# Walking access as utility: Latest advances in walkway network modeling and analysis

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This presentation is a follow up to the paper given by the authors in 2011 at Walk21 Vancouver BC. Since then we've further developed the tools, and we've also had the opportunity to work with partners on demonstration projects in the Portland region.

## Concepts

- Walking access
- The walkway network
- Walkway network models
- Walkway network analysis

The first concepts we'll cover today are walking access and walkway networks. Then we'll describe the process of modeling the walkway network and the process of walkway network analysis, using some examples from our two case studies.

# Walking access

We’ll start with walking access.


**The concept of walking access is important.** The focus is on walking as transportation. It means we're looking at the walkway network as a *utility* rather than as *amenity*.

## Walking access

In the utility model we assume 100% demand for walking access from every dwelling

In the utility model we assume 100% demand for walking access from every dwelling, just as we assume 100% demand for a utility like water service.

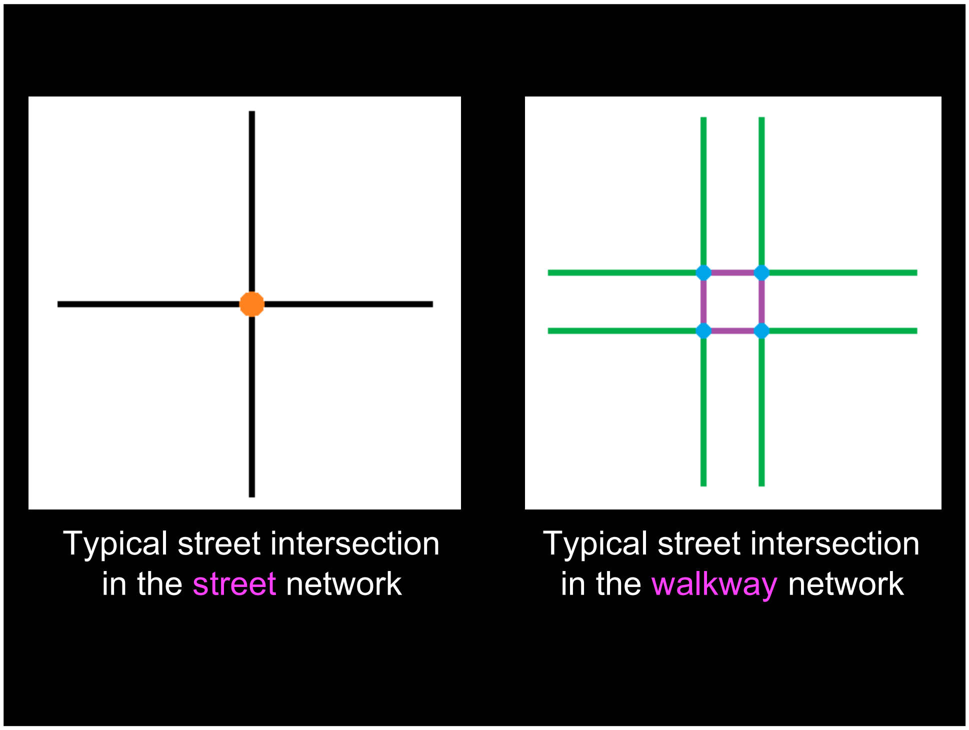
## The walkway network

Now I'll describe what we mean by the walkway network.


The walkway network consists of all the public ways available for pedestrian transportation. It includes sidewalks along streets, shortcuts, trails and paths through parks, and—most importantly—it includes crosswalks.

# Walkway network models

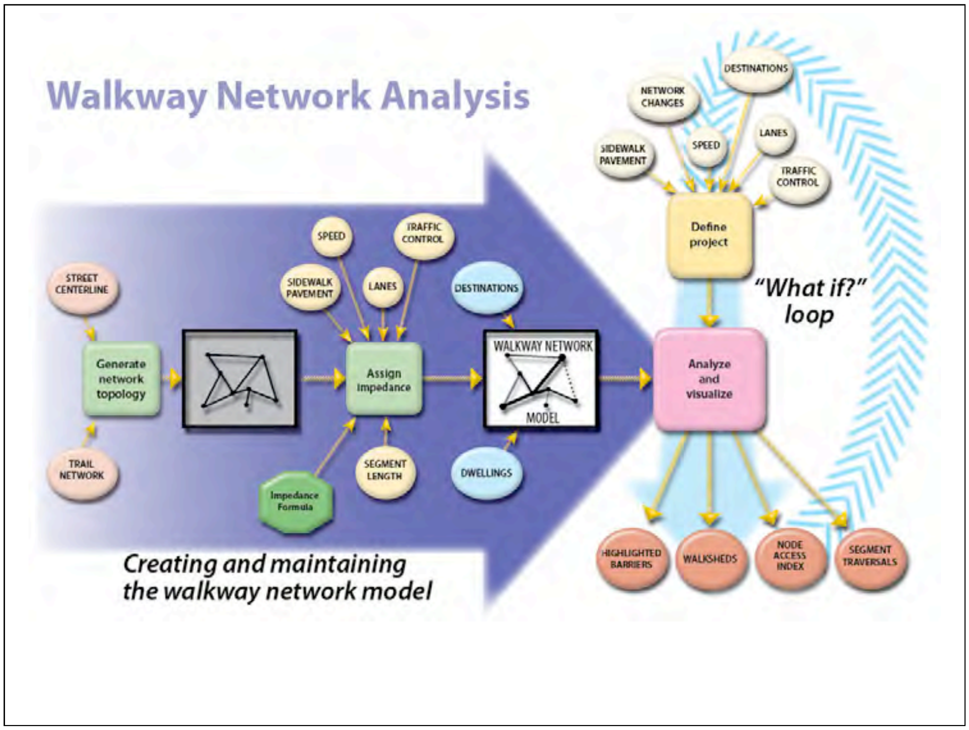
Our next step is to model the walkway network.




In the street network model the nodes are intersections and the arcs are the roadway segments. In the walkway network model the nodes are street corners and the arcs represent both sidewalk segments, in green, and crosswalk segments, in purple.

## Walkway network analysis

You can use a walkway network model to analyze where there are opportunities for improvement and who will benefit from any given improvement. And you can use it to quantify the impact of a project that might negatively affect walking access, such as widening a highway.

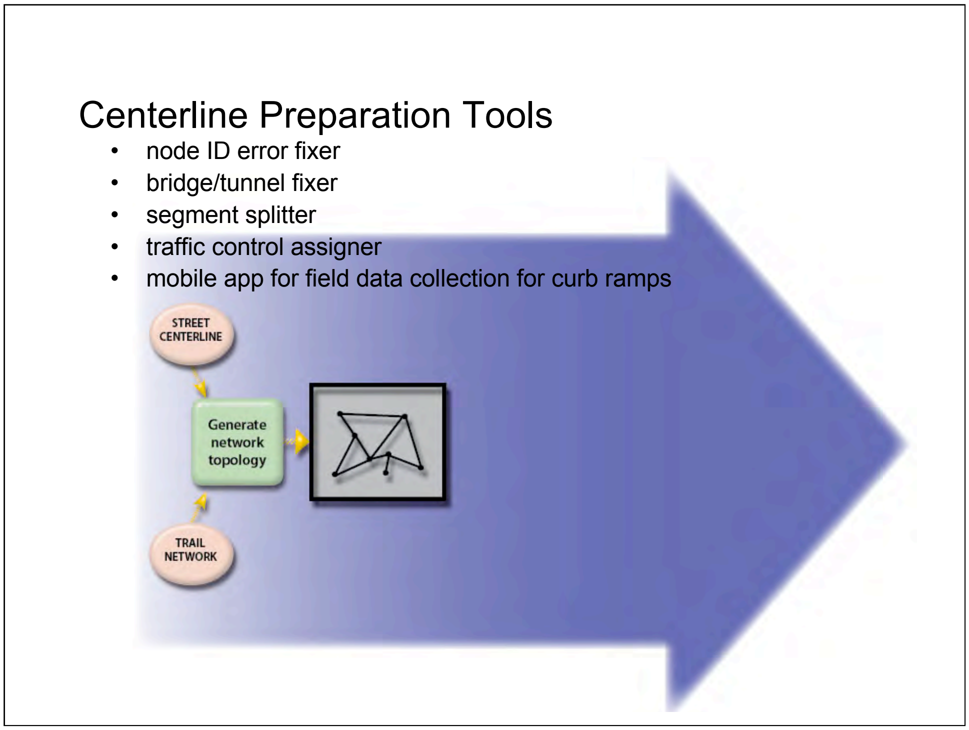



The walkway network analysis process has two parts: creating and maintaining the walkway network model, indicated by the big dark blue arrow, and the “what if?” loop, represented by the light blue arrows, where you can try out and compare different improvements.

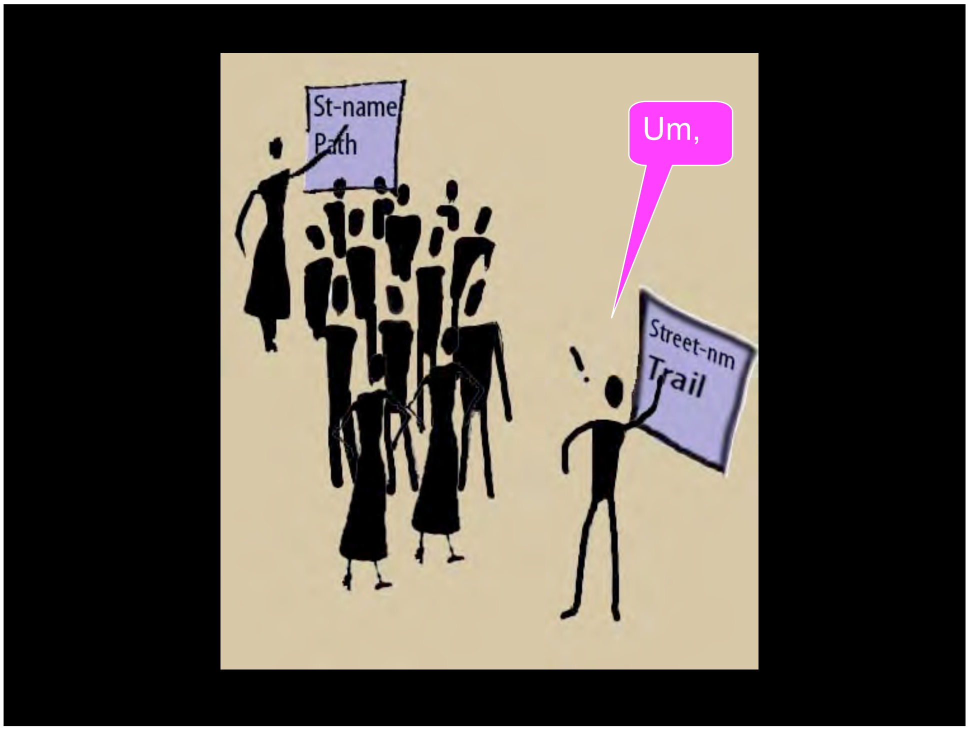
## Walkway Network Analysis Tool Sets

- Centerline preparation
- Walkway network generation
- Impedance calculation
- Project Definition
- Analysis
- Visualization

As we explore this process I'll touch on the GIS tools that Scott has developed and explain how they fit into each phase.

