Bicycle Delivery Feasibility:

Portland Restaurant Service Areas based on Energy Cost

Portland State
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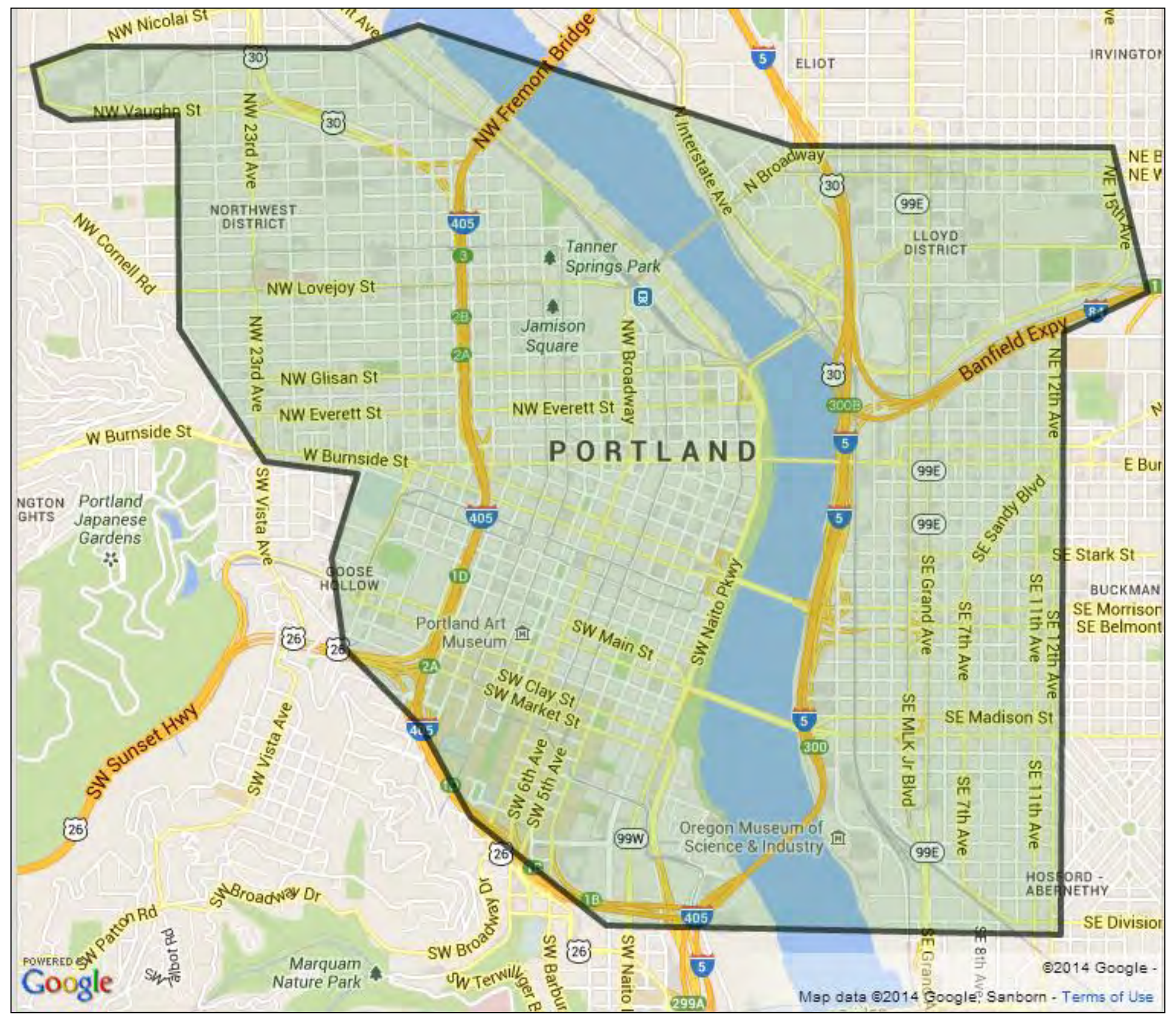
Background

