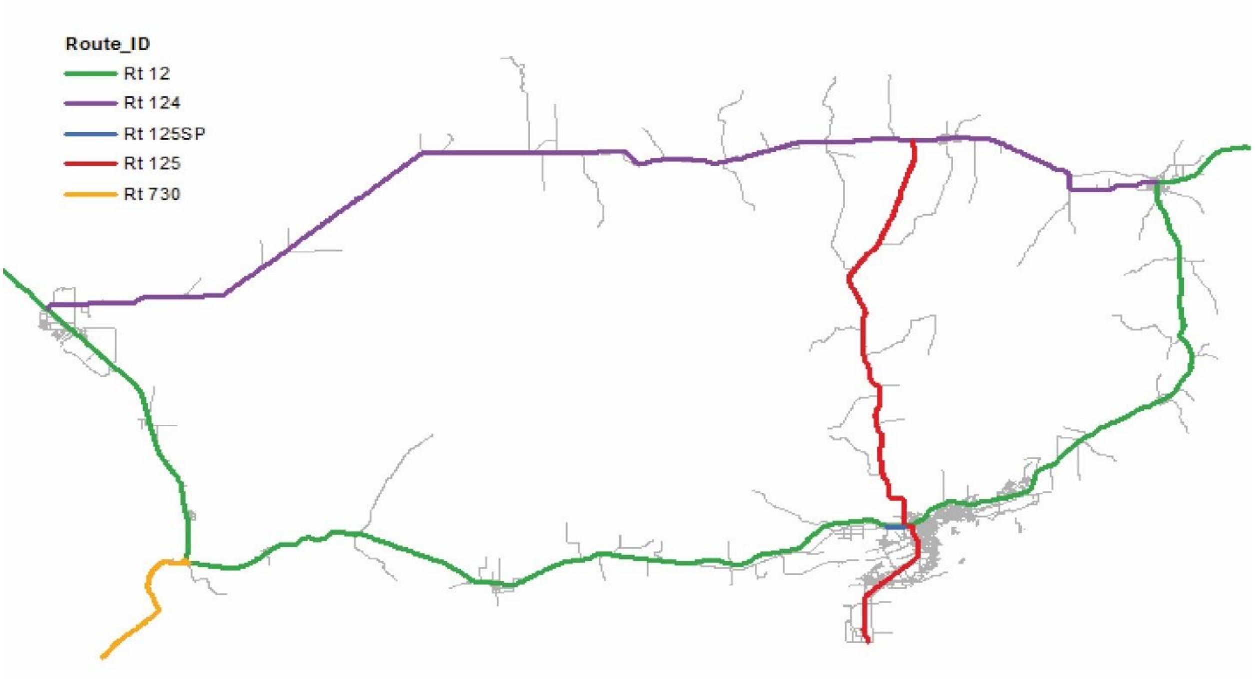

Figure 10. State roadways in the Walla Walla Valley MPO/SRTPO. State routes shown in different colors for ease of identification only. Analysis results for each route are described in Table 2.

Statewide Analysis of Population Centers vs. Rural Areas

Based on results of the regional analysis, a statewide summary was developed for population centers versus rural areas. Population centers were defined as the boundaries of cities/towns and Census Designated Places (CDP).[12] An intersection was classified as part of a population center when it intersected or fell within the boundary of a city/town or CDP; all other intersections were defined as rural. The reported metrics were expanded to include intersections within a reasonable walking distance of a destination.[13] Table 3 describes the results. The average RDI, as well as distance between crossings, are lower in population centers. Around 1,500 intersections on the state system are close to a destination and afford relatively direct crossings. About half of these intersections would be considered comfortable for the average adult. The average RDI, distance between crossing opportunities, and average RDI by intersection LTS are useful tools for comparison of corridor, county, or regional crossing information. However, additional context would be needed to determine overall investment needs. A suggested next step of study is to develop a comparison of population centers by geographic size to better understand and compare crossing levels of service.