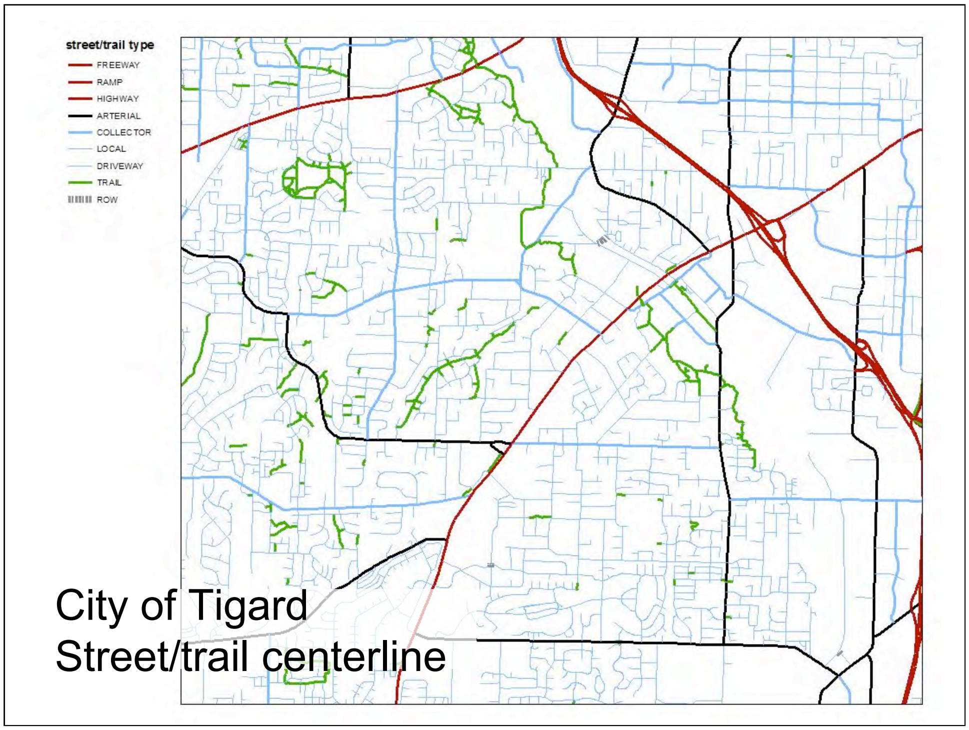



Let's unpack that busy process diagram phase by phase. We begin by collecting existing datasets like the street centerline and trail network so they can be merged into a clean centerline. Sometimes the data needs restructuring or correcting, and Scott has created tools to make that easier. The names of some of the tools give you some clues to the challenges of this first phase of the work. For example, centerlines generated from old TIGER datasets often have false nodes at bridges, so that unconnected segments appear to be connected. In this case you need the "bridge/tunnel fixer." You need the "segment splitter" for creating nodes to attach trail centerlines that meet streets at mid-block. Use the "traffic control assigner" when the only location data you can get for signals and signs is latitude and longitude.




This initial phase can take months, and so far it tends to involve a lot of manual GIS work. Datasets for streets, bikeways, and trails may be maintained by different departments and they're not always compatible. The structure of the datasets tends to reflect the structure of the bureaucracy. Sometimes it's tedious to restructure the data to work well for the walkway network model.

It's possible that Open Street Map will be the fix to some of these problems, but that has other problems of its own.

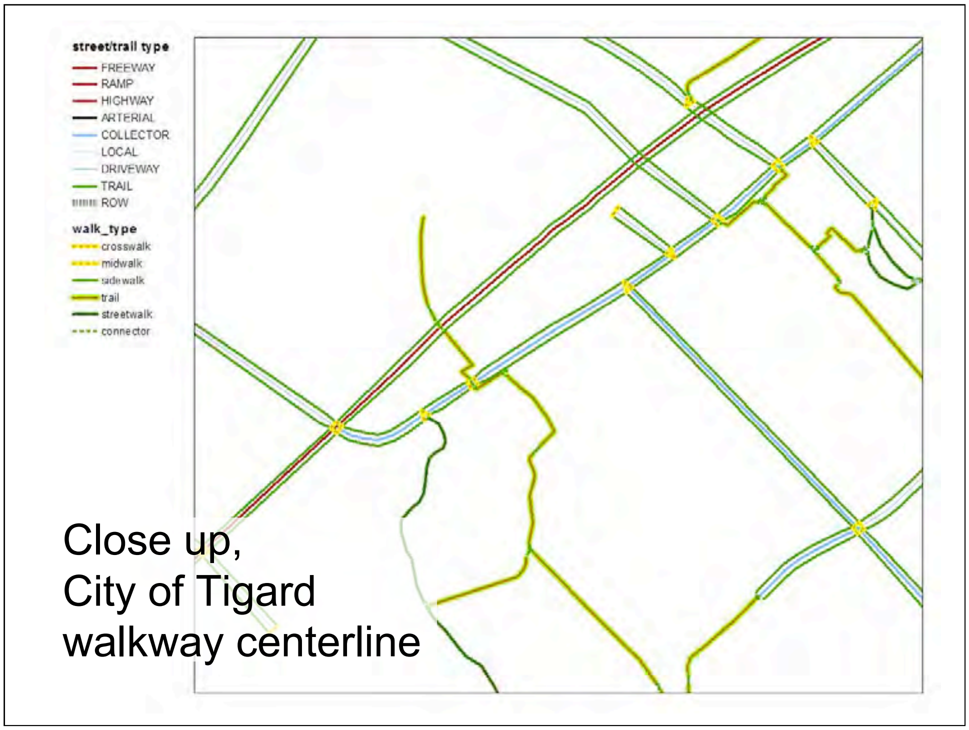



Here is an example of the clean merged centerline from one of our case studies where we're working with the City of Tigard. The Tigard City Council adopted a Strategic Plan to make Tigard the most walkable city in the Pacific NW.

## Walkway Network Generation Tools

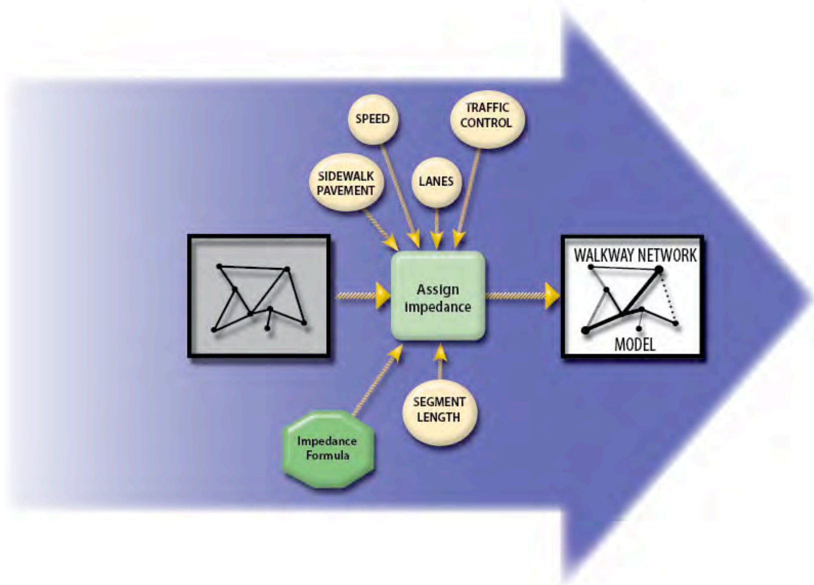
- Walkway generator
- Walkway segment remover
- Corner mover

From the clean merged centerline we generate the basic walkway network topology, using the walkway generator, cleaning it up if needed.




Here’s a close up of Tigard’s walkway centerline laid over the street/trail centerline. You can see sidewalks, crosswalks and trails.

- Impedance calculator



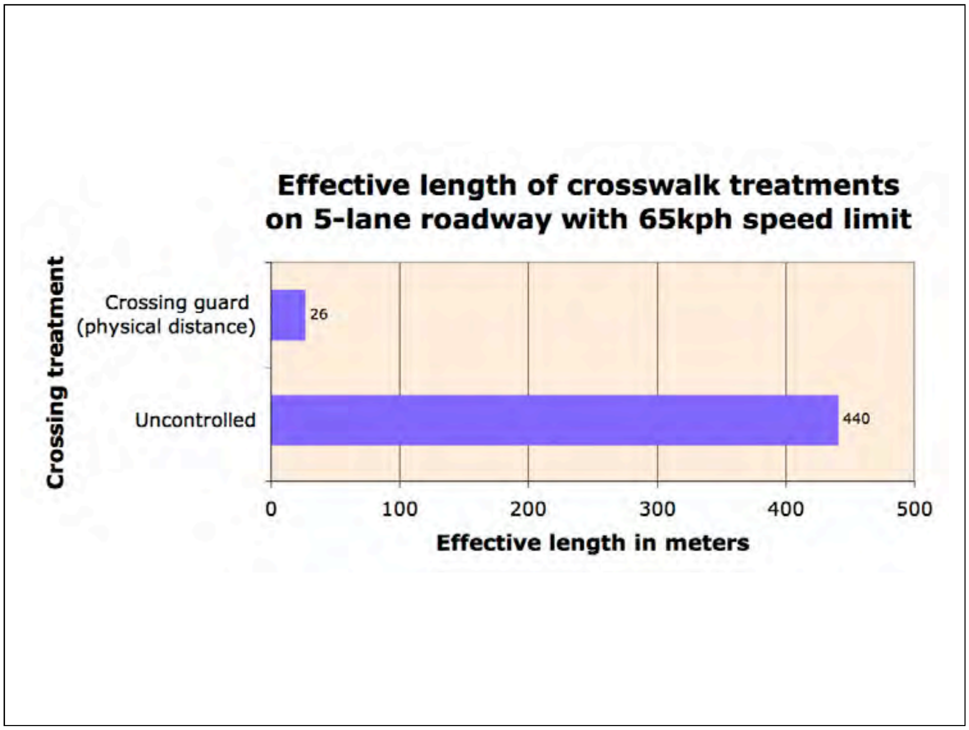

Computer models work with numbers, so for the walkway network model to approximate the real world difficulties encountered while walking, like traffic and missing sidewalks, it's essential to quantify what we're calling "impedance." We do this using attributes like speed, the number of lanes and the presence or absence of sidewalks or traffic control.

