Comparing Transit-Oriented Development Sites by Walkability Indicators

Marc Schlossberg and Nathaniel Brown

Transit-oriented development (TOD) represents an integrated approach to transportation and land use planning. An often unspoken but key component to TOD theory is pedestrian access between the transit stop and the immediately surrounding area. Understanding the opportunities for pedestrian movement should be a key component in understanding and evaluating TOD projects. The TOD—pedestrian link is addressed by using 12 geographic information system (GIS) based walkability measures, within two geographic scales, and across 11 TOD sites in Portland, Oregon, to visualize and quantify the pedestrian environments at each site. The main addition to the larger research on TOD and pedestrian access is the classification of the street network into pedestrian-friendly and pedestrian-hostile categories. Subsequent analysis based on this refined street data is conducted to identify the quantity of different street types, densities of “good” intersections and dead ends, and the catchment areas pedestrians are likely able to reach. The presence and location of pedestrian-hostile streets have a significant, negative influence on the pedestrian environment surrounding transit stops, often cutting off more-pedestrian-friendly environments from the transit stops. The three primary sections include a comparative TOD ranking, a detailed explanation (visual, quantitative, and textual) of the relationships between individual walkability measures and overall TOD rankings, and a presentation of possible refinements for future GIS-based walkability analysis.

Transit-oriented development (TOD) represents an integrated approach to transportation and land use planning. An often unspoken but key component to TOD theory is pedestrian access between the transit stop and the immediately surrounding area. That is, the success of TOD significantly rests on the capacity of pedestrians to navigate and access the range of land uses in close proximity to transit stations. Thus, it seems that understanding the opportunities for pedestrian movement should be a key component in understanding and evaluating TOD. In fact, it has been these kinds of fine-grained, spatially explicit types of analyses that have been lacking in TOD and smart growth efforts (1).

In most locations, the capacity to walk is based on the same infrastructure as the ability to drive: the street network. Although not all streets include sidewalks and not all walking paths are adjacent to streets, the street network provides a reasonably comprehensive proxy for the capacity to walk within a neighborhood. For this reason, understanding the pattern and form of the street network can provide critical insight into how consistent TOD designs are with walkability. Of course, more subtle differences in sidewalk or street circumstance—such as the ease of crossing streets, the quality of the sidewalk, and whether the sidewalk is offset from the street—are important components to the overall walking environment. Nevertheless, although the street network has some limitations for modeling walkability, it remains the most accessible proxy data for walking to any jurisdiction in the United States and thus can provide a reasonable planning and evaluation foundation for walkability studies. That is, until local jurisdictions have more comprehensive base data on the various elements of walkability, the street network can serve as a useful indicator of local pedestrian appropriateness.

This paper addresses the TOD–pedestrian link by using 12 geographic information system (GIS)–based walkability measures, within two geographic scales, and across 11 TOD sites in Portland, Oregon, to visualize and quantify the pedestrian environments at each site. It presents both an intra-urban analysis of these 11 TOD sites and an extended analysis of two specific sites (one positive and one negative example of walkability) to demonstrate the usability of the analysis techniques. The paper concludes with some possible refinements for further analysis.

**BACKGROUND**

Effective TOD depends on various factors, including higher-than-average density, land use mix, roadway connectivity and design, and building design (2, pp. xii and 387; 3–6). A core component of TOD success also rests in the capacity of transit users to access the transit stop to begin with or to access key destinations after reaching their destinations. This access, within the theoretical conceptions of TOD, is often accomplished by foot or local transit connections. Clearly, those trips that are within the theoretical TOD zone of 0.25 or 0.5 mi are more oriented toward pedestrian travel. Thus, the pedestrian environment surrounding transit stops is a key element in understanding TOD because transit riders are pedestrians on at least one end of their transit trips (7). This paper focuses primarily on this one element: the connectivity of the walking environment. Although larger issues of the transportation–land use connection are important and relevant to the overall understanding of TOD (and of smart growth more generally), this particular paper does not focus on the dimensions of walkable environments related to density and land use mix.