[12] US Census Bureau. 2019. TIGER/Line Shapefiles. State of Washington Urban Area. https://www.census.gov/cgi-bin/geo/shapefiles/index.php

[13] Reasonable proximity to a destination was defined as within one mile of a destination included within the Cube Access places database.

Table 3: Population Center and Rural Statewide Metrics

	Population Centers	RURAL
• Average RDI	6.64	9.67
• Average distance between any crossing opportunities (RDI > 0)*	1,186 FT	1,345 FT
• Average distance between crossing opportunities where RDI < 2	2,517 FT	2,899 FT
• Average RDI by (by crossing) LTS**	LTS 1: N/A LTS 2: 11.05 LTS 3: 8.4 LTS 4: 7.35	LTS 1: N/A LTS 2: 11.44 LTS 3: 3.36 LTS 4: 5.95
• Number of intersections within 1 mile of a destination where RDI < 2	3,159	292
• Number of intersections within 1 mile of a destination where RDI < 2 and LTS scores are 1 or 2	639	21
• Percent of intersections within 1 mile of a destination where RDI < 2 and LTS is 1 or 2 compared to similar intersections with ANY LTS score	20%	7%

County level analysis was conducted to understand variations in crossing conditions across the state. Conditions were found to vary widely, based in part on the size and character of population centers within the different counties. As the analysis only considers RDI of intersections near existing destinations, areas with relatively few destinations are heavily influenced by the condition of a relatively small number of locations.

County Comparison of Crossing Density and RDI for All State Routes

Tables 4 and 5 and Figures 11 and 12 summarize county-level results. Figure 11 shows the average distance by county between all state route crossing opportunities where RDI values are less than two. Requiring that RDI values be less than two results in only analyzing crossings where pedestrians or bicyclists will not have to travel more than double the length of the straight-line distance between destinations. King County has the shortest average distance (603 feet / 0.15 miles) between these types of crossings. King County exhibits more urbanization than most other counties across the state and the City of Seattle in particular influences the overall average crossing density. Counties with low average distances between crossing opportunities, where RDI values are less than two, include: Clark, Kitsap, Snohomish, Spokane, Pierce, and Thurston. Garfield County has the farthest average distance (10,944 feet / 2.07 miles) between crossing opportunities. Several other counties average more than one mile between lower stress state route crossing opportunities, including: Ferry, Skamania, and Columbia.

County Comparison of Crossing Density and RDI for State Routes within Population Centers

Figure 12 restricts the county comparison to population centers where more crossing opportunities would be expected. The map shows the average distance by county between all state route crossing opportunities in population centers where RDI values are less than two. Population centers are defined by city/town or Census Designated Place boundaries. Lincoln County has the shortest average distance (255 feet / 0.05 miles) between lower RDI crossing opportunities in population centers. Other counties with low average distances between crossing opportunities in population centers where RDI values are less than two include Columbia, Pend Oreille, Adams, Garfield, Lewis, Stevens, Douglas, and Asotin. Interestingly, with the exception of Lewis County, these better scoring counties are all located in Eastern Washington and do not include counties that are home to the state's largest cities (Seattle, Spokane, Tacoma, and Vancouver). It is possible that some rural counties are characterized by older, walkable population centers that have not undergone as much sprawl-type development. However, other rural counties do not exhibit this pattern. Ferry County has the highest average distance (2,966 feet / 0.56 miles) between low RDI crossings in population centers. Other counties with more than 1,000 feet (approx. 0.20 miles) on average between lower RDI crossings include Wahkiakum, Skamania, Jefferson, and Mason.

County Comparison for RDI and Proximity to Destinations for State Routes

Figure 12 looks at intersections with a low RDI with relatively good destination accessibility and where the crossings are high quality (low LTS). The map shows the percentage of intersections by county that are:

- within one mile of destinations,
- where RDI values are less than two, and
- crossings are safe and comfortable for pedestrians (intersection LTS values are equal to 1 or 2).