# IMPEDANCE

- Cost weight
- Friction
- Effective distance

Don’t let the word “impedance” scare you. It comes from the verb “to impede,” whose Latin root means to hinder the foot, and that is just the meaning we want you to be thinking about: what are the environmental factors -- like heavy traffic -- that hinder walking, and how can they be quantified? Some other ways to describe impedance are cost weight or friction. In our walkway network model, we use effective distance as the measure of impedance.


Impedance is represented in our model by what we call "effective distance." Let's take this uncontrolled crosswalk as an example.




Although the actual distance to cross is only about 26 meters, the effective distance in the walkway network model is 440 meters.

**Effective distance for crosswalks:**

$$D_{cross} = n(b + c^{(n-1)}\, as^2(1-f))$$

where n = number of lanes and s = speed limit in mph
and where parameter c is the multi-lane factor
and where parameter b is the equivalent distance of an ideal lane crossing (in feet)
and where parameter a is the speed limit proportionality factor (in feet/(mph$^2$))
and where parameter f ranges from 0 to 1 depending on traffic control

The following parameter values are proposed:

c = 1.2 The proposed value is chosen so that crossing a 4 lane road is three times more difficult than crossing a 2 lane road.

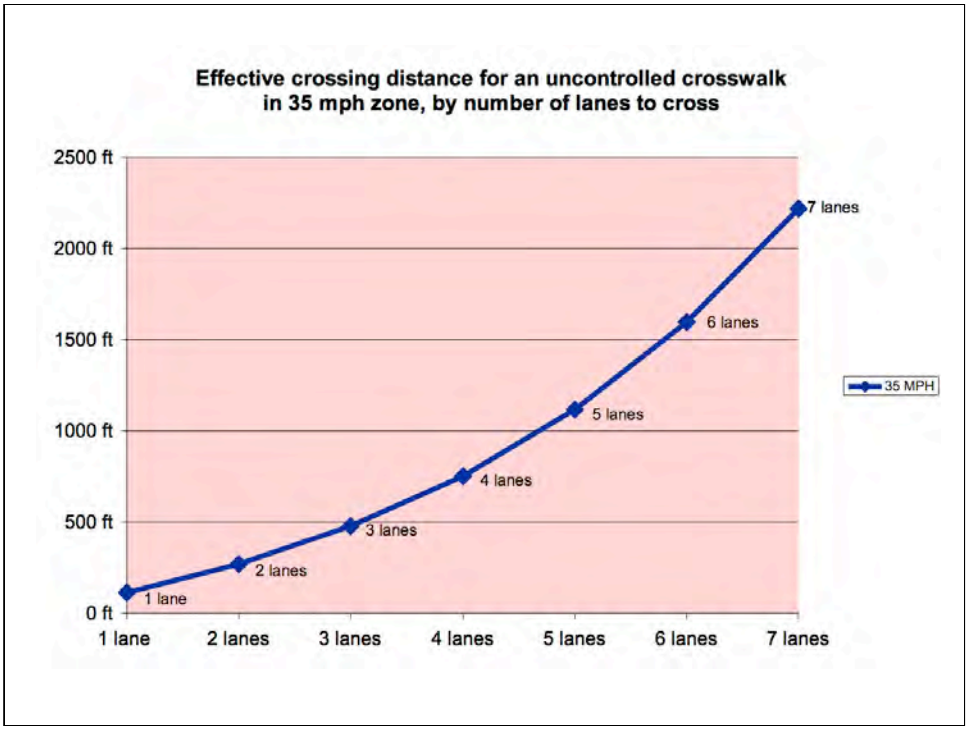
b = 12 ft. The proposed value is the typical lane width in feet.

a = 1/12 The proposed value results in about 1 minute waiting time plus crossing time (about 200 equivalent ft at 3.5 ft/sec) for a 2 lane road with 30 MPH speed limit at peak traffic.

| traffic control | f |
|---|---|
| stop | 95% |
| signal | 75% |
| flashing warning | 50% |
| no control | 0 |

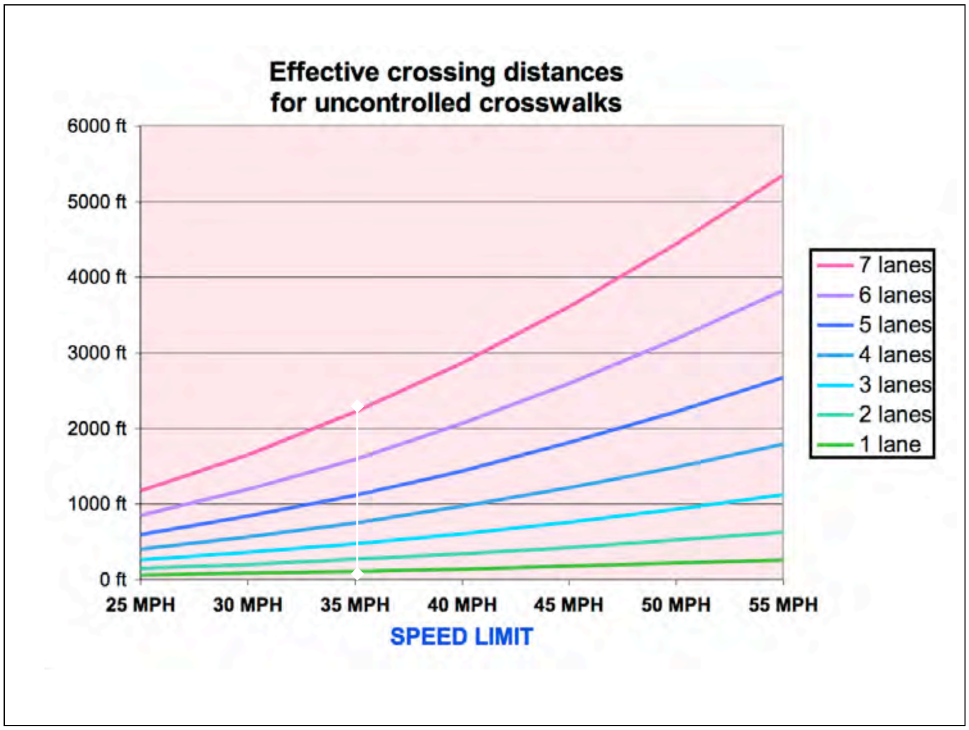
Where did we get that number? Here is the formula we use for calculating effective distance for crosswalks. The formula takes into account the number of lanes, the speed limit, and whether there is any traffic control present.

We have modeled three kinds of traffic control: stop signs, signals and flashing warnings. There are many more traffic control and crossing types that could be added.




Let’s look at the equation graphically, starting with just one class of crosswalks, those in a 35 mph zone (that’s 56 kmh), by the number of lanes to cross.

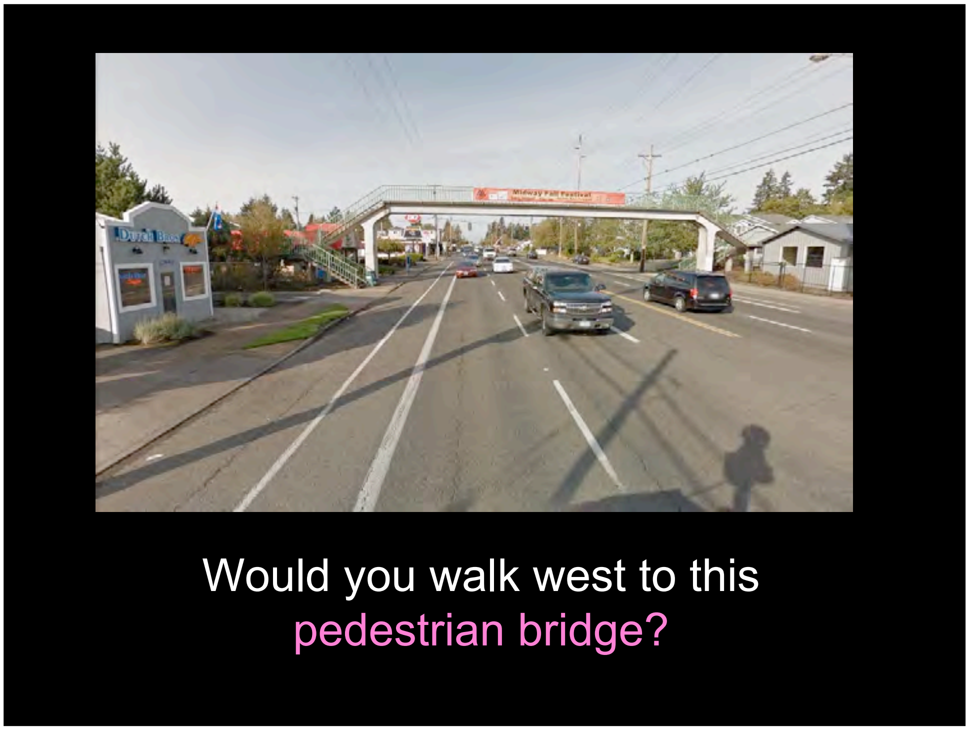
The shape of the effective distance versus lanes curve is an exponential. This shape is proposed on the assumption that the extra difficulty of crossing a multi-lane road is proportional to the number of lanes.




The shape of the effective distance versus speed limit curve is a parabola; in this case, it is also a power function. This shape is proposed because it is the shape of the stopping distance versus speed curve for motor vehicles.

