

Optimal bike routes to Tacoma public high schools

A least-cost path analysis to encourage student
bicycle commuting from populated neighborhoods

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Introduction

This geospatial analysis project seeks to identify optimal bicycling routes to high schools from neighborhoods having high youth populations. Recommendations are made for the five bounded public high schools within the city of Tacoma. The least-cost path analysis uses positive and negative attributes within the road network to determine the best route from each population base to its target school. In this project, the goal is to minimize effort while maximizing safety. Parents, students, school officials, and transportation advocates might use conclusions from this analysis to select routes to school, organize bicycle trains, and promote active commuting. Additionally, data from this project may assist City of Tacoma Planning and Public Works staff as they prioritize infrastructure improvements to enhance safe routes to school.

Motivating factors

This project was initiated with the hope of facilitating change. Bicycling commuting can be a means to improve health, enhance community livability, and promote environmental sustainability. Providing prospective cyclists with factual information can help dispel myths and contribute increasing cycling rates among youth (4).

Health and obesity issues

Youth obesity is epidemic due to cultural changes in diet and exercise. With physical education programs lacking, bicycling is a fun way to increase daily activity among youth populations (9). Many adults enjoyed bicycling as children, and consider family biking to be a positive experience. Utilitarian bicycling, including commuting, can be presented as a natural extension to bicycling solely for pleasure.

Safety concerns

Because parents' attitudes and beliefs are a significant influence in their child's decision to bike (11), this project seeks to establish feasibility of bike commuting, minimize perceived safety concerns (1, 5), and inform parents and students on the many benefits of bicycle

commuting. The national Safe Routes to School program provides funding to identify and improve active commuting for elementary and middle schools, but does not include high schools (7). This project seeks to extend the safe routes concept to older students seeking active transportation.

Environmental sustainability

Bicycling is an efficient, environmentally friendly mode of transportation. Over short distances in urban areas, it can be nearly as efficient as driving a car (10). Because most Tacoma high school students live within three or four miles of their school, bicycle commute times would typically be less than 30 minutes, and often less than 10 minutes. If a significant number of students used active commuting or bus transit, traffic at and near schools would decline significantly. Rush-hour traffic near schools, pedestrian hazards, and related environmental impacts are significantly higher due to increasing numbers of parents driving their kids to school.

Mobility as public policy

Tacoma is building momentum for increased bicycle, pedestrian, and transit mobility. With the adoption of the Mobility Master Plan in June 2010, the Tacoma City Council demonstrated its commitment to providing a safe and livable built environment that encourages the use of non-motorized, active transportation methods (12). The Green Transportation Hierarchy (Figure 1) reinforces the status of bicycles in local transportation planning. The city's Bicycle and Pedestrian Action Committee, upon which this author sits, has been instrumental in identifying bikeways and prioritizing implementation. The top-four bikeways project, to be completed by the end of 2012, will feature a connected network of bike boulevards designed "to attract cyclists of all ages and abilities." In addition to infrastructure improvements, public outreach must be included in order to affect significant change (5).



Figure 1: Green Transportation Hierarchy

Methodology

Data sources

Data for this project was acquired from several credible sources. Unless otherwise noted, data is from the May 2011 Pierce County Geodatabase (PCG) published on WAGDA. Other sources are noted when appropriate. Layers included:

- TPS high school service boundaries (digitized)
- schools
- census blocks
- youth population (2010 U.S. Census)
- tax parcels w/ zoning designations
- roads
- bus routes (Pierce Transit)
- 10-ft DEM of urban area (Dr. Kelley via USGS)
- base layer

Locating schools and service area boundaries

The first step in performing a network analysis is identifying the start and end locations for each trip. In this case, the goal was to provide routing directions to each of the five bounding high schools in Tacoma. Point and polygon data for schools was included in the Pierce County Geodatabase. Point data was based on the polygon centroid, so school addresses were geocoded to produce an ending point that reflected the main entrance on a road.

Polygons for the five high school service area boundaries were digitized manually. Refer to the Data availability section on page 7 for a complete discussion of this process.