This calculation identifies the counties with the most and least number of high-quality crossing opportunities near destinations. In Pend Oreille County, 96% of crossings near destinations occur at high-quality intersections (22 out of 23 total crossings within one mile of destinations occur at intersections with LTS values of 1 or 2). Other counties with over 90% of their crossings occurring under these circumstances include Lincoln and Thurston. Spokane County has just 5% of crossings near destinations that are higher quality (20 out of 130 total crossings within one mile of destinations occur at intersections with LTS values of 1 or 2). Other counties with fewer than 20% of their crossings occurring under these circumstances include Columbia, Wahkiakum, and Grant. There is considerable variability in this metric and it is unclear if a pattern exists across counties related to historical land uses or other factors.

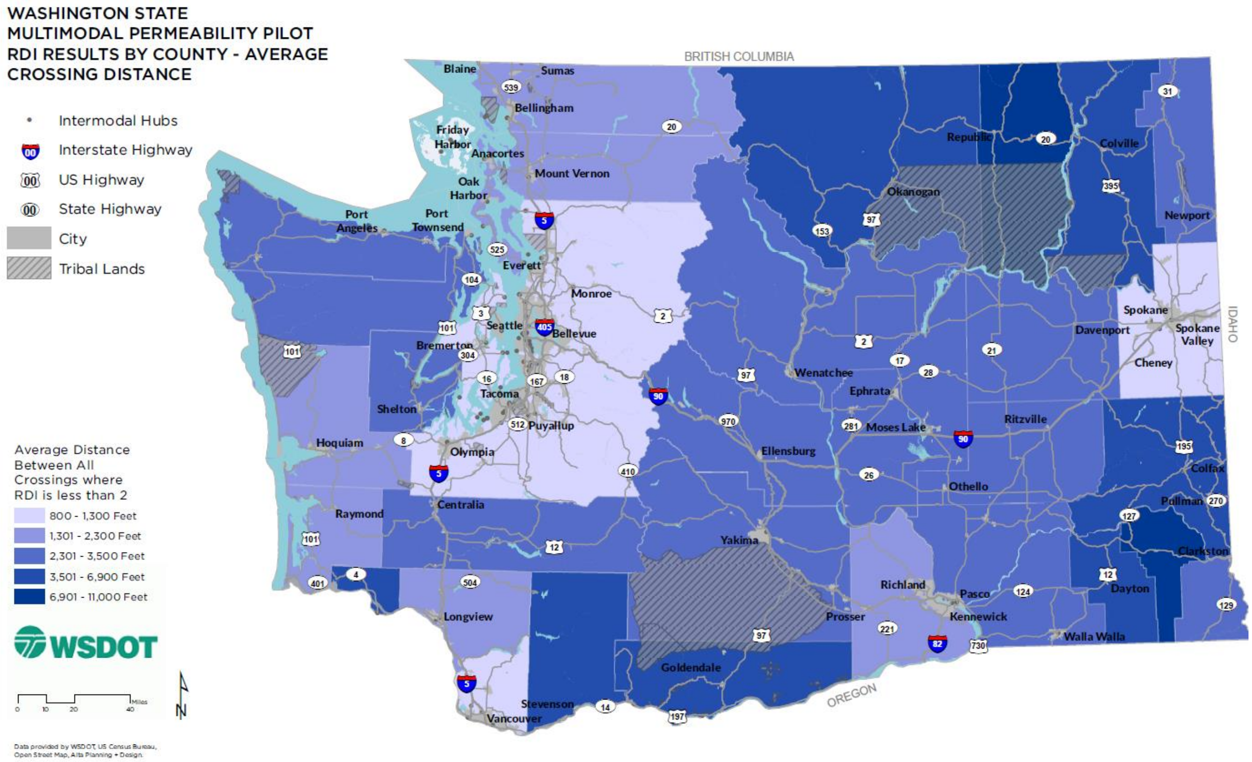

Figure 11. Average distance between low RDI crossings by county. This map is color coded by county to show counties with greater permeability (e.g., shorter distances between state highway crossings). At the county level, the average distance between all crossings where RDI is less than two might be expected to approximate the overall state highway permeability (1,869 feet, see Table 1). The results indicate that some counties show much greater permeability and others much less than the state as a whole. Counties with more urban areas tend to have shorter average distances between lower RDI crossings. Longer distances between low RDI crossings, in counties like Pend Oreille, may be related to an overall lower number of destinations.