Portland Pedal Power (PPP) is a bicycle delivery company that allows customers to order food from restaurants and have it delivered by bicycle to their home or business. PPP has a current delivery zone based on areas where slope increases beyond a certain threshold, but it does not exclude trips within the delivery zone for any reason (such as an across-town trip that crosses multiple hills). Additionally, delivery fee calculations currently account for Euclidean distance between the restaurant and the customer, rather than the true routed distance of the trip. Both the slope of streets along the route, as well as the distance traveled, determine the difficulty of the trip for the rider. Because the delivery bicycles are larger than standard bicycles and much heavier, they are difficult to ride and should be limited to trips along bicycle-friendly streets. In order to determine whether a delivery trip is too difficult for a delivery rider, PPP needed a tool to evaluate the trip cost, accounting for true distance and slope between locations, and based on a network of safe streets. Using the calculated trip cost, orders placed on the PPP website by customers could then be automatically accepted or declined.

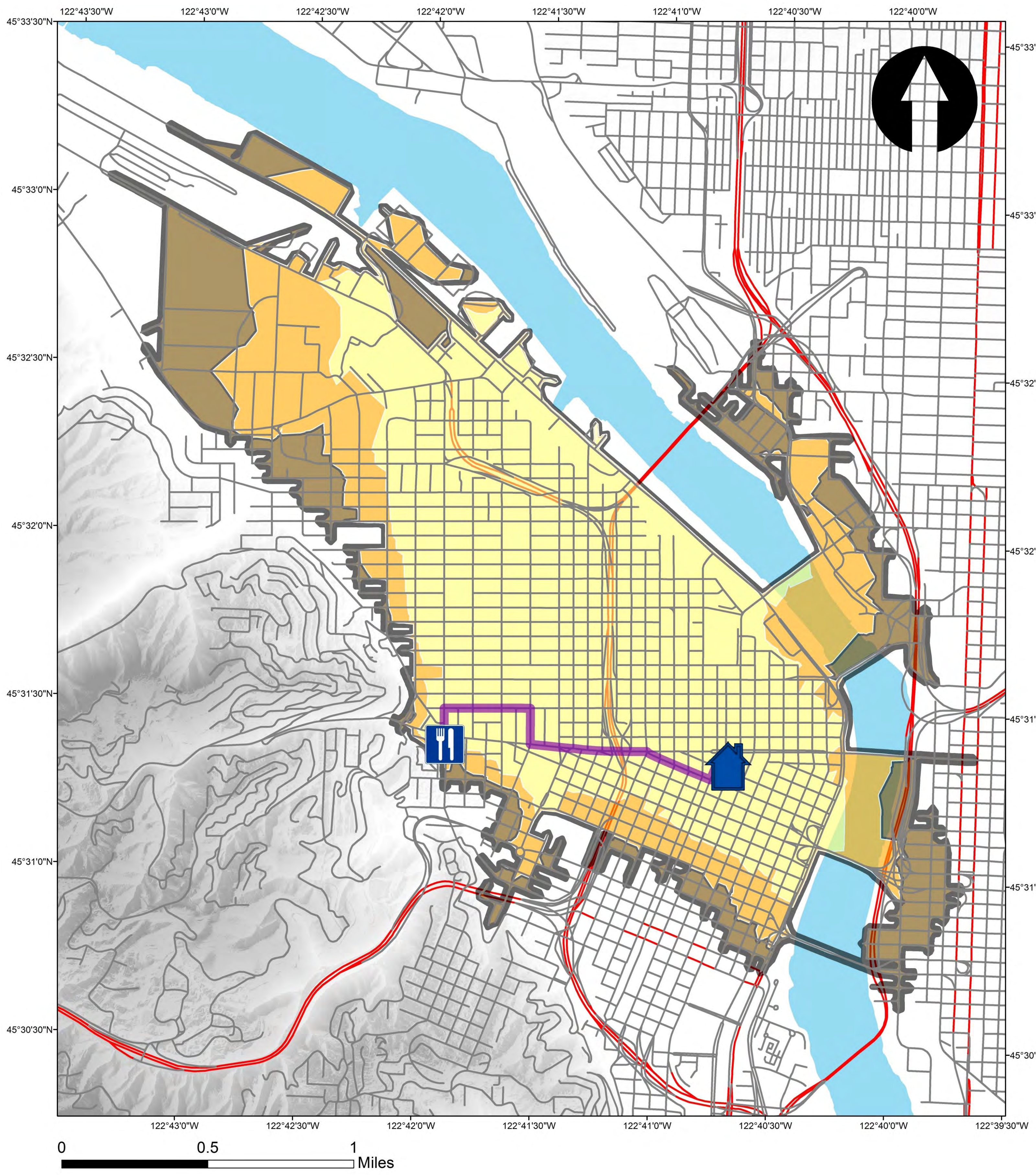
Current PPP Delivery Zone



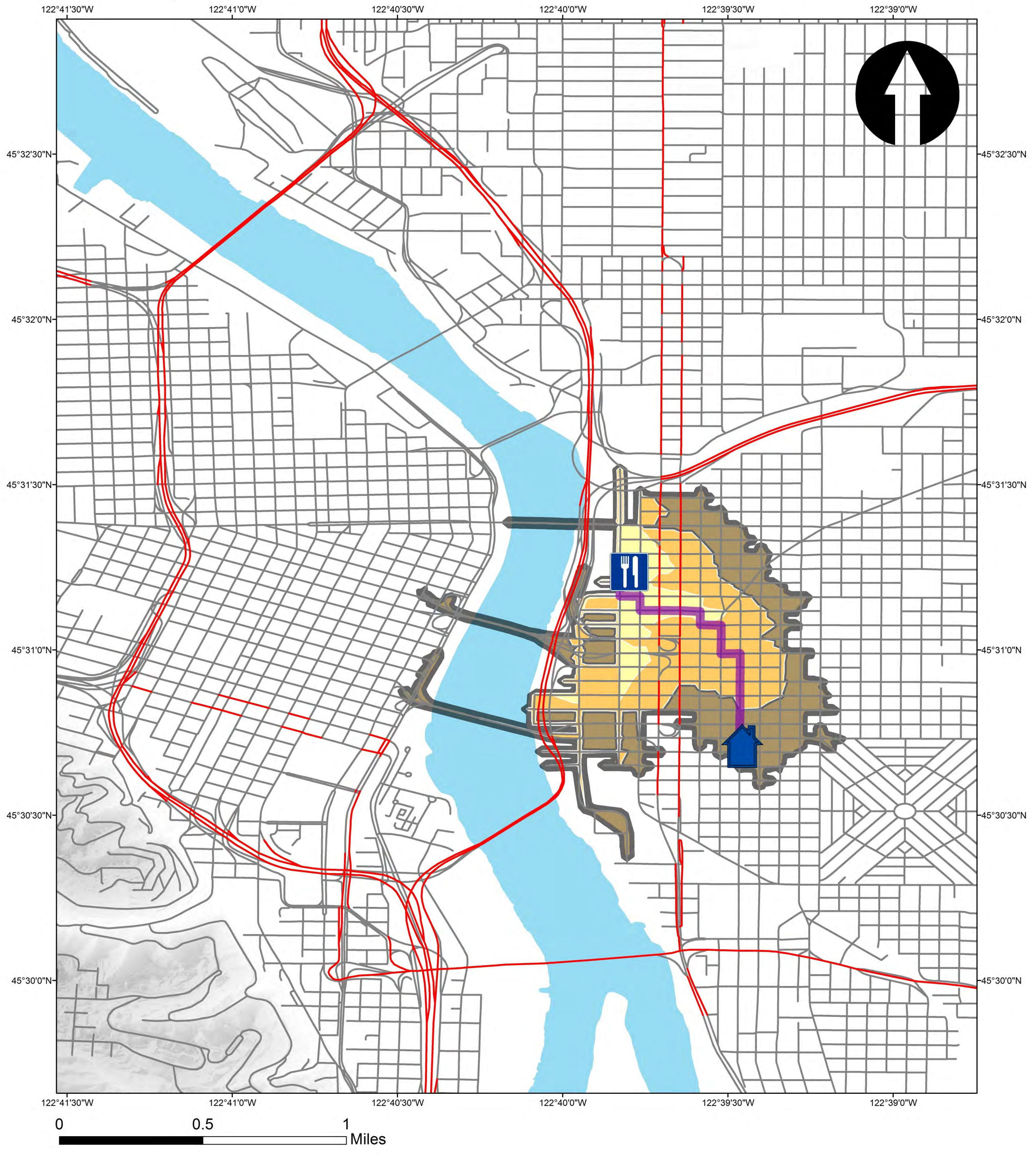
Methods