Identifying student population clusters

Providing routing directions for individual addresses was beyond the scope of this project. Instead, it focuses on identifying residential areas having high densities of potential high school students. Population data (grouped by age) for the smallest census divisions (census blocks) was acquired from census.gov. High school student population counts for each census block were derived by aggregating gender groups across ages 14-18. Similar data for middle school students aged 10-13 was saved for possible future use. This data was joined with census block polygons to produce hot spots. To further refine the analysis, tax parcels having residential uses were identified within each census block. The residentially zone parcels were then dissolved into multi-feature polygons. This allowed a better view of density because population counts within each census block could be normalized over a smaller area known to have residential uses. The top 2 tiers of a 4-tier Jenks natural selection method were selected to represent the most densely populated hot spots from which routes would begin.

Outliers were also identified and excluded from the analysis. These included Reiman Hall and University of Puget Sound. Both had extremely large youth populations that were by definition not attending a target high school.

Assembling cost layers

Three cost factors were included in the cost distance analysis: Distance traveled on the road network, changes in topographical slope (2, 10), and traffic hazard (1) based on road classification. Each factor was rasterized, reclassified into a similar scale, and combined into a total cost grid using raster algebra:

```
("TacPierceUrban_RoadRaster100Class" * .5) + ("TacPierceUrban_SlopeClass" * .3) +  
("DistRasterClass_Foss" * .2)
```

Distance cost was initially performed using a Cartesian distance analysis (Figure 2). Upon further review, it was determined that boundary shapes and local geography made this less useful. Students commuting from NE Tacoma to Stadium, for instance, had to follow very indirect routes because Commencement Bay and the Port of Tacoma act as a barrier to direct travel. To better reflect these realities, a service area analysis of the road network was conducted (Figure 3).

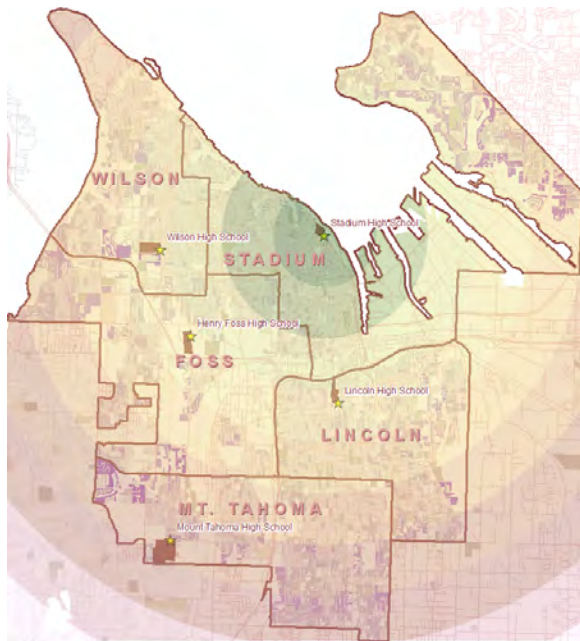


Figure 2: Cartesian distance analysis ignores road network

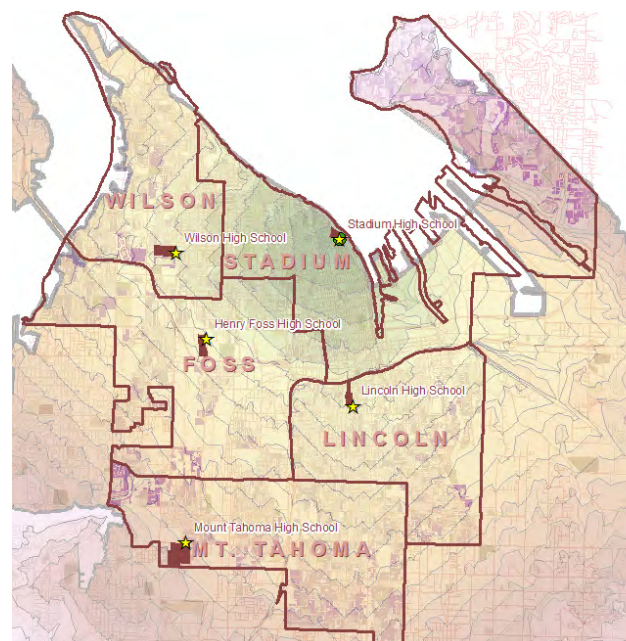


Figure 3: Service area distance analysis based on road network

Slope cost was based on a raster algebra slope process run on a USGS 10-ft resolution digital elevation model (DEM) of the Tacoma urban area. Data was provided by Dr. Kelley for use in an earlier lab assignment. Slope was expressed in degrees.

