RATING THE PERFORMANCE OF STATION AREAS FOR EFFECTIVE AND EQUITABLE TRANSIT ORIENTED DEVELOPMENT

Stephanie Pollack
Northeastern University
310 Renaissance Park
360 Huntington Avenue
Boston, MA 02115
t: 617-373-8341
f: 617-373-7905
e: s.pollack@neu.edu

Anna Gartsman*
Northeastern University
310 Renaissance Park
360 Huntington Avenue
Boston, MA02115
t: 617-373-3110
f: 617-373-7905
e: a.gartsman@neu.edu

Albert Benedict
Center for Neighborhood Technology
2125 W. North Avenue
Chicago, IL60647
t: 773-269-4026
f: 773-278-3840
e: albert@cnt.org

Jeff Wood
436 14th Street Ste 1005
Oakland, CA 94612
t: 510-268-8602 x201
e: jwood@reconnectingamerica.org

* Corresponding Author

Submission Date: August 1, 2013
Word Count: 7,217 = Text (5,717 Words) + Figures (6 × 250 = 1500 Words) + references
ABSTRACT:

Planners and policymakers working to encourage high performing transit-oriented development (TOD) that can effectively reduce driving and increase transit ridership often struggle due to lack of consensus on what factors best predict the performance of TOD. The task is even more difficult for those who want to ensure that TOD improves social equity. This research creates a “rating system” that measures the capacity for equitable TOD within a station area by identifying easily quantifiable and comparable built, social and transit attributes that reduce driving, increase transit ridership, and promote equity.

*eTOD Score* was piloted in Massachusetts due to the availability of vehicle-miles traveled (VMT) data for validation. The rating system ranks station areas – half-mile buffers around rail stations and certain bus stops – on three scales encompassing ten nationally-available indicators chosen based on their correlation with VMT. The sub-scales for transit, orientation and development indicate the relative transit orientation of a station area and which attributes most need improvement. The composite score ($R^2=.82$) and each of the sub-scales (transit subscale $R^2=.73$, orientation subscale $R^2=.75$ and development subscale $R^2=.74$) are very strongly inversely correlated with VMT.

By providing a specific definition of equitable TOD station areas, this rating system can be used to direct TOD and TOD funding toward high performing station areas. The sub-scores can be used by developers, planners, and community stakeholders to understand which station area attributes to focus on in order to improve the *eTOD Score* and thereby the performance and equity of TOD in a given station area.
INTRODUCTION: PURPOSE & NEED FOR A TOD RATING SYSTEM

Planners and policymakers working to encourage high performing transit-oriented development (TOD) that can effectively reduce driving and increase transit ridership often struggle due to lack of consensus on what factors best predict the performance of TOD. The task is even more difficult for those who want to ensure that TOD improves social equity. The Dukakis Center for Urban & Regional Policy at Northeastern University, Reconnecting America, and the Center for Neighborhood Technology worked in collaboration to create a “rating system” that measures the capacity for equitable TOD within a transit station area.

This rating system, which we call eTOD Score, does not measure the quality of specific TOD projects, but instead seeks to measure the capacity for equitable TOD within a given public transit station area by identifying easily quantifiable and comparable built, social, and transit attributes that reduce driving, encourage higher transit ridership, and promote transit equity and accessibility.

Several systems have been proposed to assess the quality of TOD projects, station areas or neighborhoods including GreenTRIP(1), LEED for Neighborhood Development(2), and CTOD’s Performance-Based Transit-Oriented Development Typology(3). Each such system considers elements of the development’s location in a general way, focusing on a limited number of attributes of the “as built” project and its site. For instance, LEED for Neighborhood Development includes “smart location” and neighborhood patterns in its rating system, combining both area characteristics and project characteristics in the same rating system. In contrast, this proposed rating system rates only the suitability of transit station areas for equitable TOD – not individual TOD projects.