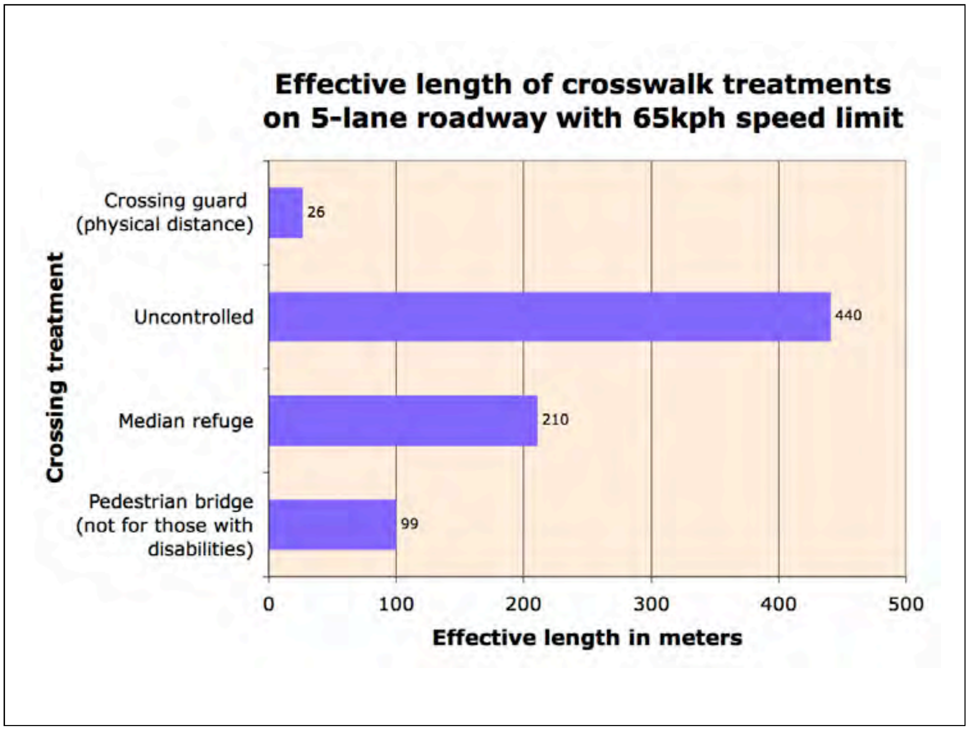
The white line cuts through the values represented in the effective distance versus lanes curve in the previous slide.


You might find it useful to think about effective distance as how far out of direction you would walk to avoid THIS crossing.

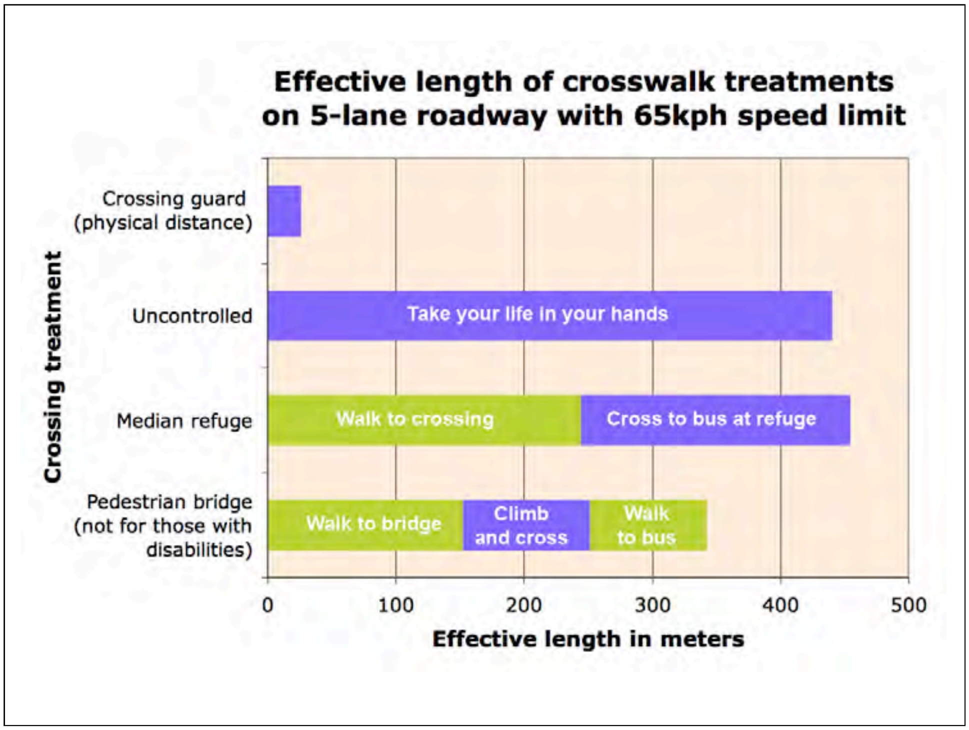



Actually, you COULD walk west to a pedestrian bridge.


Or, if you can’t climb the stairs to that bridge, you could walk east to a marked crosswalk with a median refuge.




Let’s compare the relative effective distances for these different crossing treatments. The effect of the median refuge island on effective distance is accounted for by summing the sub-crossings, which substantially reduces the effect of the multi-lane term for the total crossing. For the pedestrian bridge, we estimated the effective distance as twenty-four times the vertical gain, plus the actual distance to cross.




Suppose you are trying to reach any bus stop on the opposite side. Is it worth going out of your way to an easier crossing? Here's how the options stack up, including walking along the street from where you started.


The curves look a little different for sidewalk corridors. How do we quantify how difficult it is to walk where there is no sidewalk paving in the sidewalk corridor?

**Effective distance for sidewalks:**

$$D_{side} = L*(p(1 - g) + g)$$

and

$$g = s^2/d + s/e + 1$$

where
L = sidewalk length
p = the fraction with sidewalk pavement
g = a multiplying factor
s = speed limit in mph

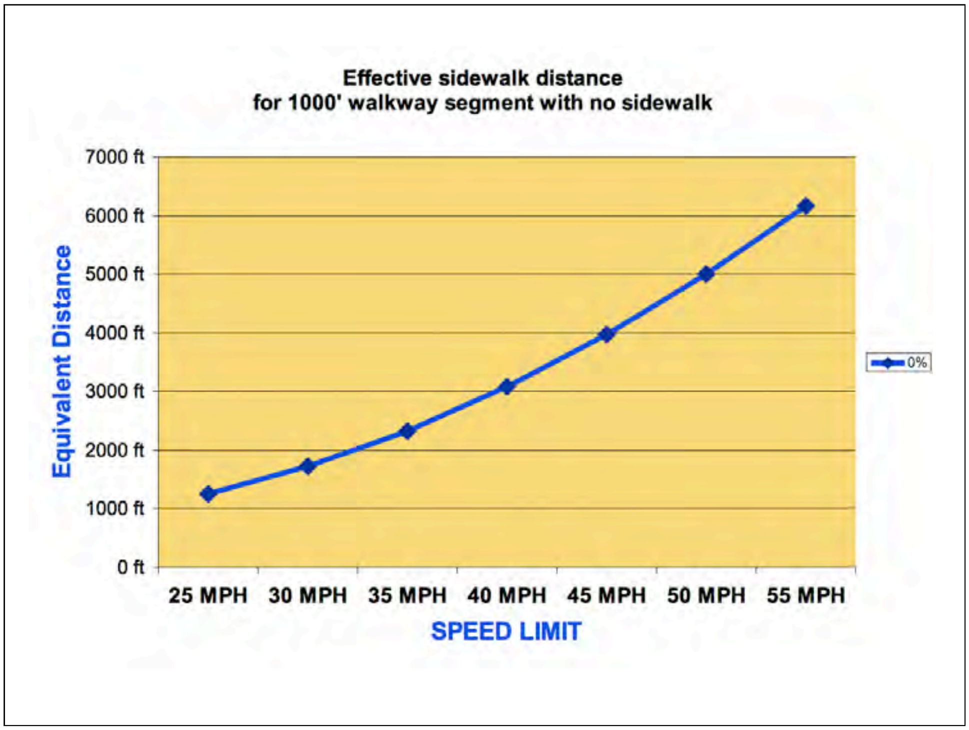
and where parameters d and e are curve fitting factors

The following parameter values are proposed:

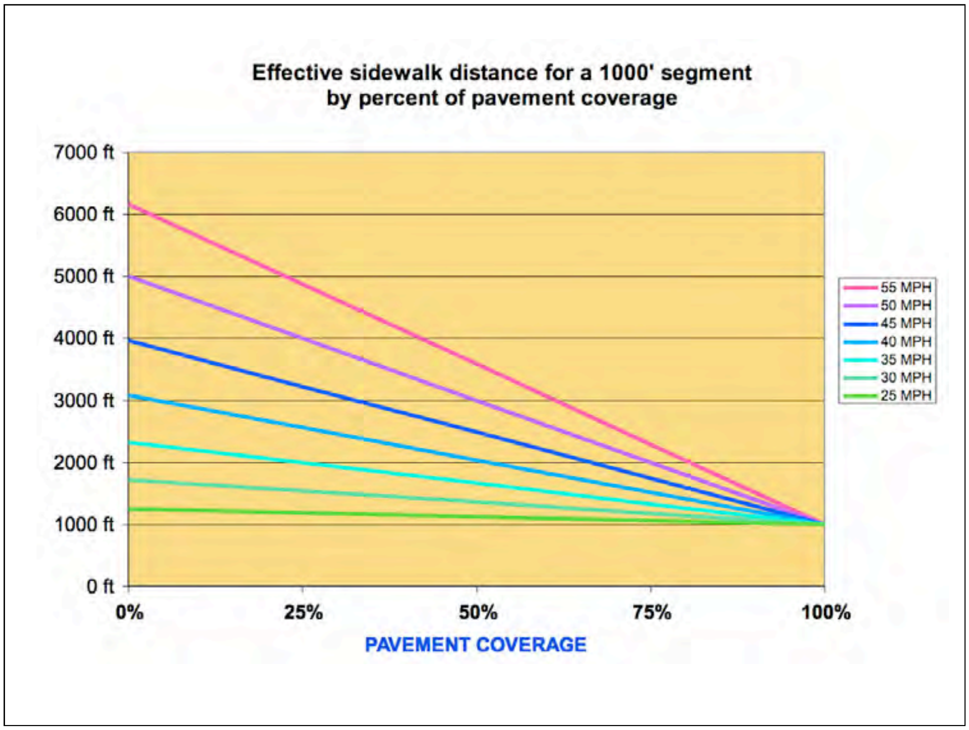
$d = 3.5/1250$ (in $mph^2$)
$e = -3/50$ (in mph)

The proposed values are chosen so that an unpaved walkway by a 25 mph street is weighted at 125% of length and an unpaved walkway by a 50 mph highway is weighted at 500% of length.