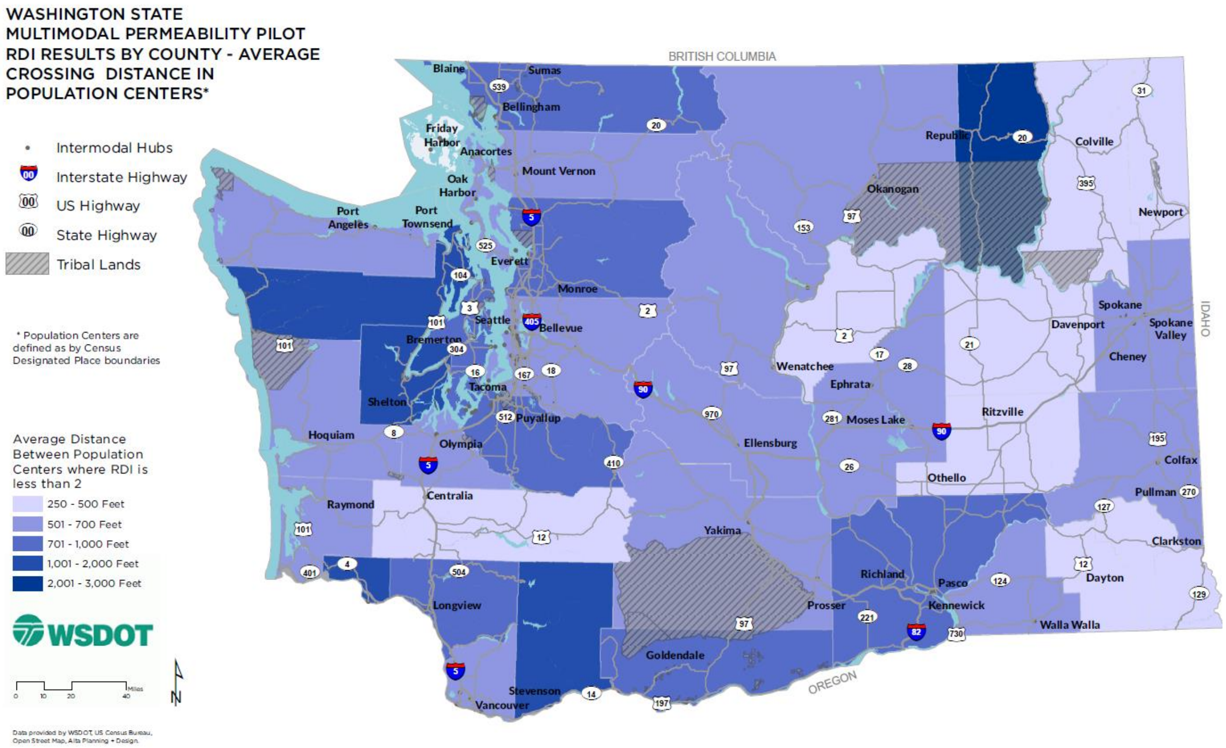

Figure 12. Average distance between low RDI Crossings within population centers by county. This map is color coded by county to show counties with greater permeability (e.g., shorter distance between state highway crossings) within population centers. At the county level it might be expected that state roadways passing through population centers would have similar permeabilities. However, substantial variation occurs between counties, ranging from an average spacing of less than 500 feet to more than 2,000 feet. Variation may result from the location of destinations and local roadway network configuration.