Existing rating systems and TOD typologies also consider the travel behavior of the residents and users of the TOD projects with the explicit or implicit aim of decreasing vehicle-miles traveled (VMT). GreenTRIP, for instance, projects the expected household VMT of the residents of the new TOD in its rating system (4). Our research concurs that VMT is the key performance metric for transit-oriented development and sees areas with already low VMT as optimal locations for TOD. In order to validate the rating system, eTOD Score was piloted in Massachusetts where household VMT data was available for use in analyzing which attributes to include in the rating system and validate the resulting scoring system. Because the resulting rating system – as well as each of its three sub-scores – is shown to have a very strong and inverse relationship with VMT, regions without available VMT data can adopt this rating system with confidence that it accurately predicts which station areas are likely to demonstrate the best TOD performance as measured by reduced VMT.

STATION AREAS DATASET

The Boston area is home to the oldest subway system in the nation; as a mature system, its station areas are well-established neighborhoods that have been influenced by transit for many decades. At the same time, the station areas are ripe for TOD opportunities: while transit-rich neighborhoods (the area within one-half mile of a transit station) cover only 3.5% of the metropolitan area’s land, they are home to 22% of all residents and 30% of all households. According to the Metropolitan Area Planning Council, since 2000, nearly 15,000 housing units located near transit hubs have either been completed or are under construction(5).

The Massachusetts Bay Transportation Authority (MBTA) service district covers 175 municipalities, equal to 3,244 square miles and a population of over 4.6 million residents. The transit system mainly consists of three different modes: commuter rail, rapid transit, and bus routes, which allow for the development of a rating system that applies to different types of transit. The MBTA system includes more than 250 rapid transit and commuter rail station areas and over 1,000 additional bus stops, although the dataset compiled for this research focused only on the system’s high frequency “Key Bus Routes”(15 of its busiest bus routes designated by the MBTA, each of which operates at a high frequency - 7 days a week - to meet passenger demand in high-density corridors).

TOD needs to be located near a transit station. This research defines a transit station area as the half-mile buffer around a subway or commuter rail station, a measure generally consistent with other research(6). Since high-frequency bus routes can also support TOD(7), the system is also designed to evaluate TOD...
suitability along high frequency bus routes using a similar half-mile buffer around selected bus stops along segments of the MBTA’s “key bus routes”.

There are 345 station areas in the data set, including 276 rapid transit station areas and 69 bus stop areas. Neighborhoods outside of the station areas are not eligible for rating under this system.

FRAMEWORK FOR DEVELOPING AN EQUITABLE TOD RATING SYSTEM

One promising strategy for reducing VMT is to champion a common understanding of what constitutes “exemplary” TOD. Quantifying and disseminating this definition throughout transportation policy circles establishes a common baseline and replicable understanding of what constitutes a high-quality TOD project. For purposes of this research, high-performing TOD is comprised of three elements:

1) It is locally and regionally equitable;
2) It is oriented toward people who use transit; and
3) It changes travel behavior in the station area.

Reduction in Vehicle Miles Traveled (VMT) is frequently used as a measure of changes in travel behavior. While not a comprehensive measure, per capita or household VMT is an important proxy for measuring which neighborhoods are likely to generate the most transit riders, promote walking and biking, lower household transportation costs, and reduce greenhouse gases. From the perspective of travel behavior, the “performance” of TOD can be measured in a relatively straightforward matter – by assessing whether it helps reduce driving and increase transit use.

More difficult, however, is measuring the performance of equitable TOD. In this project we set out to analyze whether we could identify a set of measurable station area characteristics that could be shown to contribute both to TOD performance in the traditional sense and also to improved social equity. They key to this process was focusing on the middle and least-understood word in the phrase TOD: orientation. What or who is TOD oriented toward? In our equitable TOD framework, the answer is that TOD should be oriented toward those most likely to use transit, who we refer to as “core riders.” If both Transit and Development are oriented toward core riders, we theorized, the resulting TOD would be both high performing and equitable.