A North American continental street network dataset was clipped to the Portland Metro Area. The start and end vertices of these polylines were assigned elevation values corresponding to a 1 meter DEM of the Portland Metro Area. From these values we determined directional slope values (expressed as percent slope) between these FromTo and ToFrom points. However, many of the resulting slope values were erroneous as elevation values around the river and bridge did not account for overpasses and instead reflected bare earth elevations, thus leading to steep slopes at the drop off points between the road network and these urban canyons. For street segments within 1000 feet of rivers or 500 feet of freeways that also had unrealistic slope values (7 < slope < -7), we assigned a slope value of 0 as most overpasses are fairly flat. We then calculated the power rate (watts) needed to maintain a speed of 10 mph along each road segment (in each direction) using the formula $w=[K_A*v^2+m*g(S+C_R)]*v$, where K_A, the drag factor of air, was set to 0.245, v was the estimated velocity of the rider (4.47 m/s or 10 mph), m was the mass of the rider and bike (81.65 kg or 180 lbs), g was the force of gravity (9.807 m/s^2), S was the slope of the road segment in the direction of travel, and C_R was the rolling resistance coefficient of the bicycle tires (.004). Using the estimated average speed of 10mph, we then calculated the travel time in hours of each road segment and multiplied that time by the watts in order to get an energy expenditure value in watt-hours. We removed unsafe road segments that had speed limits greater than 35 mph and those that were related to highway exits, interstates, and roads without bike lanes that are known to be extremely congested with cars. We assumed that healthy cyclists can sustain an energy rate of 150 watts for a few hours, and also used PPP's suggestion that trips be limited to 20 minutes to preserve food, and determined that areas that could be reached with 50 watt-hours of energy expenditure (150 watts * ⅓ hours) would be within that restaurant's delivery zone. Our model takes an Excel worksheet with geographic coordinates of the restaurant and customer, and uses Network Analyst with the Service Area and Route tools to determine the 50 watt-hour delivery zones (subdivided into 20, 35 and 50 watt-hour zones), determine whether the customer falls within the delivery zone, and calculate the trip cost in terms of watt-hours, time, and miles. The output is an Excel table, allowing the process to be run without knowledge of ArcMap's tools, and the model also automatically adds the locations, service area and route to the map document for easy visual inspection.

