Appendix 7- Accounting for Slope and Creating Pedestrian Sheds

Accounting for Slope

Two variables often ignored in walkability modeling and pedestrian catchment construction are the steepness of street segments (i.e., the slope) and the impact slope inflicts on pedestrian traversal time. In a recent study by Daniel & Burns[36], the authors put forth a new methodology for incorporating slope in the creation of 'realistic' pedestrian catchments, via geographic information science/systems (GIS). Using Tobler's Hiking Function[37], Daniel & Burns applied slope-adjusted walking speeds to calculate pedestrian traversal times both up and down hills, for average adults in the city of Milton, Scotland. Tobler[37] estimated that an average adult walks 5 km/hour on flat ground and reaches maximum speed of 6 km/hr going downhill at a -3° slope. Daniel & Burns[36] found that 2-dimensional pedestrian catchment models (i.e., not considering slope) are significantly larger and less realistic compared to slope-adjusted 3-dimensional models. The current analysis aims to implement the methods outlined by Daniel & Burns to model walkability and construct slope-time pedestrian catchments for children traversing to and from school, as part of a Safe Routes to School grant proposal for the city of Houghton, MI.

The city of Houghton resides on the south side of steep valley overlooking Portage Lake, with both the Elementary and Middle Schools positioned at or near the top of the ridge. Using a newly acquired 1.5 meter digital elevation model (DEM) and the 3D Analyst extension in ESRI ArcGIS Pro 2.3.2, slope values (i.e., max slope, average slope, and slope-adjusted segment length) were added to a pedestrian network, consisting of street segments and informal pathways, using the Add Surface Information tool. Calculations for child walking speeds and times were based on the premise that a child walks 20% slower than an adult, at an estimated 4 km/hour. Uphill and downhill traversal times per network segment (minutes) were calculated using the slope-adjusted segment lengths (meters) and slope-adjusted child walking speeds (km/hour) based on modified version of Tobler's Hiking Function. The result of this slope and traversal time analysis yielded two maps for the city of Houghton's pedestrian network: (1) a map featuring the steepness of streets and pathways and (2) a map featuring the uphill slope-adjusted time it takes to traverse each segment of the pedestrian network.

While this analysis aims to model realistic conditions for children walking to and from school, these two maps come with assumptions, caveats, and limitations. The two most apparent assumptions this analysis makes are (1) that children walk 20% slower than adults and (2) that a modified Tobler's Hiking Function is valid for slope-adjusted walking speeds for children. Mathematically, the modified Hiking Function assumes children can walk 4 km/hour on flat ground, however this has not been verified with field tests. The two most important caveats to take into account for this analysis are (1) the spatial resolution of DEM for determining slope and (2) that the use of average slope per network segment instead of the maximum slope for traversal time calculations. These two caveats go hand-in-hand, in that they are related to the elevation data (i.e., DEM). The DEM resolution of 1.5 meters is high enough to capture slopes of rooftops and tops of trees, which creates anomalously high slopes along certain network segments. To account for these anomalies, a threshold value of 35° was designated as the steepest acceptable slope and segments with slopes greater than 35° were visually inspected and adjusted to a realistic slope based on neighboring network segments or removed from the analysis. Although the anomalous slope segments were taken into account and adjusted, two obvious limitations must be stated regarding this analysis: first of all, the current analysis is only based on quantitative spatial data, not qualitative psychological perceptions of slope as a pedestrian barrier; and secondly, these slopes, traversal times, and slope-adjusted walking speeds for children still need to be verified with field observations. A future study that compares, GPS (location + personal accelerometer) data vs. DEM vs. Tobler Hiker's Function should be conducted to verify the results the current analysis.

Creating the Pedestrian Sheds

Building off of the previous methodology and our understanding of both Daniel & Burns[36] and Tobler[37] we decided on a figure to use for time traversal along our network. In choosing a break point for our pedestrian sheds we decided to maintain our earlier figure of 1 mile (1.6km) used in Larsen[38], in order to make this compatible with our traversal time we took the time it would take a child walking our assumed 4 km/hr over flat ground, this resulted in a break time of 1449 seconds (1610 m / 4000 m/hr * 360). In applying this traversal time in journeys to and from school, we made some assumptions in how the geography could affect those journeys. Due to the geography of the area it was generally assumed that going to school would use our uphill traversal time, and going downhill would use our downhill traversal time. This was done by setting the function values within our accumulator to the corresponding to-from and from-to values. However, the resulting pedestrian sheds did not match up with our understanding of actually traversing the area from our field audits. In reviewing our traversal times we found some relatively small, segments with traversal times nearing 10 minutes, this may have been due to inaccuracies in the DEM, or because Tobler's hiking function was never really intended to be used with children. As Dan suggested, a future study comparing GPS (location + personal accelerometer) data vs. DEM vs. Tobler Hiker's Function would be useful in verifying our results. To account for this lack of confidence we decided to make a compromise in our pedestrian sheds. Using the slope from the DEM we calculated a slope adjusted length for each street segment and generated new pedestrian sheds with a break point at 1610 m.

Pedestrian Shed Maps