This equitable TOD framework builds on prior research identifying a set of “core riders”, i.e., demographic and socioeconomic groups who are over-represented among transit riders compared to their proportion of the population. Core transit riders, even when not referred to as such, have been identified by analyzing travel survey data, public transit on-board surveys, as well as Census and American Community Survey (ACS) data on public transportation commuters.

Core riders are important to TOD performance because they have been demonstrated both to drive less and use transit more. Station areas with more of these “transit oriented neighbors” are more likely to produce the travel characteristics associated with successful TOD. At the same time, a number of the socioeconomic and demographic groups who constitute a disproportionate share of transit users are also important from an equity perspective and so ensuring that TOD is “oriented” toward these groups also ensures that the TOD will further the objectives of equitable regional development.

A variety of demographic groups have been shown to be overrepresented among transit riders, including the working-age population (25-54 year olds), people of color, low-income people, people in zero-vehicle households, immigrants, and renters. Figure 1 uses data from the American Community Survey to demonstrate some of these core ridership groups in metropolitan Boston who are disproportionately represented among those who report using transit for their work commutes. These groups include renters, members of zero-vehicle households, immigrants, people of color and lower income households. TODs and their station areas need to effectively target the socioeconomic makeup of their neighborhoods while striving to keep housing affordable, in order to retain the populations oriented toward transit in the station areas.
In order to construct an equitable TOD rating system, we focused on those core rider groups associated with attributes that could be affected by public policy in general and development choices in particular, such as vehicle ownership (which is affected by parking management strategies), housing tenure (rental vs. ownership), and income (which can be influenced through the inclusion of affordable housing). We did not incorporate other “core ridership” demographics—such as race, ethnicity and immigration status—into the rating system because they are not easily influenced by such policy and development choices.

Perhaps the most difficult choice made in constructing the “orientation” sub-scale of the rating system was whether or not to include racial groups. Racial diversity measures (including percent Black, percent Hispanic, and dissimilarity measures) were analyzed and found to be related to VMT (areas with more racial and ethnic minorities had lower household VMT). However, both because this relationship was not as strong as the other relationships in the orientation subscale and because the racial composition of a station area is difficult to influence through policy, planning, and development tools, attributes designed to measure racial diversity were not included in the rating system.

In constructing the rating system, we also wanted to incorporate the quality of the “transit” that the TOD was “oriented” toward, as well as the type of development or built environment in the station area. Both of these factors have been shown to influence the success of TOD. Transit service, for example, needs to be sufficiently frequent, fast, and connected to useful destinations. The better the quality of transit, the more interested residents are in making use of the service (16).

As for development and the built environment, proximity to a station in and of itself does not necessarily encourage less driving or more transit use; the environment in the station area can transform the area from transit-adjacent to transit-oriented (17, 18). Elements of the built environment, such as ready availability of parking, high-density, pedestrian and cycling infrastructure, and mixed land uses can influence the travel choices of both residents and visitors of the station area (16, 19, 20).

CONSTRUCTING THE TOD RATING SYSTEM

The extent to which both the transit and development in TOD are “oriented” to both transportation and equity outcomes cannot be distilled to a single factor. Instead, it is a function of activity-based, demographic, and accessibility-related characteristics in a given neighborhood. A station area rating system therefore needs to include a blend of metrics linked to desired public outcomes (e.g. lower VMT, equitable access to transit). These measures of the built and social environments are then combined into a composite transit orientation...
index for each station area that can be readily compared to others in the region. For purposes of transparency
and consistency, the chosen elements should be readily understood and available for ongoing analysis into
the future, even as conditions are expected to change.