In theory, TOD strives to create neighborhood-scale places where walking and transit become viable transportation options. Berman and Cervero (2, pp. xii and 387) report that people who live in pedestrian-oriented environments are more likely to go to the market on foot. Handy (8, pp. 253–267) reports that residents who live in traditional neighborhoods have also been found to make two to four more walk or bicycle trips per week to neighborhood stores than those living in

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DEVELOPMENT

METHODOLOGY FOR FAIR-TRADED ORGANIC COFFEE

The primary objectives were to develop and implement a framework for the development and certification of fair-trade organic coffee production, based on the principles of sustainable development. The framework is designed to ensure that coffee producers in developing countries receive fair prices for their coffee, which is produced in an environmentally sustainable and socially responsible manner.

The framework is based on a set of core principles, including:

1. **Sustainability**: The coffee production must be environmentally sustainable, with a focus on reducing the use of pesticides and chemical fertilizers, and promoting the use of organic and sustainable farming practices.
2. **Fairness**: Producers must receive fair prices for their coffee, which reflect the true value of their labor and the cost of production.
3. **Community Development**: The framework must support the development of local communities, including investment in education, health, and infrastructure.
4. **Transparency**: The framework must be transparent and accountable, with clear standards and monitoring mechanisms in place.

The framework is designed to be flexible and adaptable, allowing for local variations and cultural contexts. It is also designed to be scalable, with the potential to be applied to coffee production in other regions and countries.

The implementation of the framework will involve a multi-stakeholder approach, with involvement from coffee producers, buyers, governments, and civil society organizations. This will ensure that the framework is effective and sustainable over the long term.
oriented streets (impedance arcs) removed to visually show the pedestrian gap that emerges when automobile-dominant roads are removed from a pedestrian’s set of potential walking routes.

- Pedestrian catchment areas (PCAs; also known as Ped-Sheds). Theoretical walkable zones can be mapped to show the actual area and network within a 5-min (0.25-mi) or 10-min (0.5-mi) walk from a rail station. The data are presented as a ratio between the Euclidean distance and the network distance from a given point (e.g., transit station), illustrated in Figure 2. Impedance pedestrian catchment areas (IPCAs) also have been calculated. The IPCA represents a recalculated PCA, but with the high-speed, high-volume roads removed. The result is a ratio that measures an area that a pedestrian is likely to actually travel.

- Impedance-based intersection intensities. In general, the intersection intensity analysis examines the concentration of intersections indicative of pedestrian choice (three way and four way) as well as the concentration of dead ends, which limit pedestrian access. In the impedance-based intersection intensity analysis, freeways and major arterial roads have been excluded from the overall data set, resulting in intersections derived only by neighborhood streets crossing each other. Additionally, dead ends now exist when a neighborhood street reaches a major arterial; with the arterial removed from the data set, the neighborhood road dangles in space. Intersections are not recorded for neighborhood roads that cross through a major arterial. Thus, intersections and dead ends are more consistent with how a pedestrian might view the walking environment rather than how a motorist would navigate the road network. The box at the top of Figure 3a highlights fewer intersections (open circles) than in Figure 3b and some new intersections (open triangles).

These analysis techniques yield two geographic scales (0.25 mi and 0.5 mi) and 12 separate measures (6 positive and negative):

- Quantity of accessible paths (high/low),
- Quantity of impedance paths (high/low),
- PCA ranking (good/poor),
- IPCA ranking (good/poor),
- Intersection density (high/low), and
- Density of dead ends (high/low).

**COMPARING TRANSIT ENVIRONMENTS**

Calculations for each of the 11 TOD sites were conducted. To simplify and focus the output, the three TOD sites that scored best and the three TOD sites that scored worst on each measure were extracted and grouped by TOD, resulting in 72 separate data points. (A total of 75 data points is presented in this paper because some of the sites received similar quantitative scores on some of the measures.) Figure 4 illustrates the final ranking of the 11 TOD sites; each time a TOD was ranked in the top three or bottom three for a given analysis method, it received a square on the chart.