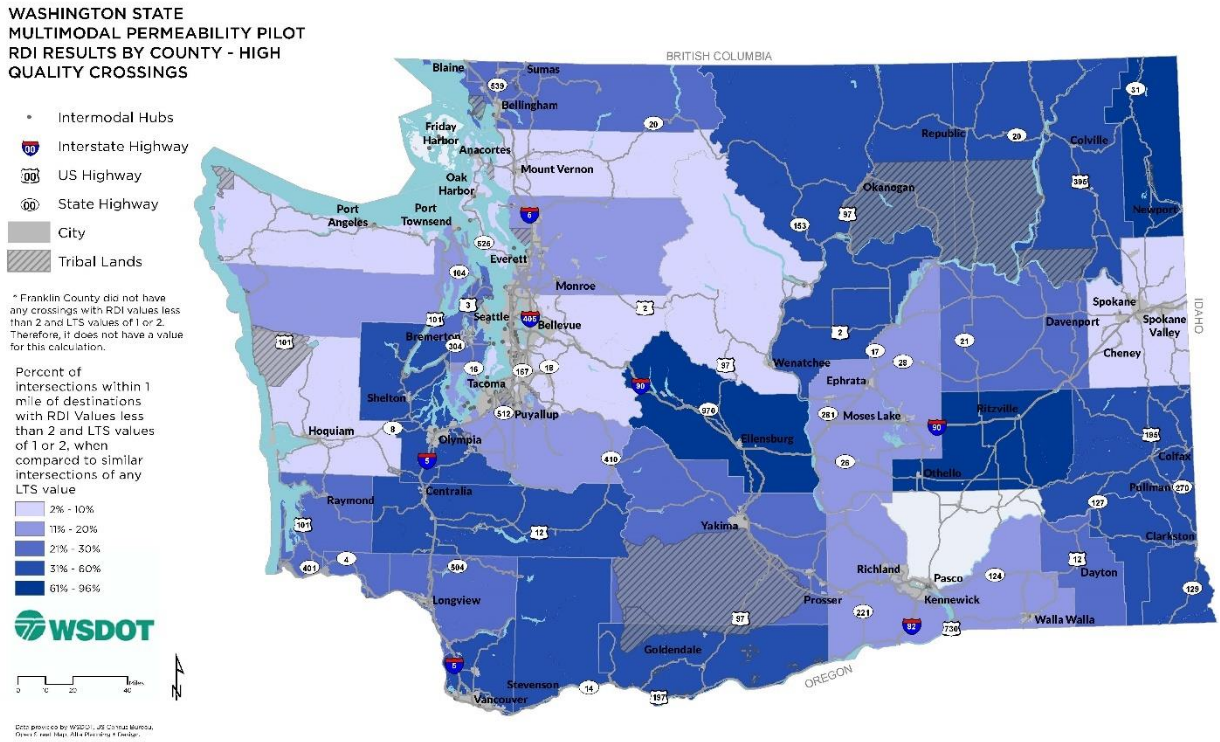

Figure 13. Percentage of high-quality crossings close to destinations with low RDIs. This map shows percentage of state roadway crossings in population centers within one mile of destinations that afford both relatively direct (RDI < 2) and comfortable (LTS 1 or 2) crossing opportunities. At the county level it might be expected that the percentages would be similar. However, results showed considerable variation. In some counties, as little as 10% of intersections provide direct and comfortable crossing opportunities, while in other counties over 60% do so. Overall, results appear better for counties with lower population densities, indicating that conditions may generally be better based on roadway characteristics (e.g., lower speed and volume roadways).

Table 4: Number/percent of intersections by county that are within 1 mile of a destination where RDI < 2 and LTS scores are 1 or 2. The table compares counties to identify jurisdictions that have direct, comfortable crossings of the state highway system in proximity to destinations.