The \textit{eTOD Score} TOD rating system proposed here is based on the concept that successful and
equitable transit-oriented development should focus on all three of the words in the acronym TOD:

- The availability, quality and use of public \textit{transit} (as well as other non-automobile means of
  transportation)
- \textbf{Orientation} toward “transit oriented neighbors” who make up the core of transit ridership
- The characteristics of \textit{development} in the neighborhoods surrounding the transit station

The rating system considers measures to capture each of these areas (\textit{Transit}, \textit{Orientation},
\textit{Development}). The purpose is to generate a rating system that will allow for comparisons of station areas
across the region, while also identifying the strengths and opportunities presented within individual station
areas.

For each of the three rating system sub-scales, we needed to determine those station area
characteristics most important in determining successful and equitable TOD. We focused on measurable
attributes statistically associated with less driving, measured as VMT per household in each station area as
available from the Massachusetts Registry of Motor Vehicles from annual odometer readings taken during
safety inspections. Data from 2008-2010 is used in this analysis. VMT per household varies from a low of
15.6 daily miles in the downtown core station areas to a high of 91 daily miles per household in some of the
suburban commuter rail station areas. The mean daily household VMT is 37 miles.

Since VMT data are not available nationally, the system does not directly rely on the availability of
such data. Instead, the rating system is comprised of attributes that we found to be strongly correlated with
stations areas in which residents drive less.

Following extensive analysis of a variety of potential scoring attributes, ten station area attributes
were selected for inclusion in the rating system, divided among three different sub-scales. In order to create
an easily understandable rating system, each attribute received a score of up to 5 points (for a total possible
“rating” of 50 points across the ten measures. Points are assigned based on the quintile distribution of that
attribute, with the lowest quintile scored as “1” and the highest quintile as “5”.

\textbf{Transit Sub-Scale}

Transit access is measured through General Transit Feed Specification (GTFS) data collected from all of the
transit agencies that serve the Boston area. The GTFS data includes the location of every bus stop and rail
station, how each is connected by what service including the travel time for adjacent stations/stops, and the
frequency of service. For purposes of constructing the transit sub-scale we relied on three measures of the
quality and utility of transit service (see Table 1 for descriptive statistics).

\textit{Transit Access Shed}

The Transit Access Shed (TAS) index, developed by the Center for Neighborhood Technology (CNT), is a
100 point scale derived from GTFS schedules. The TAS is defined as the optimal accessible area from any
block group within 30 minutes by public transportation, scaled by the frequency of service. For each transit
stop, all stops that can be reached within 30 minutes were identified. One transfer within 600 meters of a stop
was allowed, and all transfers were padded with 10 minutes of walking and/or waiting. The stops reachable
within 30 minutes were all based on the minimum travel time between the two stops, allowing the inclusion
of more distant stops that are reachable within 30 minutes via express service. For each origination stop, a
quarter mile buffer was created around the destination stops. Based on the location of the originating stop,
the access shed was then aggregated for each stop to the block group and multiplied by the frequency of
service (trips per week). Finally, the frequency of service scaled accessible area was then renormalized such
that the minimum value is 0 and that maximum value is 100, in order to create the TAS index. The TAS
index and VMT have a negative linear relationship; as TAS increases, VMT decreases ($r = .851$).
Transit Connectivity

The Transit Connectivity Index (TCI), developed by CNT, is also a 100 point scale. To calculate this measure, a buffer was constructed around each transit access point (¼ mile radius for bus stops and ½ mile radius for rail stations and all other access points). Next, five concentric annuluses were constructed, each with the width of the initial buffer. These six access areas were then assigned a service frequency value (total trips per week) for the transit access point they surround. Next, at the block group level, six access values were calculated. These were calculated as:

\[
\text{Area}_{\text{intersection}} \cdot \text{Service frequency} \cdot \text{Weight}_{\text{annuluses}}
\]

\[
\text{Area}_{\text{blockgroup}}
\]

The weighting multiplier identified in the above equation is calculated using regression analysis. The value of all of the annuluses access values are then summed to form the raw TCI. This raw TCI is renormalized such that the minimum value is 0 and that maximum value is 100, in order to create the TCI. The TCI index and VMT also have a negative linear relationship (r=.899).