Traffic hazard cost was calculated from a classified raster of the Pierce County roads layer. Road classification was used as a proxy for traffic hazard. Residential roads were given the lowest cost (1 point) based on the premise that it is safer to travel on low-traffic side roads. Each successively higher arterial type was assigned an incrementally higher cost ranging

from 5 to 8 points. Highways and off-road areas were given a cost value of 100 to eliminate them from consideration. An uncaught author oversight regarding classification of freeway ramps led an SR-16 ramp to be included in a recommended route to Foss High School.

Calculating travel costs

For each school, a cost distance analysis (Figure 4) determined the total cost of traveling to the school over each raster cell from its population centers. The Cost Distance tool produced a backlink raster (Figure 5) and distance raster (Figure 6) to be used in the subsequent cost path analysis.

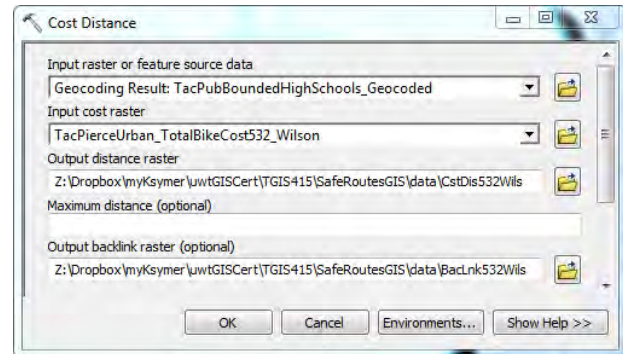


Figure 4: Cost Distance parameters for Wilson High School

Cost path analysis

The cost path analysis was used to identify the least costly routes based on a weighted combination of effort and hazard. Minimization of effort was based on distance traveled and elevation change. Road classification type was used to approximate traffic hazard. The optimal route was thus based on the most direct route having the least slope across low-traffic roads.

Starting point hot spots were selected from census blocks with highest target population density normalized for residential land area. Road network nodes within 60 feet of these hot spots were selected as specific starting points (Figure 7). Commuters living in hot spot areas could thus find a route from their census block's nearest perimeter intersection regardless of where in the block they reside (Figure). It should be noted that several smaller parcel clusters located between distant intersections were omitted from the selection using this method.

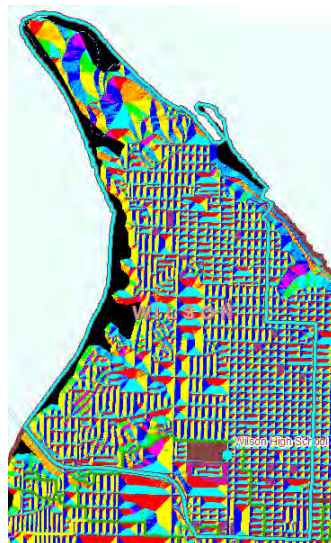


Figure 5: Backlink raster for Wilson High School

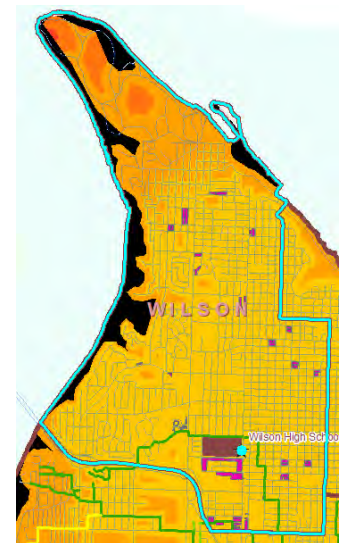


Figure 6: Cost Distance Raster for Wilson High School

Notable challenges

Data availability

The initial cost analysis concept included diverse attributes shown on the City of Tacoma’s GovME mapping site. A richer model might have included factors such as bike facilities, land use intensity, pavement condition, lane width, arterial type, speed limit, street lighting, sidewalks, crosswalks, signals, and traffic calming measures. Due to challenges acquiring data from local jurisdictions, the model was simplified. Available data included topography, zoning designations, and road class. Current and planned bike facilities, although clearly in the City’s GIS, were not made available (Figure 11).