County	Number of Intersections within 1 Mile of a Destination where RDI < 2	Number of Intersections Within 1 Mile of a Destination where RDI < 2 and LTS Scores are 1 or 2	Percent of Intersections within 1 Mile of a Destination where RDI < 2 and LTS is 1 or 2*
Adams	14	13	93%
Asotin	37	18	49%
Benton	46	6	13%
Chelan	124	10	8%
Clallam	109	6	6%
Clark	57	19	33%
Columbia	10	3	30%
Cowlitz	83	24	29%
Douglas	24	12	50%
Ferry	11	6	55%
Franklin	10	0	0%
Garfield	6	3	50%
Grant	87	9	10%
Grays Harbor	191	7	4%
Island	52	1	2%
Jefferson	42	8	19%
King	618	33	5%
Kitsap	137	33	24%
Kittitas	24	18	75%
Klickitat	33	11	33%
Lewis	97	56	58%
Lincoln	45	10	22%
Mason	33	14	42%
Okanogan	83	48	58%
Pacific	91	24	26%
Pend Oreille	23	22	96%

County	Number of Intersections within 1 Mile of a Destination where RDI < 2	Number of Intersections Within 1 Mile of a Destination where RDI < 2 and LTS Scores are 1 or 2	Percent of Intersections within 1 Mile of a Destination where RDI < 2 and LTS is 1 or 2*
Pierce	249	25	10%
San Juan	0	0	0%
Skagit	112	11	10%
Skamania	5	2	40%
Snohomish	307	32	10%
Spokane	280	15	5%
Stevens	57	23	40%
Thurston	81	45	56%
Wahkiakum	12	3	25%
Walla Walla	34	5	15%
Whatcom	103	30	29%
Whitman	81	45	56%
Yakima	43	10	23%

*Compared to similar intersections with any LTS score.

Table 5: Average distances between crossings where RDI < 2 by county.

County	Average Distance Between Population Center Crossings where RDI < 2	Average Distance Between Rural Crossings where RDI < 2	Average Distance Between All Crossings where RDI < 2
Adams	375	3,088	2,817
Asotin	460	5,544	2,666
Benton	818	3,620	2,224
Chelan	524	5,585	3,031
Clallam	511	4,472	2,509
Clark	669	2,027	888
Columbia	273	12,603	5,939
Cowlitz	707	3,252	2,021
Douglas	440	4,071	3,110
Ferry	2,966	12,271	7,884

County	Average Distance Between Population Center Crossings where RDI < 2	Average Distance Between Rural Crossings where RDI < 2	Average Distance Between All Crossings where RDI < 2
Franklin	920	5,311	2,747
Garfield	411	19,585	10,945
Grant	621	4,245	2,906
Grays Harbor	646	3,733	1,735
Island	587	1,866	1,334
Jefferson	1,350	4,697	3,217
King	603	2,362	803
Kitsap	773	1,400	977
Kittitas	649	3,507	2,782
Klickitat	875	6,042	4,498
Lewis	415	3,663	2,344
Lincoln	255	4,535	3,170
Mason	1,040	3,936	3,072
Okanogan	595	11,138	4,211
Pacific	538	2,857	1,967
Pend Oreille	341	4,085	3,130
Pierce	723	3,039	1,168
San Juan	NULL	NULL	NULL
Skagit	570	4,020	2,067
Skamania	1,417	7,937	6,871
Snohomish	770	2,602	1,022
Spokane	508	2,388	1,152
Stevens	422	4,696	3,517
Thurston	570	2,042	1,280
Wahkiakum	1,996	13,063	5,167
Walla Walla	635	5,033	2,559
Whatcom	726	3,414	1,915
Whitman	558	8,810	4,611

County	Average Distance Between Population Center Crossings where RDI < 2	Average Distance Between Rural Crossings where RDI < 2	Average Distance Between All Crossings where RDI < 2
Yakima	694	3,375	2,592

Applications to Decision-Making

The tools and metrics developed as part of the MPP have several identified applications.