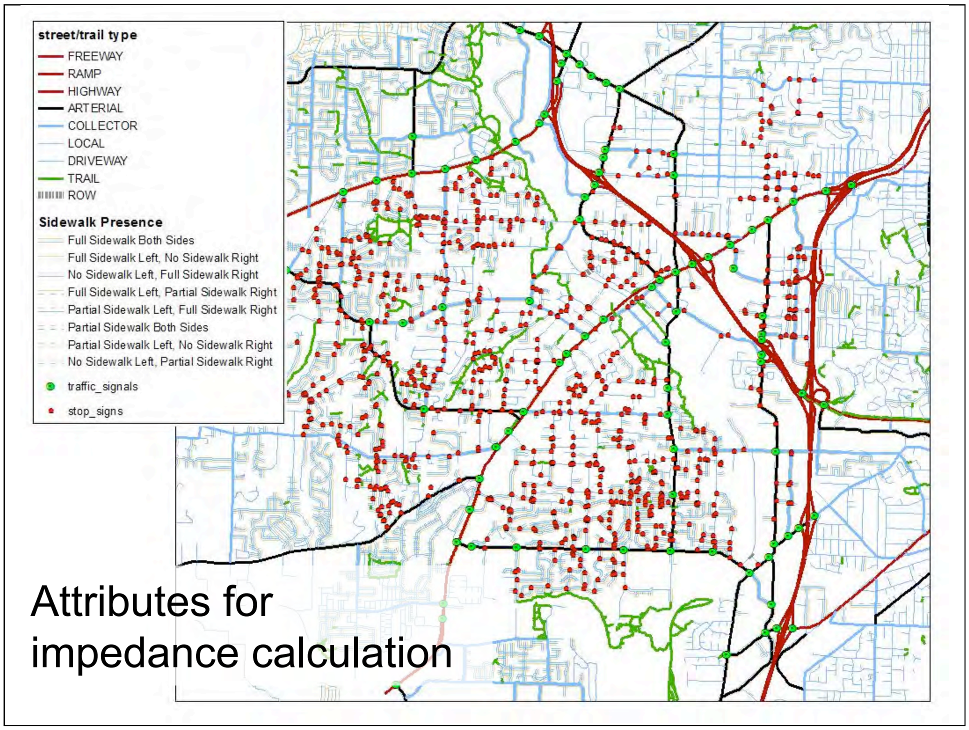
Suppose you have 100% complete sidewalk pavement in a segment. Then the effective distance is equal to the geographic distance.




In the case of sidewalk segments with incomplete sidewalk paving, we've proposed that effective length is related to the speed of traffic on the associated street segment, and…

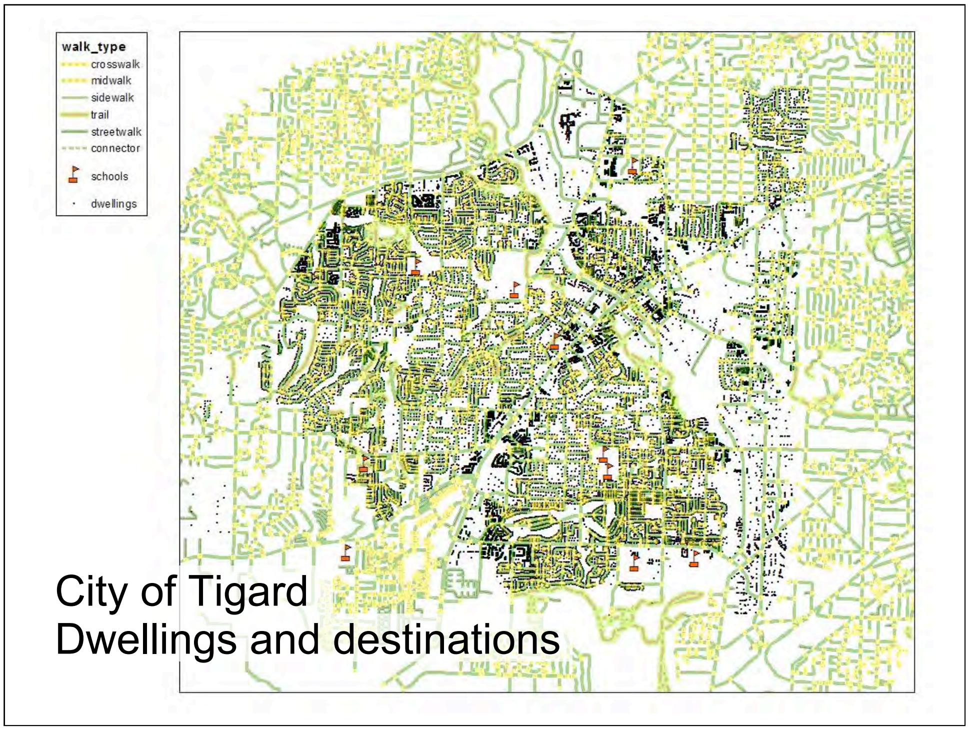



… also proportional to the percent of pavement coverage. Here the proposed curve fitting parameters are chosen so that an unpaved walkway segment on a 25 mph (40kmh) street has an effective length of one and a quarter times its geographic length, and an unpaved walkway segment on a 50 mph (80kmh) highway has an effective length five times its geographic length.




You may not have thought of traffic control like stop signs and traffic signals as attributes of the walkway network, and neither did the folks at the city of Tigard. To their GIS people, stop signs and traffic signals are assets to be maintained, and they're represented in a database that reflects that focus. So it took some work to assign them to the proper walkway segments.

Another attribute we use for impedance is sidewalk presence and absence, also shown on this map, and for Tigard we were able to get that data from Metro, the regional government.



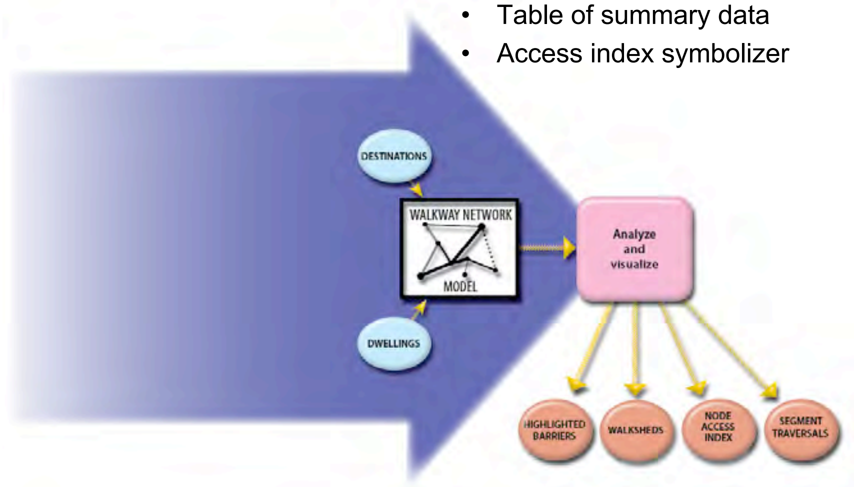

To analyze the network, trips must be routed from origins to destinations. In the walkway network model, dwellings are the origins and many different classes of destination can be loaded, such as schools, shown here, or grocery stores, or parks.

## Analysis Tool

- Traversal generator
- Access index generator

## Visualization Tools

- Walkshed calculator
- Slope-shading to highlight barriers
- Table of summary data
- Access index symbolizer




The core of the analysis is a routing engine that can calculate tens of thousands of lowest impedance paths in a minute. It calculates the lowest impedance path from each dwelling in the data set to its closest destination in a class of destinations.

And while it does this, it keeps track of two scores: **traversals** for each segment; that is, the count of effective shortest paths across that segment; and the **access index** for every node; that is, the total length of the effective shortest path to get from that node to the nearest destination in a given class of destinations.

When the minute of analysis is up, we’re ready to visualize results.


*Poster courtesy Metro*

One way to visualize results is to draw walksheds, and we'll show some example from another case study. Our regional government, Metro, used our tools to do walkshed analysis on every stop of a proposed new bus rapid transit route. The following slides are from a presentation planner Alan Gunn made to show that work to citizens.

## Half-mile walkshed

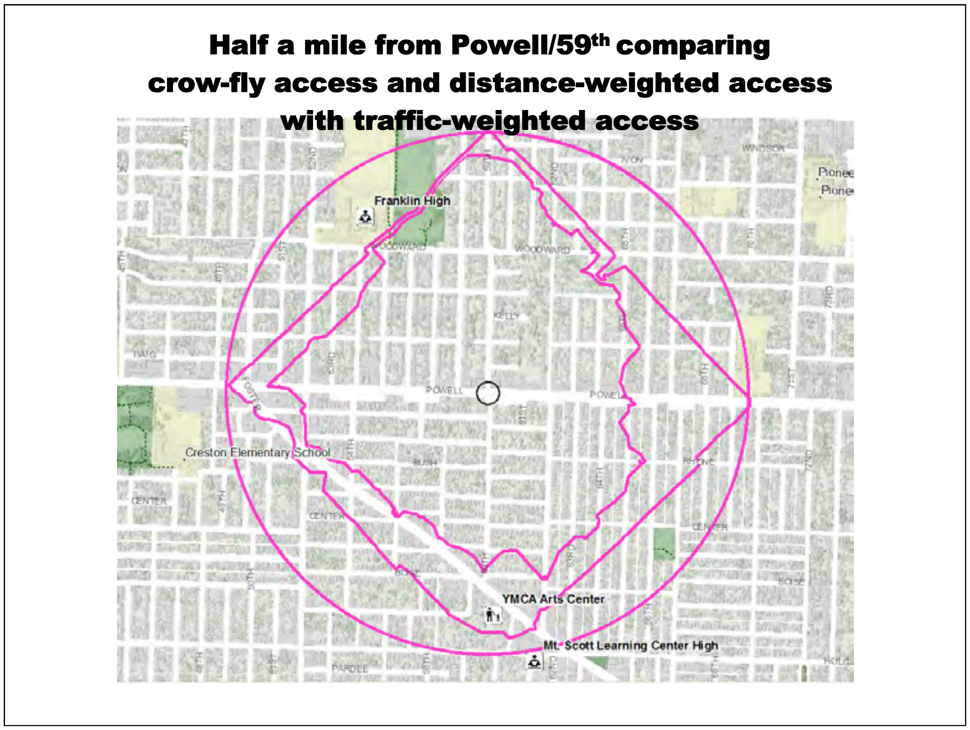

A walkshed is the area that can conveniently be reached on foot from a given point. Many people would consider it reasonable to walk a half mile or about ten minutes to reach a rapid transit station, so it makes sense to study the half-mile walkshed around each station area. To be useful for analysis, an effective walkshed must take into account both the constraints of the walkway network **and** the delays created by traffic.