Non-Automobile Commuting

In addition to the previous measures of transit access and service frequency, we wanted a measure that accounted for actual travel behavior within the station area. The best available proxy for this is measured as the percentage of workers who use transit, bike, or walk to work in the station area, as reported by the American Community Survey (ACS) for years 2005-2009. This measure of non-automobile commuting has a negative relationship with VMT (r=.859).

Transit Sub-Scale Results

The transit sub-scale was calculated using these three measures. All three transit measures are correlated with each other, but they are not identical; together, they explain 85.1% (F=649.4, p<.001) of the variance in station area VMT.

Transit ratings for MBTA station areas vary from a low score of 3 (in the bottom quintile of station areas for all three measures) to a high score of 15 (top quintile for all three measures). 36 stations score the maximum possible transit score; unsurprisingly, most of them are rail and bus stations located in the downtown core. 48 stations score the minimum possible transit score; all of them are commuter rail stations.

The differences between bus and rapid transit are all significant; the selected bus areas perform better than the rail areas (TAS: t=9.943, p<.001; TCI: t=9.740, p<.001; Transit Use: t=3.054, p=.003). By selecting only the key bus routes but all rail station areas, our methodology overemphasizes the “well-performing” bus areas. Nonetheless, the best-performing bus station areas are indistinguishable from the best-performing rail station areas on these three measures.

Orientation Sub-Scale

The “orientation” aspect of TOD refers to a project’s ability to orient travel behavior towards public transportation. When analyzing a specific TOD project, for example, planners may point to a reduced number of parking spaces in successful TOD projects that discourage automobile travel to these destinations. At the station area level, we believe that the best way to describe a station area’s transit orientation is to consider characteristics of the area’s residents and take into account how ‘transit oriented’ the residents’ travel behaviors are. Orientation is scored through the following four measures:
Transit Dependence
Because persons living in households without a car are far more likely to use transit than those in households with cars, and because serving transit-dependent populations is an important component of equity, one measure of orientation to transit involves the transit dependence of station area residents. Higher transit dependence, measured as the proportion of zero vehicle households, correlates with lower VMT ($r=.834$).

Income
Lower income households are more likely to use transit and serving lower income residents is an important component of equity, so one component of the orientation scale involves income distribution in the station area. Several income measures were considered, including median income and income disparity/diversity. The measure ultimately selected was the percentage of households with incomes under $25,000, which was the income measure with the strongest (negative) relationship to VMT ($r=.631$).

Rental housing
Since renters are more frequent users of public transportation than home owners, the percentage of renter-occupied housing units in the station area is included as the third measure of orientation. This measure also correlates with lower VMT ($r=.807$).

Affordability
Affordability is a metric derived from the H+T® Index (see http://htaindex.cnt.org) developed by CNT, which measures the percent of income spent on transportation in the station area. The index is based upon a set of equations that model household transportation behavior. This includes autos per household, annual VMT and transit use. Since cars are more expensive to purchase and maintain than transit or non-motorized modes of transportation, it is not surprising that higher transportation costs are strongly correlated with higher VMT ($r=.903$).

Orientation Sub-Scale Results
The orientation sub-scale was calculated using these four measures. All four orientation measures are somewhat correlated with each other; together, they explain 87.0% of household driving differences ($F=571.1, p<.001$).

Orientation ratings for MBTA station areas vary from a low score of 4 (again, mostly commuter rail stations but also several stations on the Green “D” Line that goes to affluent suburbs) to a high score of 20 (found at many bus stops, as well as surface Green “B” and “E” Line stops). As with the transit sub-scale, the differences in the orientation measures between bus and rapid transit are significant; on average, bus stop areas have more residents in zero-vehicle households, more low-income households, and more renters than rail station areas. Rail station areas have a higher average percent of income spent on transportation than bus stop areas.