Delivery Zone and Route 1



Delivery Zone and Route 2



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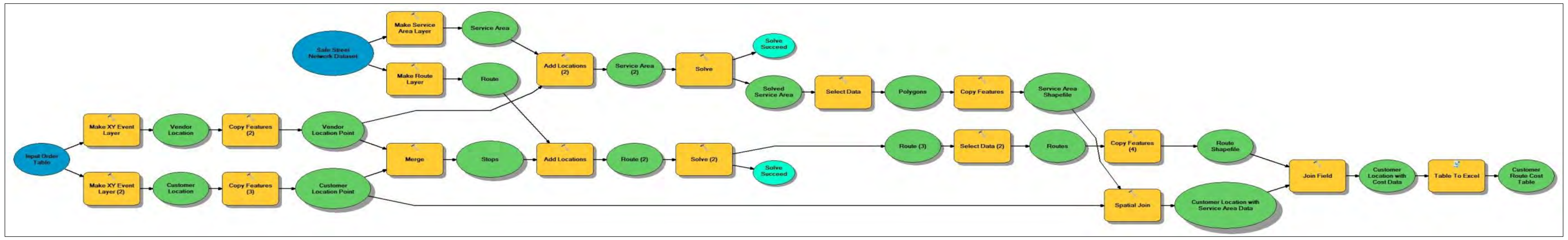
Data Sources
Portland Bureau of Planning;
Portland Pedal Power; ESRI

References

Iseki, Hiroyuki, and Tingstrom, Matthew. *A New Approach in the GIS Bikeshed Analysis Considering of Topography, Street Connectivity, and Energy Consumption*. 1 Nov 2012. National Center for Smart Growth Research and Education, University of Maryland.

Service Area and Routing Model frpm ArcGIS ModelBuilder



Results

Our tool generates an Excel spreadsheet for each delivery trip, including data about the restaurant's location, customer location, inclusion within the delivery zone, watt hours expended by the rider, miles traveled, and estimated minutes of travel. For the first route shown, the restaurant location was at 2340 W Burnside and the customer was located around SW Broadway and SW Ankeny. Our model determined the trip distance to be 1.33 miles with an estimated travel time of 8 minutes and an energy cost of 7.57 watt hours, well within the delivery area defined by an energy cost of 50 watt hours. The second route began at 304 SE 2nd Ave and ended near SE 8th and SE Hawthorne. Our model determined the trip distance to be 0.89 miles with an estimated travel time of 5.4 minutes and an energy cost of 43.93 watt hours. Despite the shorter distance of the second trip, the energy cost was much higher because of the slopes of the connecting streets. The first route involved mostly downhill travel, beginning at an elevation of about 189 ft and ending at around 37 ft, while the second route involved more uphill travel, beginning at an elevation of about 34 ft and ending at around 46 ft. Accordingly, the service area of the first restaurant is larger than that of the second restaurant because of the large portion of the city that lies downhill from it.

Conclusion

The service areas created in this study offer a more robust deterministic analysis for each customer order request compared to PPP's current generalized service area map. The watt-hours, delivery time estimates, and routing results offer accurate variables that would be very helpful for PPP to increase productivity and better know when to accept or decline an order request. If integrated with their website it may also allow automatic determination based on the results produced per order.

However, the current model suffers from a lack of refined data. The missing elevation values for bridges and overpasses forced us to assign new slope values in order to preserve network continuity, thus leading to inaccurate trip costs and potentially including or excluding inappropriate road segments from the network. Additionally, though our intention was to make a multimodal network with a hierarchy that prioritizes bike routes, the data available did not include important network data such as oneway restrictions. We attempted a spatial join to append street network data to coincident bike routes, but this was not possible because the two data sets came from different sources and were misaligned. Thus, our routing does not prioritize bike routes but does avoid particularly unsafe streets.

For future refinements, the assumed average travel speed could be calculated by timing riders, and desired watt-hour limits could be refined by performing test rides or running the model over the history of orders to see what the norm has been for trip costs. Further project work could contain a scripted dialog box for the model to allow direct data integration through a web form without the need for the data to be inputted and exported in an Excel worksheet. To allow PPP to provide routes to their riders in the field, location points and ideal route could be exported in a KML format, which could more easily be overlaid on a web map for riders to use on their own GNSS enabled smartphones.