**Half a mile from Powell/59th as the crow flies:**


If people could fly, or if they could walk in a straight line through buildings, bushes and backyards, a half-mile walkshed centered on a potential station would be a perfect circle a half-mile in radius.

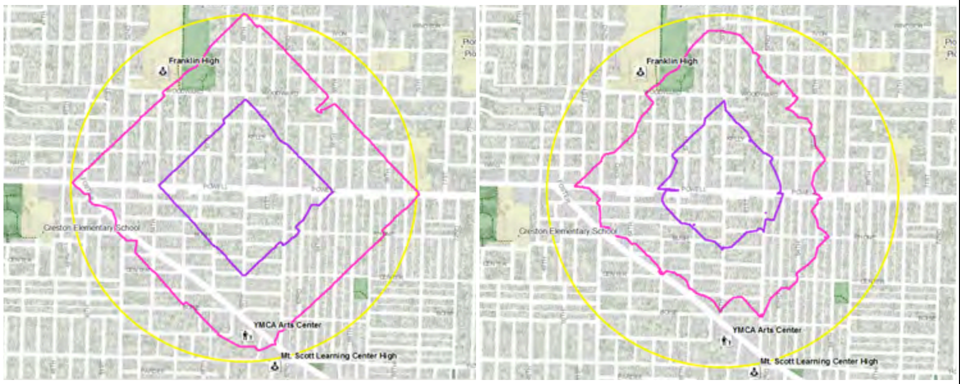
**Half a mile from Powell/59th comparing crow-fly access with distance-weighted access**


Since pedestrians don’t fly, the walkshed must be constrained to the network, as shown by the inner line here. For a perfect street grid, constraining trips to the network produces a diamond-shaped walkshed. Here you can see how slight anomalies in the grid affect the walkshed shape.



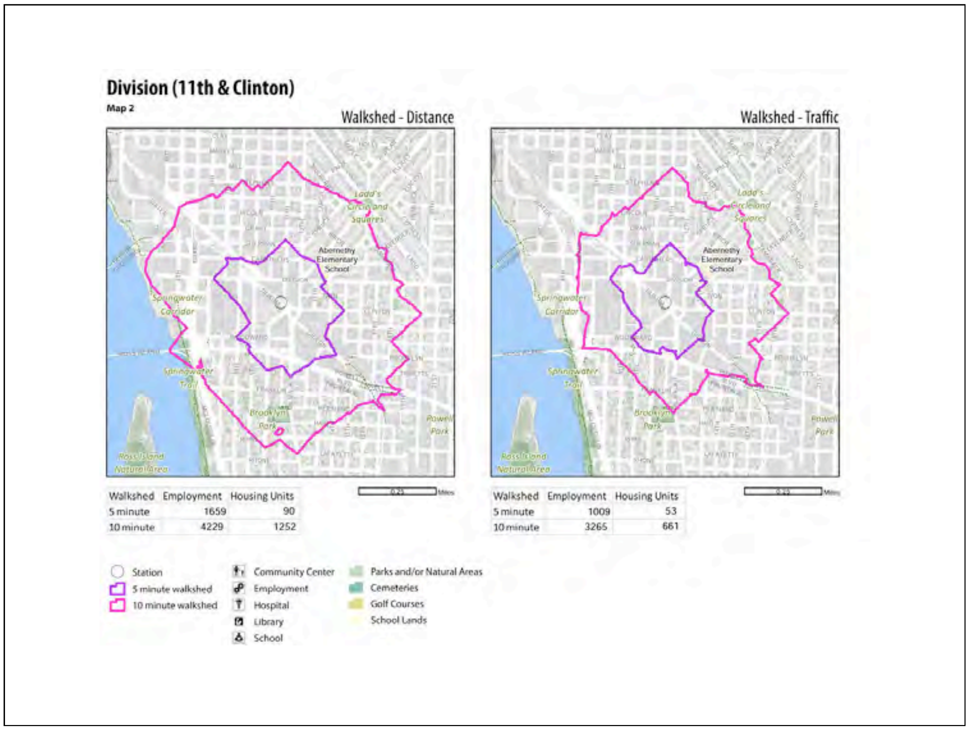

However, just as they can't walk through buildings or fly across private property, neither can people walk through speeding cars or fly across busy streets. The innermost line here shows the effective half-mile walkshed that takes into account both the constraints of the walkway network and the delays created by traffic.

**Distance-weighted vs. Traffic-weighted**



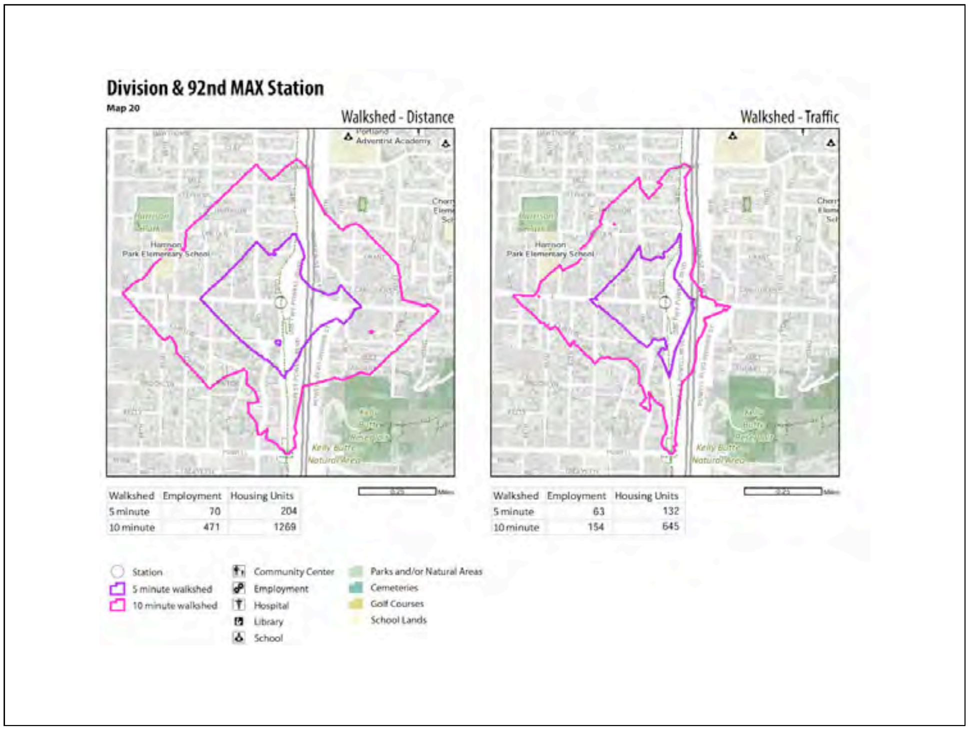

Here you see an example of the kind of side-by-side walkshed comparison that the walkway network model team created for each proposed transit station. On the left are the half-mile and quarter-mile walksheds with walking constrained to a network weighted only by distance. These distance-weighted walkshed diagrams can help illuminate where connectivity might be improved using cut-throughs.

On the right are the half-mile and quarter-mile walksheds with walking constrained to a network weighted by both distance and traffic. These traffic-weighted walkshed diagrams indicate where the walkway could be effectively expanded using tools such as crossing improvements, sidewalk construction, road diets, and traffic calming.

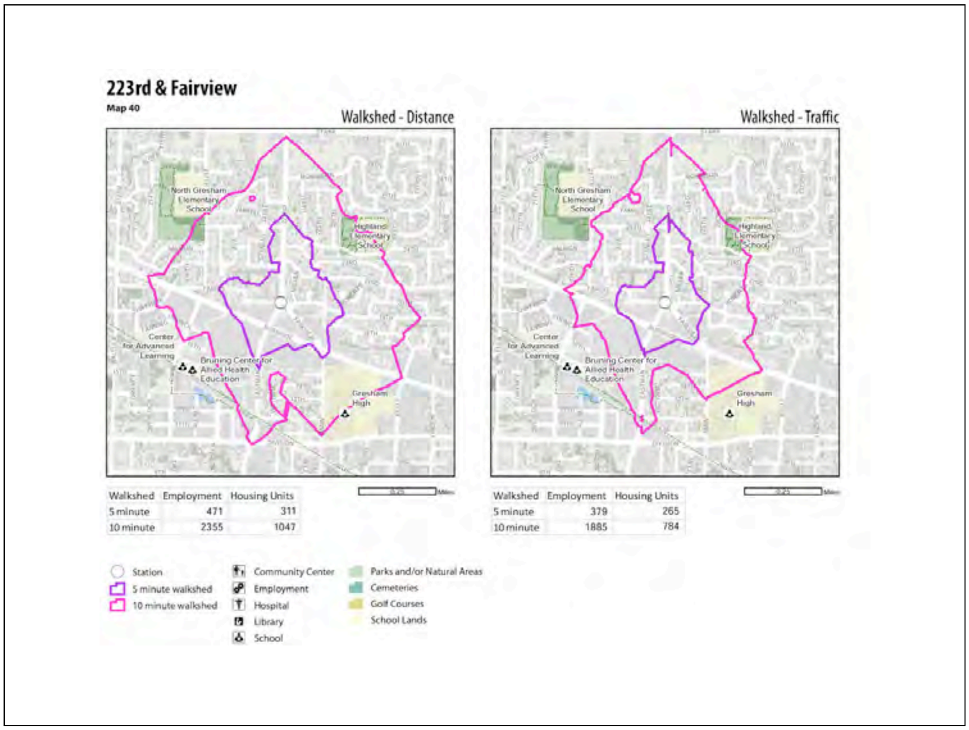



The walkway network team created a summary sheet like this for each of the 47 potential station areas. In addition to the walkshed diagrams, the summary sheets list the number of employment sites and dwelling units within each walkshed.