Development Sub-Scale
The remaining three station area attributes are related to the built environment or development within the station area.

Walkability
The independently developed WalkScore® of the station’s location (using latitude and longitude) measures important destinations within walking distance of the station as well as urban form, and is well-correlated with lower household VMT ($r=.725$). WalkScore® is calculated using a point-system awarded by distance to nearby amenities (e.g. grocery stores, bars, schools, coffee shops, libraries, etc) as well as measures of
pedestrian friendliness including population density, block length, and intersection density. WalkScore® has been validated as a measure of walkability (21).

**Residential density**

The number of households per acre in the station area is used as a measure of how many people live in the station area; generally, higher density is associated with lower household VMT ($r=.687$). This measure of residential density was selected over others (population, population per acre, households per residential acre, etc) due to its stronger relationship with VMT.

**Employment gravity**

The Employment Gravity measure, developed by CNT, is determined using a gravity model, which considered both the quantity of and distance to all employment destinations, relative to any given station area. Using an inverse-square law, an employment index was calculated by first summing the total number of jobs (obtained from data set derived from Dunn and Bradstreet business database) and then dividing by the square of the distance to those jobs. This quantity allows us to examine both the existence of jobs and the accessibility of these jobs for a given station area. Because a gravity model enables consideration of jobs both directly and not directly in a given station area, the employment gravity gives a better measure of job opportunity, and thus a better understanding of job access, than a simple employment density measure. Higher employment gravity is correlated with lower VMT ($r=.657$).

**Development Sub-Scale Results**

The development sub-scale was calculated using these three measures. The development measures explain 67.9% of the variance in station area household VMT ($F=240.0, p<.001$).

The development rating varies between MBTA station areas from a low score of 3 to a high score of 15. Most of the lowest-scoring stations are commuter rail station areas, and the highest-scoring are mainly bus stop areas.

Unlike the other two subscales, the development measures do not show a clear difference between the average bus station area and the average rail station area. The only significant difference at the 0.05 level is that bus stop areas have higher residential density than rail station areas ($t=2.479, p<.05$).

**TABLE 1 eTOD Score Measures**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Measure</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Mean (Rapid Transit)</th>
<th>Mean (Bus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit Access Shed</td>
<td>Transit Access Shed Index (TAS)</td>
<td>0</td>
<td>99.3</td>
<td>70.2</td>
<td>23.0</td>
<td>66.9</td>
<td>83.3</td>
</tr>
<tr>
<td>Transit Connectivity</td>
<td>Transit Connectivity Index (TCI)</td>
<td>29.1</td>
<td>99.5</td>
<td>79.9</td>
<td>20.1</td>
<td>77.1</td>
<td>90.9</td>
</tr>
<tr>
<td>Non-Automobile Commuting</td>
<td>Percentage workers who use transit, bike, or walk to work</td>
<td>3.3</td>
<td>78.8</td>
<td>39.1</td>
<td>22.6</td>
<td>37.6</td>
<td>45.1</td>
</tr>
<tr>
<td>Transit Dependence</td>
<td>Percentage of 0-car households</td>
<td>.00</td>
<td>.62</td>
<td>.262</td>
<td>.178</td>
<td>.25</td>
<td>.31</td>
</tr>
<tr>
<td>Income</td>
<td>Percentage of households with income &lt; $25,000</td>
<td>2.49</td>
<td>60.9</td>
<td>24.0</td>
<td>11.3</td>
<td>22.7</td>
<td>28.9</td>
</tr>
<tr>
<td>Rental Housing</td>
<td>Percentage renters</td>
<td>3.3</td>
<td>78.8</td>
<td>39.1</td>
<td>22.6</td>
<td>37.6</td>
<td>45.1</td>
</tr>
<tr>
<td>Affordability</td>
<td>Percent of Income Spent on Transportation</td>
<td>8.47</td>
<td>25.4</td>
<td>15.8</td>
<td>4.20</td>
<td>16.2</td>
<td>14.1</td>
</tr>
<tr>
<td>Walkability</td>
<td>WalkScore®</td>
<td>6</td>
<td>100</td>
<td>76.5</td>
<td>19.5</td>
<td>75.9</td>
<td>79.1</td>
</tr>
<tr>
<td>-------------</td>
<td>------------</td>
<td>---</td>
<td>-----</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Residential Density</td>
<td>Households per acre</td>
<td>0.11</td>
<td>36.2</td>
<td>9.20</td>
<td>7.60</td>
<td>8.79</td>
<td>10.8</td>
</tr>
<tr>
<td>Employment Gravity</td>
<td>Employment Gravity Measure</td>
<td>0</td>
<td>3.88</td>
<td>1.21</td>
<td>1.08</td>
<td>1.21</td>
<td>1.19</td>
</tr>
</tbody>
</table>