Practical Solutions Framework and Project Identification

The Practical Solutions model represents WSDOT's approach to selecting the right project or solution, for the right location, at the right time. As stated on the Practical Solutions website: "This approach uses performance-based, data-driven decision making and early community involvement to guide the development and delivery of transportation investments."[14] Practical Solutions should be implemented early in the project lifecycle not only to identify options for intervention, but also to better consider the use of all modes from the beginning.

WSDOT's draft Mobility Performance Framework[15] ties Practical Solutions to key WSDOT decision points in a project lifecycle by establishing performance measures and metrics appropriate for each stage. The Framework responds to development context (rural, rural center, suburban, town/urban, or urban core) and the established goals of the Framework, as shown in Table 6 below.

For each decision point, the Mobility Performance Framework outlines measures and metrics that are applicable and identifies which land use contexts they apply to. For example, Corridor Sketch Planning is the first phase, and it includes measures of housing and jobs density, availability/connectivity of pedestrian facilities, and access for special needs populations. The intent of providing these measures is to help prioritize projects, compare solutions, guide public involvement, and ultimately determine interventions that best respond to the identified needs.

Table 6: Accessibility goal in WSDOT's Draft Mobility Performance Framework.

Goal/Category	Definition
Accessibility: Ability to easily connect to goods and services across modes, abilities, and socioeconomic groups.	
Proximity to Service	Quantity of jobs, households, services, schools, ports, freight terminals, etc. available within a reasonable distance or time, by mode
Travel experience	Convenience and ease of accessing destinations, by mode

[14] WSDOT Practical Solutions planning https://www.wsdot.com/about/practical-solutions/planning

[15] WSDOT Practical Solutions performance framework https://wsdot.wa.gov/about/practical-solutions/performance-framework

RDI tools align well with the draft mobility framework and can be adopted as metrics to make future state roadway projects more bicyclist and pedestrian friendly. For example, a desired maximum distance between LTS 2 crossings in population centers could be set. An RDI of less than two could be required to encourage use of newly constructed crossings or evaluation of proposed closings of crossings to determine overall effect on RDI and distance between LTS 2 crossings.

The MPP study uncovered the complex relationship between permeability (crossing spacing), crossing quality (traffic stress), and crossing directness (out-of-direction travel). In order to develop a flexible, data-based policy framework around low-stress crossing frequency needs, several questions must be addressed:

- Is there an appropriate crossing density standard based on land use?
- Can a minimum RDI be established based on anticipated users, existing roadway configuration, proximity of current destinations, and any changes to these based on planned land-use changes?
- How can the crossing quality or LTS be paired with RDI data to inform policy decisions?

Active Transportation Plan and Performance Metrics

WSDOT has released the state's Active Transportation Plan 2020 and Beyond – Part 1 (ATP), which includes a significant focus on network analysis for gap identification. Performance metrics based on LTS are being evaluated. A primary constraint on adopting a given metric will be data availability. Two metrics calculated as part of the MPP have been selected as viable performance metrics to be included in the ATP:

- Average distance between LTS 2 crossings
- Percentage of intersections within one mile of a destination where RDI is less than (X) and LTS is 1 or 2

Note the second potential metric leaves the acceptable RDI level unspecified (X). This study uses an RDI of 2 as a starting point, but the level chosen has significant user and/or policy implications. Given the current average population center RDI of 6.64, a target of RDI 2 would be ambitious. Together these two metrics describe both the need for new crossings on the state system as well as the need to improve existing crossings that are likely to serve active transportation users.

Additional Uses of Results

The following is a list of additional ways the tools developed as part of the MPP may be used; these are just a few examples of how the results can be applied to real-world planning situations:

- **Determine likely crossings**: Low RDI values indicate routes that provide a relatively direct crossing for people who walk and ride a bike. Therefore, routes with low RDI values may experience more crossings than routes with high RDI values, which require additional out-of-direction travel. This information can be used to identify crossings that may be more frequently utilized by pedestrians and bicyclists. Knowing where those key intersections are can then be used to help prioritize safety improvements at those crossings and on the routes that lead to them.