We'll show you just a few of these summary sheets to illustrate some of what can be learned from the diagrams. Here, for example, is a walkshed that's not diamond-shaped, due to the interesting mix of angled streets in the area.

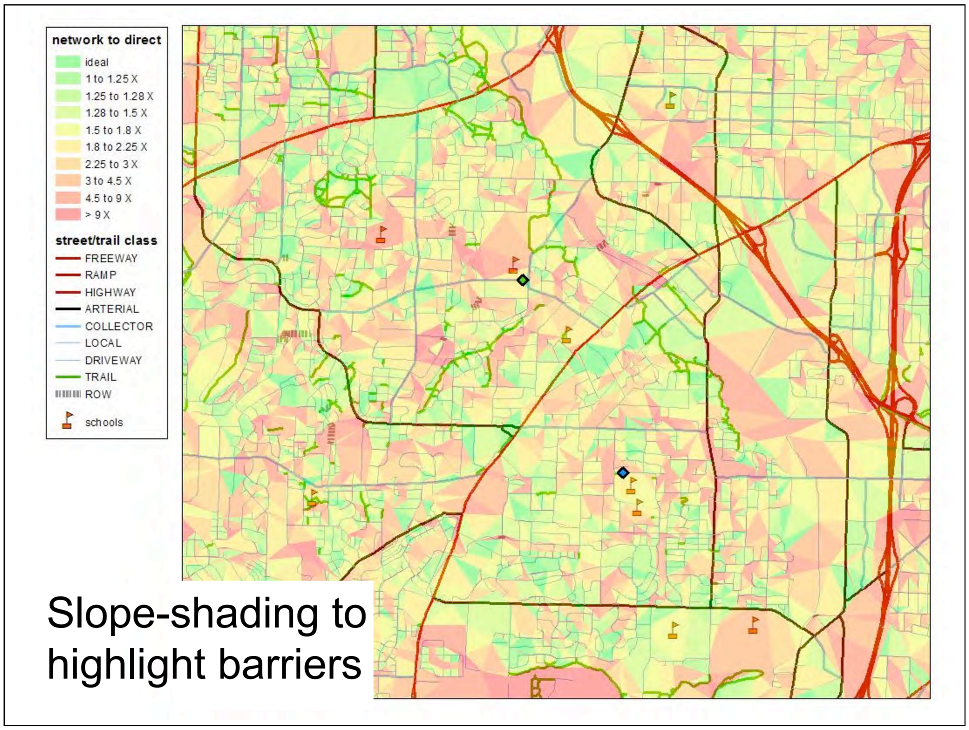



Here you can see how the walkshed is constrained by the I-205 freeway running north and south near the station stop.



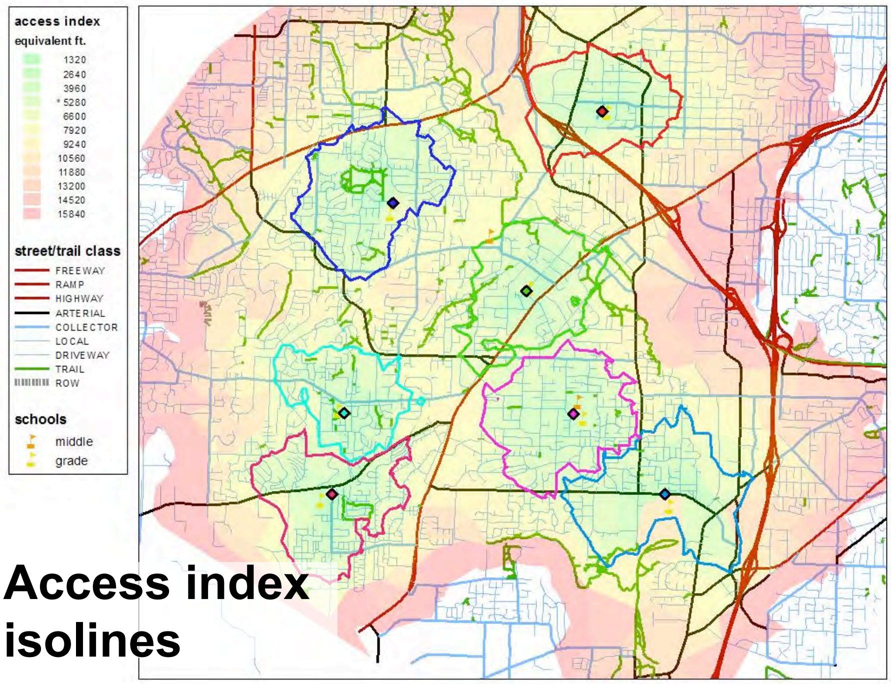

Here discontinuities in the grid create indentations and islands in the half-mile distance-weighted walkshed, and traffic shrinks the realistic walkshed even more.

The walkway network model tools make it easy to generate these walksheds, and the diagrams are helpful to illustrate barriers to transit access and opportunities for improvement to ridership.



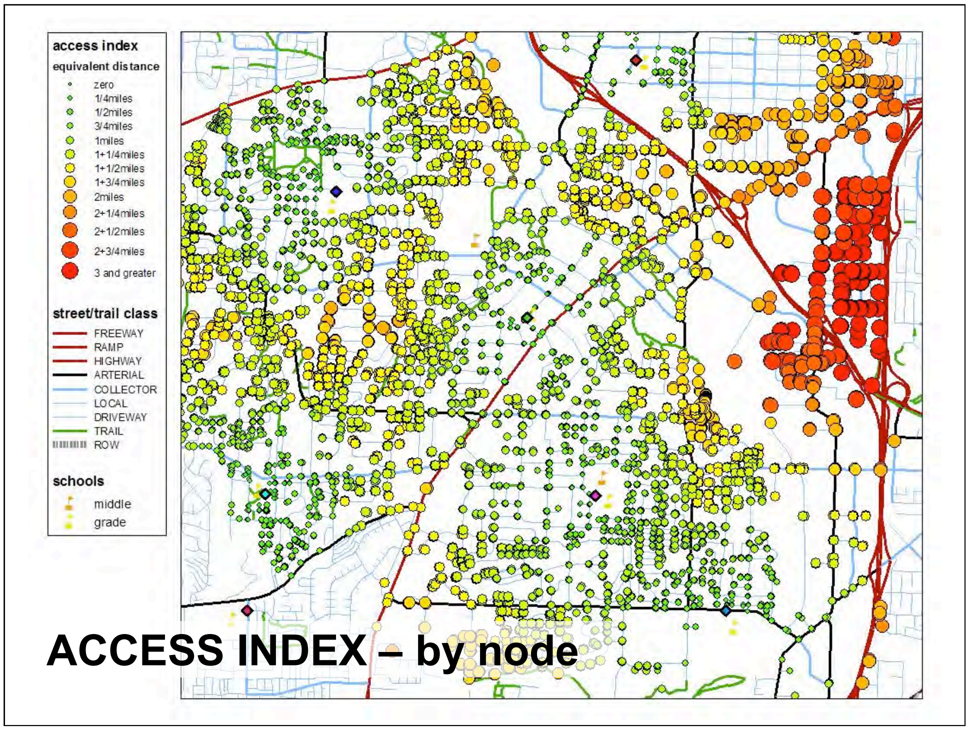

Another way to visualize analysis results is to use slope shading to highlight barriers. Here we're back to Tigard, looking at access to the two middle schools. Green areas represent places where the ratio of effective distance to crow fly distance is one, or close to one. In the red areas the effective distance is nine times the crow fly distance, or more.

Here’s an example of how we can use the barrier map. If we zoom in, we see a red area close to a school. Investigation reveals that the real life barrier is a creek, and that the City of Tigard has an unimproved right-of-way through the creek.

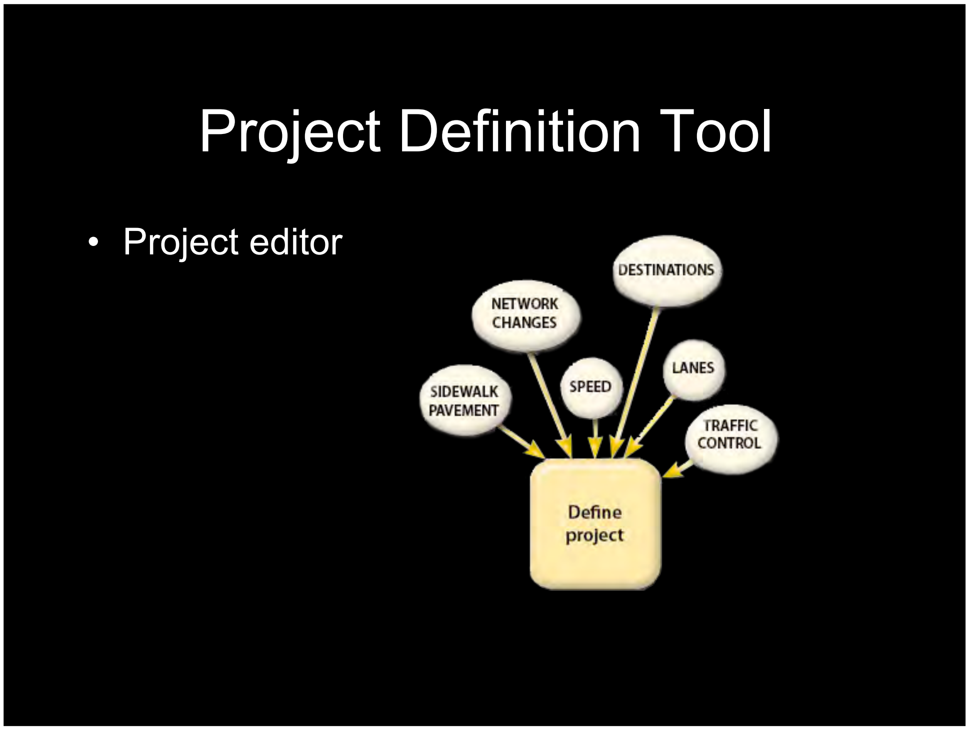



**Access index isolines**

The access index is a value for each node that represents the sum of the impedance values for all the segments on the lowest impedance path from that node to the nearest destination of a class -- in this case, the nearest school. This shaded map shows areas colored according to their access index values, with isolines representing the effective one-mile walksheds around each school.