Figure 4 is organized parallel to the main transit line in Portland, ranging from the terminal stop in the west to the terminal stop in the east. Transit stops within downtown Portland were not included in this analysis; rather, the focus of the selected sites was on green-fill and suburban retrofitting TOD sites, because those areas traditionally lack adequate transportation choice. TOD sites that have many squares to the left reflect environments with poor walkability, and sites with many squares to the right have more walkable environments. Although these measures include two geographic scales...
(0.25 mi and 0.5 mi), it is not the case that a TOD that scores well at 0.25 mi automatically scores well at 0.5 mi. In fact, many sites change dramatically between the two distances. Two transit stops rank highly in terms of walkability (Tuality Hospital and Gresham Central Transit Center), and three transit stops rank poorly (Beaverton Civic, Beaverton Transit Center, and Cleveland Avenue). Orenco Station is mixed, with several variables ranking highly in terms of walkability and several variables ranking low.

With the chart presented in Figure 4, it becomes possible to conduct an intra-urban analysis on a series of TOD sites within one metropolitan region. Portland has a positive reputation for its TOD system, but even within Portland, there clearly is a range of good and bad TOD examples. Or perhaps more appropriately, several TOD sites are consistent with TOD theory, and some TOD sites are significantly disconnected from TOD theory.

To provide some further insight into these rankings, a visual spatial analysis and a breakdown of the quantitative results for Gresham Central Transit Center (positive example of a walkable TOD) and Beaverton Transit Center (a negative example of TOD walkability) are illustrated in Figure 5. GIS-derived maps provide a visual analysis of

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**Figure 5** Visual comparison of TOD walkability for Gresham Central Transit Station (left) and Beaverton Transit Center (right): (a) street network classification; (b) intersection visualization; (c) impedance-based intersection visualization.

(continued on next page)


In the vicinity of intersections, a lower pedestrian level of service is observed compared to the service level at the intersections

Difficult. To ensure safety, it is recommended to slow down and be aware of the presence of pedestrians. Keep a safe distance from vehicles and maintain a steady speed.

Street Network Classification

The classification of streets in the network is based on the following criteria:

- **Main Streets**: High-volume, major arterials
- **Secondary Streets**: Medium-volume, minor arterials
- **Local Streets**: Low-volume, dead-end streets
- **Pedestrian Walkways**: Wide sidewalks, pedestrian crossings

![Diagram of Street Network Classification](image)

*Figure 5 (continued)*

Traffic volume and congestion are important factors in determining the classification of streets. A high volume of vehicles indicates a need for higher priority and more frequent monitoring. Conversely, low traffic volumes may indicate a need for reduced maintenance efforts.

In conclusion, the classification of streets plays a crucial role in ensuring the safety and efficiency of the transportation system. It is essential to continuously review and update the classification based on changing traffic patterns and demographic shifts.
TABLE 1 Quantitative Comparison of TOD Walkability

<table>
<thead>
<tr>
<th></th>
<th>Distance from Transit Stop (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beaverton Transit Center</td>
</tr>
<tr>
<td></td>
<td>0.00 - 0.25</td>
</tr>
<tr>
<td>Minor Roads (miles)</td>
<td>2.2</td>
</tr>
<tr>
<td>Major Roads (miles)</td>
<td>2.5</td>
</tr>
<tr>
<td>Intersection Density (per square mile)</td>
<td>147.6</td>
</tr>
<tr>
<td>Dead-End Density (per square mile)</td>
<td>20.4</td>
</tr>
<tr>
<td>Impedance-Based Intersection Density</td>
<td>20.4</td>
</tr>
<tr>
<td>Impedance-Based Dead-End Density</td>
<td>91.6</td>
</tr>
<tr>
<td>Pedestrian Catchment Area</td>
<td>0.2</td>
</tr>
<tr>
<td>Impeded Pedestrian Catchment Area</td>
<td>0.0</td>
</tr>
</tbody>
</table>

In terms of dead ends, neither location suffers from an abundance of them.