- **Identify Potential for New Connections to Existing Crossings:** Working with partner jurisdictions and using RDI data, there may be opportunities to make access to existing, low-stress crossings more direct. A new trail that connects to an existing crossing, for example, could be a much more feasible means of lower RDI than building a new crossing.
- **Identify new, more direct, crossings**: The tool's results can be used to help identify new, more direct crossing opportunities, especially where they serve major destinations. Where there are major destinations, but long distances between existing crossings, there may be an opportunity to increase permeability through installation of a new crossing.
- **Project prioritization**: Where network improvements are being considered and a number of projects have been proposed, RDI values can be used to prioritize among them. The data can help inform decisions about new crossings or improvements to existing crossings. In areas with high RDI values (no direct crossings) safe and comfortable crossings are essential for creation of a balanced and connected network that enables pedestrians and bicyclists to cross state routes in order to reach destinations.
- **Create walking/biking maps**: The RDI scores can help identify efficient and comfortable routes and contribute to development of walking and biking maps for neighborhoods or municipalities. These results can also be cross-referenced with intersection LTS scores to make crossing recommendations. A "safe route to school" is not always obvious to community members who are more familiar with driving routes that use collectors to reach destinations.

These are just a few examples of the uses for this tool. Organizations can use these results to help inform future projects, expand upon these results with additional analyses, and ultimately improve the quality of life for all throughout the State of Washington.

Appendix A: Route Directness Analysis Process

Detailed RDI Calculation Methods

1. Determine analysis software.
2. **Define barriers**. All state-owned roadways are identified as potential barriers.
3. **Obtain data**. Data has been obtained from the Walla Walla Valley MPO, Open Street Map and WSDOT.
4. **Calculate Level of Traffic Stress**[16]. LTS was calculated as part of the development of the 2020 Washington State Active Transportation Plan. For details of the methods used, consult Appendix D.
5. **Build analysis network.** The analysis network will be constructed using the ArcGIS Network Analyst extension.
6. **Develop barriers data.** Barriers were broken into 250 foot-long segments, which will provide an analysis of cross-barrier connectivity at intervals of 250-feet along each barrier. For a finer-resolution analysis, barriers could be broken into shorter segments, or for a coarser analysis, longer segments.
7. **Compute following steps for each segment.**
    a. **Define "offset points" to either side of the segment.** Points will be drawn 500 feet perpendicular to either side of the segment midpoint. These points represent theoretical start and end points of a short trip with the sole purpose of crossing the highway.
    b. Connect offset points to the routable network.
        i. Offset points will be connected to the routable network at the closest available point along the network.
        ii. If no network access point is available within 500 feet of an offset point, routing between the access points will be considered unviable.
    c. Found shortest path along network.
        iii. Dijkstra's algorithm will be used to find the shortest path between the network access points.
        iv. The routing algorithm will account for roadway weights so that priority will be given to more comfortable cycling or walking routes.
    b. Calculate "directness" ratio between network path length to straight-line distance.
        i. Network path length is the overall length of the shortest path calculated in the previous step.
        ii. Straight-line distance is calculated between the two network access points.
    c. The ratio between network path length and straight-line distance summarizes the directness of connectivity between the two sides of the barrier. The ratio can

[16] The statewide analysis will use a proxy of roadway classification to develop an LTS proxy as data is not available for the entire state.

be interpreted as the “distance out of their way” that cyclists or pedestrians would need to travel to cross the barrier.

i. Low ratio: Greater connectivity; direct crossing
ii. High ratio: Less connectivity; indirect crossing

Appendix B – Level of Traffic Stress Analysis Methods

Refer to WSDOT Active Transportation Plan 2020 and Beyond - Part 1, Appendix D