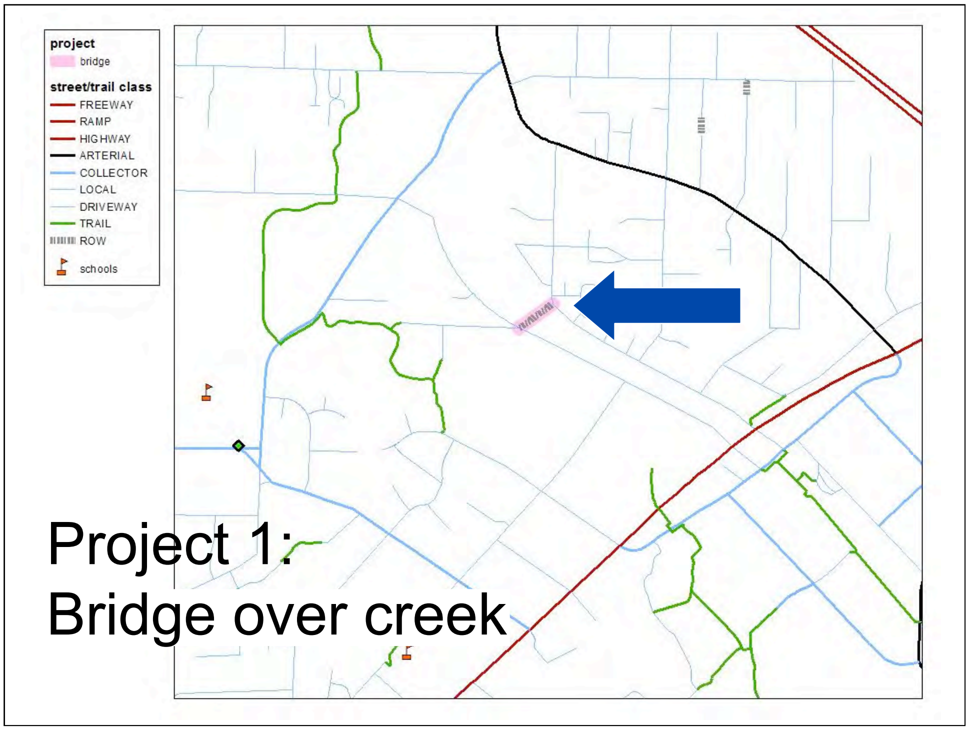



Here each dot represents the access index for one node - in this case, it’s the access index to the nearest middle school.

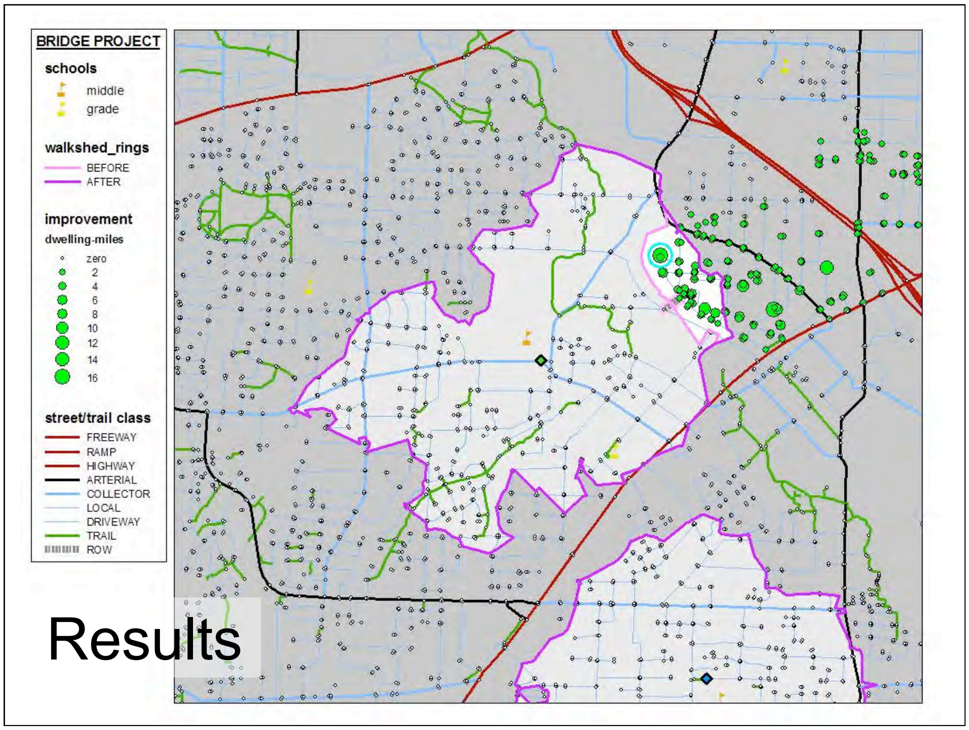



Once we’re able to run analysis, we’re ready to try out projects. A project in the model can be thought of simply as a new set of impedance values. These new impedance values reflect proposed changes to the environment such as lowering the speed limit, adding traffic control, paving sidewalks, or adding shortcuts.

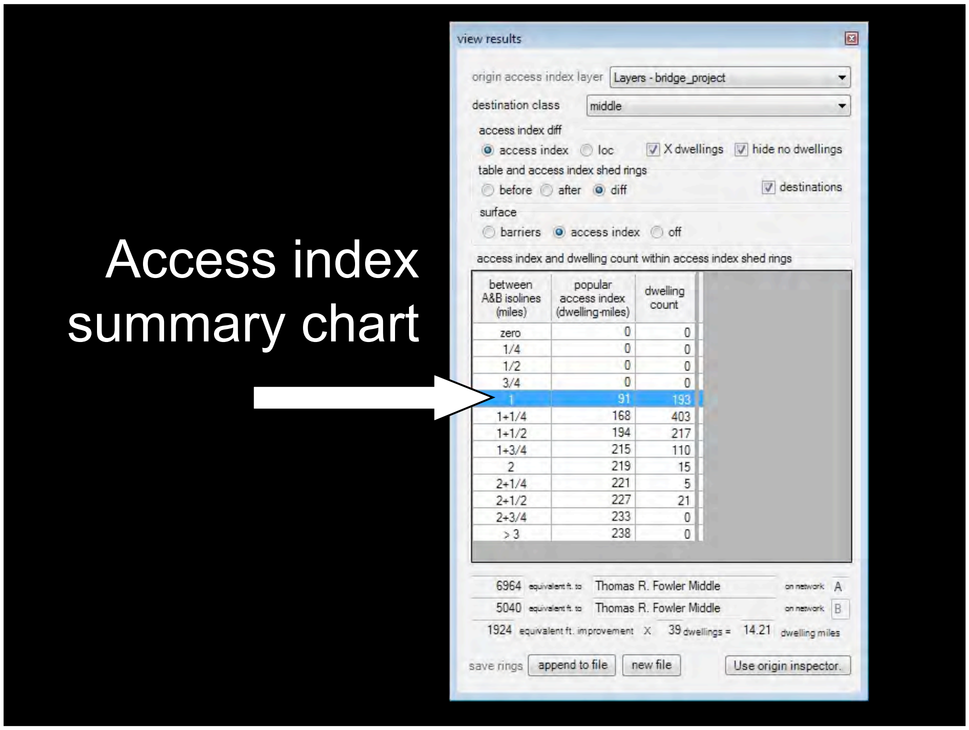
As an example project, let’s look at that barrier we investigated, and ask, “What if we built a bridge across the creek in the City’s right-of-way?”



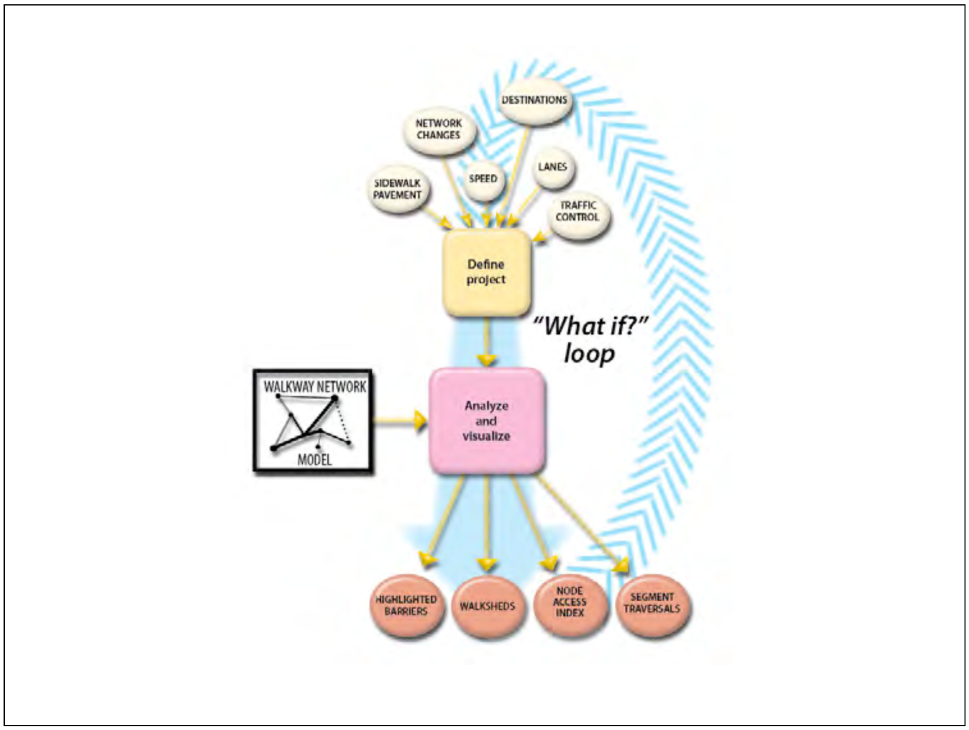

In the existing condition with no improvement that segment has an attribute of “impassible,” so its effective length is essentially infinite. Defining the project means creating a new set of effective lengths where this segment’s effective length is now equal to its geographic length.




Now we run the analysis, and a minute later we see that the project causes the walkshed boundary to expand - in the highlighted area -- and some households - the green dots - will benefit by now being effectively closer to the school.




By looking at the access index summary chart we can find out that 193 dwellings have been added within the one mile effective walkshed of the middle school. And we're not stuck with looking at one mile - we can choose from the menu of preset walkshed distances.




We can now try out and compare different improvements as many times as we want. Our long term vision is to have tools that anyone can easily use to generate instant results.