Figure 11: Top 4 Bikeways map shows existing and pending bike facilities

So existing and pending bikeways were manually digitized using information from Google Maps and the City of Tacoma website, including the Top 4 Bikeways 2011-2012 map and the 2010-11 Mobility Master Plan Progress Report.

School district digitization

Tacoma Public Schools (TPS) high school and district boundaries (i.e., attendance areas) did not exist as GIS data files. Boundaries were manually digitized for this project and then provided as a courtesy to both TPS and the City of Tacoma GIS Department.

Because the boundaries did not strictly follow the Tacoma city limits, digitization required additional information. The process was not simple. Official attendance area boundary information downloaded from the TPS website included scanned PDFs of hand drawn boundaries on a paper map and legal descriptions for each school's area. The district's webmaster confirmed that these documents were indeed the only available information. After georeferencing the map, and starting to digitize the boundaries, it became clear that neither the felt pen lines (Figure 12) nor the accompanying legal descriptions were of sufficient detail to accurately define polygons. Language in the legal descriptions such as "North along the district's western border" assumed border information not provided. A disclosure stated:

"The legal description of the perimeter boundary of Tacoma School District No.10 is maintained by the Puget Sound Educational Service District. The legal description will be the basis for resolution of disputes. The following describes the perimeter boundary of the district in more commonly used terms:"

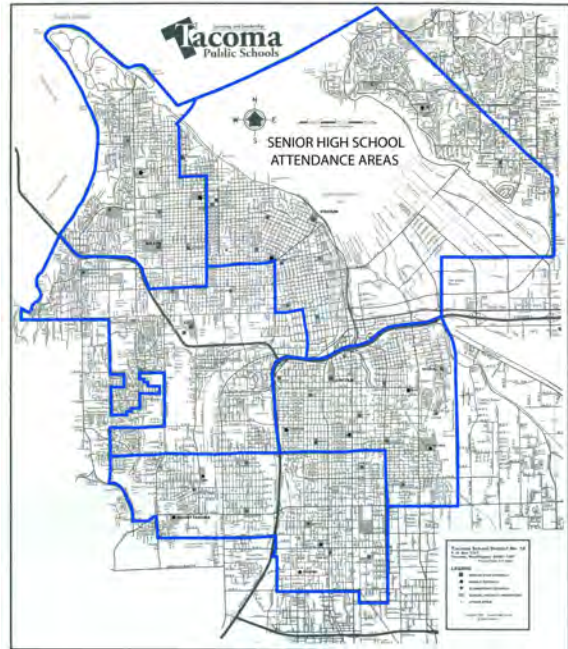


Figure 12: Map of Tacoma Public Schools High School Attendance Areas

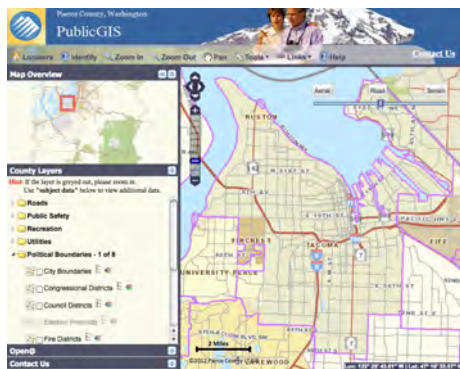


Figure 13: School Districts in the Pierce County Public GIS

No such perimeter legal description was publicly available on the Puget Sound ESD website, and time did not permit contacting them directly.

So, several additional online information sources were used to produce the perimeter TPS boundary. An overall district boundary was viewable on the Pierce County Public GIS site (Figure 13).

This polygon was accurate to the

parcel level, and was generated from the school district to which each parcel's taxes are allocated. This was judged to be a very accurate source and was used as precise visual guide to manually digitize the overall TPS



Figure 14: Pierce County Public GIS featured parcel-level boundary accuracy

district boundary (Figure 14). Tedious snapping to the Pierce County road, city, parcel, and shoreline features produced excellent results. Boundaries were also confirmed using online maps and information from neighboring districts of Fife, University Place, and Clover Park. Armed with an accurate boundary feature, the TPS legal descriptions for each high school were sufficient to digitize the internal boundaries.