Impedance-Based Intersection Analysis

Looking at the impedance-based intersection intensity analysis in Figure 5c, big differences are apparent between the two sites. Again, the impedance-based analysis removes arterials from the identification of intersections and dead ends and results in a decrease in pedestrian intersections (where minor roads cross arterials) and an increase in pedestrian dead ends (where minor roads terminate at an arterial).

The change in environment is striking, as represented by the spatial images. In this analysis, Beaverton "loses" many of its intersections due to the presence of multiple arterial roads, leaving a void of intersections—and thus pedestrian choice—within close proximity of the transit stop. In fact, within the 0.25-mi area, Beaverton’s dead-end density exceeds its intersection density by more than four to one (91.6 vs. 20.4) and Beaverton’s intersection density decreases by 86% within the quarter-mile distance. In contrast, the presence of arterials only reduces Gresham’s intersection density by 27%—a significant amount, but not nearly as dramatic as in Beaverton. At the 0.5-mi aggregated zone, Beaverton and Gresham have similar intersection densities (78.9, 82.7), reflecting an increase in connectivity in Beaverton and a decrease in connectivity (due to the presence of arterials) in Gresham.

PCA Analysis

PCAs reflect the connectivity and grain of the network by comparing a theoretical, Euclidean distance to an actual, path-based walking distance in Figure 5d. Visually, the larger the walking zone (shaded areas within the large circle), then the better the coverage of the walkability network to the full theoretical 0.25- or 0.5-mi area of the TOD. In these two sites, the sizes of the PCAs are quite different, reflecting the different patterns of street networks between the sites. In Gresham, the PCA for both radii demonstrate relatively good coverage; in fact, both zones have a PCA score of 0.6, which is considered to reflect a walkable network (25, p. 2). However, Beaverton has a limited visual coverage, which is reflected in its lower PCA scores for the 0.25-mi (0.2) and 0.5-mi (0.4) zones.

IPCA Analysis

Similar to the impedance-based intersection analysis, the IPCA in Figure 5e is a refined measure of the zone of walkability by including the presence of automobile-centric roads into the visualization and calculation. Automobile-centric roads create barriers for pedestrians, reducing or eliminating a travel choice because automobile-oriented roads often create hostile and uncomfortably scaled environments from a pedestrian point of view.

The presence and location of impedance roads radically affect the two sites. In Gresham, where the arterials are located primarily west and north of the transit stop, the IPCA maintains relatively good coverage (0.5 at both distances). In severe contrast, the area surrounding the Beaverton stop becomes completely unreachable, with the IPCA at both distances scoring 0.0. At the Beaverton stop, there is no way to leave or access the transit stop without crossing and traveling along a major, automobile-oriented arterial. To the south and southeast of the stop, multiple barriers exist, severely separating the location of the transit stop and an area of high intersection density and a tight street grid (the old downtown).

The IPCA (or lack thereof) for Beaverton reflects the feeling that one has when accessing that transit stop. Although there is an intense development being built within feet of the stop (called the Round), access to any of the surrounding 0.25- or 0.5-mi area is nearly impossible by foot without traversing a series of large, high-volume, high-speed automobile-oriented roads.

REFLECTIONS

Access, connectivity, and choice are key elements in understanding the pedestrian environment, and all can be derived using various elements of the street network. Intersections, paths, and walkable zones (known in GISs as points, lines, and polygons) can all be derived from the basic urban skeleton of the street network to ascertain and evaluate the pedestrian compatibility of certain environments. In terms of TOD, the various methods described in this paper can be particularly useful for understanding the key link in the transit–land
The work presented in this paper...

ACKNOWLEDGMENT

...describes the potential benefits of using the American Cancer Association's "Get Up and Move" program to encourage physical activity among cancer survivors. The program has been shown to increase physical activity levels and improve overall health outcomes. Further research is needed to evaluate the long-term effects of the program and to identify potential barriers to its implementation.

REFERENCES

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FUTURE RESEARCH

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Publication of this paper sponsored by Public Transportation Planning and Development Committee.