Road network analysis

A jurisdictionally complex area between Fife and NE Tacoma proved difficult to analyze

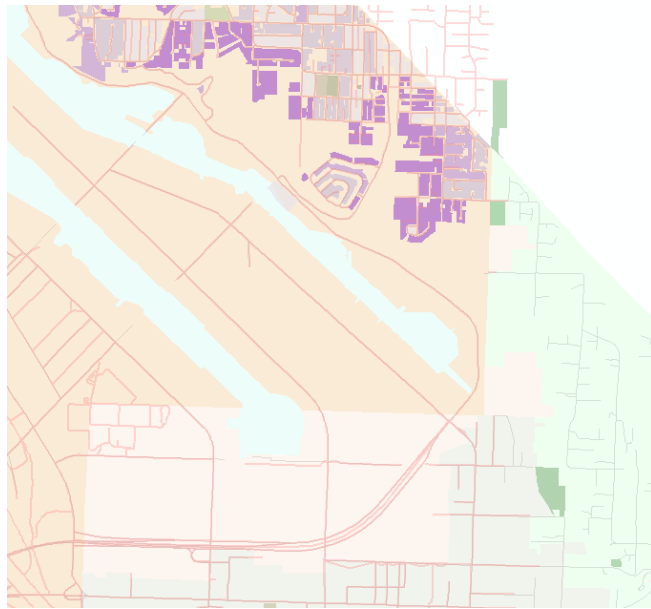


Figure 15: City of Tacoma streets (red lines) do not connect with NE Tacoma using roads in unincorporated Pierce County (light green background).

using road data. SR-509 (Marine View Drive) was the only road fully contained with the city streets data. Adjacent roads in the area of unincorporated Pierce County known as Fife Heights might have provided an alternate route, but the roads were not available for network analysis. City of Tacoma streets data (updated on 5/17/2012) had a FZLEV and TZLEV vertical coordinate field to aid in network analysis, but the roads did not extend to adjacent areas outside of the city (Figure 15). The Pierce County roads layer did extend, but had no elevation fields. A County road network analysis might thus include impossible turns at non-connected road intersections such as bridges or underpasses.

In pursuit of a model

Initial project plans included using ArcGIS Model Builder to create a tool that can be used to return routes for any school. This could be helpful for doing middle schools within the same district because all of the data is the same. Creating a model robust enough to handle data from other districts or locales might be more complex due to variations in local data tables and field types. There was not sufficient time to pursue this option. A very robust model depends on data not currently available such as lane configuration, on-street parking, bicycle lane width, truck volume, parking time limits, and right-turn volume (3).

Conclusions

Routes recommended in this study could be used to start a conversation on bicycle commuting. Students from each school might look at similar route maps to find their neighborhood and a suggested route for biking to school. As indicated by the bluish shading, many students can ride to school quite easily within 5-30 minutes. A service area analysis showed that most students live within a 4-mile drive of their school—and many within 1 or 2 miles. Traveling by bike over these distance is faster than walking and nearly as efficient as driving (in congested urban areas).

Students attending Stadium High School who live in NE Tacoma are faced with more physical challenges than their peers in other neighborhoods. Because the service area extends across the Port of Tacoma to heavily populated Northeast Tacoma neighborhoods, students are faced with significantly longer commute distances that include more hills and cover some of the most hazardous roads. One-way commute distance from NE Tacoma ranges from 8.5 to a maximum of 12 miles, more than double the distance of any other school studied. Any effort to increase cycling among the NE Tacoma population should include safety equipment and education. Infrastructure improvements, such as a separated cycle track along SR-509, are also critical to minimizing risks associated with riding on the shoulder beside highway traffic.

Recommendations for further study

Incorporating participatory techniques

This model is based primarily on available data and the author's bicycle commuting experience in Tacoma. Barriers to cycling may be based on gender, age, or cultural issues rather than strictly geography or physical environment. A Davis, California study concluded that girls and students age 16 or older are less likely to ride than other high school students (4). If the ultimate goal is to increase student participation in bicycle commuting, then additional work should include surveys to assess perceptions among parents and students. Behavioral changes begin with education and persuasion. No matter how safe the bike route, personal beliefs may limit participation. Outreach efforts must also use peer advocacy to make bicycling an acceptable alternative to driving. Finally, financial costs might prevent students from acquiring bicycles and related equipment. New and infrequent cyclists should be encouraged to obey local helmet laws because they rarely wear helmets (8). Assistance programs offering bicycle donations, low-cost helmets, and maintenance courses help ensure cycling is attainable by a diverse audience.

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