THE RATING SYSTEM AND RESULTS

The three subscales can also be summed into a final combined score, establishing a comparable eTOD Score for each station area. Each of the ten metrics is weighted equally in the combined score, so the orientation subscale, which has four metrics, ends up with a more influential fraction of the final score. This emphasis on orientation is warranted given the focus in the eTOD Score framework on the users who benefit from transit and development. The final combined score of each station area reflects its quality of transit, its orientation toward transit users, and the development of the station area. The overall score ranges from a minimum of 10 points to a maximum of 50 points.

Figure 2 presents a map of the Boston region that shows how the stations and stop areas break out by their eTOD Score. Scores for all of the station areas can be accessed on the Dukakis Center’s website (www.northeastern.edu/dukakiscenter/transportation/etodscores). As evident in Figure 2, the Transit-Oriented stations are clustered in the downtown core and surrounding neighborhoods. The scores tend to decrease with increased distance from the core, although many town centers score higher than those farther out. In addition, the more affluent suburbs to the west of the city have lower scores faster than the less affluent towns to the north and south.

FIGURE 2 Central Boston Region eTOD Scores
We divided the scores into four rating categories (see Figure 3), corresponding to significant changes in average VMT measures ($F=432.809, p<.001$). The highest rated station areas, with scores of 41 and above, are rated as Transit-Oriented and have an average household VMT of 21.3 daily miles, while average daily VMT in the lowest scoring (20 or below) station areas, those we term Transit-Adjacent, was more than 2.5 times higher at 58.5 daily miles.

**FIGURE 3 eTOD Scores and Daily Household VMT**
The three subscales (transit, orientation, and development) together explain 82% of variance in VMT, with development having the strongest effect, followed by orientation, and transit quality (see Table 2). Increasing the development score by 1 point reduces a station area’s daily VMT by approximately 1.4 miles per household. Increasing the orientation score or transit score by 1 point reduces VMT by approximately 1.3 and 1 daily miles respectively. The explanatory power of the subscales is similar between bus and rail station areas; bus station areas show a stronger effect of transit and orientation while rail station areas show a stronger effect of orientation and development on VMT.

### TABLE 2 eTOD Score Subscales’ Effect on VMT

<table>
<thead>
<tr>
<th>Subscales</th>
<th>All Station Areas</th>
<th>Bus Station Areas</th>
<th>Rail Station Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit Score</td>
<td>-.985***</td>
<td>.0221</td>
<td>-.238</td>
</tr>
<tr>
<td>Orientation Score</td>
<td>-1.316***</td>
<td>.151</td>
<td>-.400</td>
</tr>
<tr>
<td>Development Score</td>
<td>-1.395***</td>
<td>.229</td>
<td>-.315</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>345</td>
<td>69</td>
<td>276</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>74.240***</td>
<td>58.414***</td>
<td>75.461***</td>
</tr>
<tr>
<td><strong>Adjusted R^2</strong></td>
<td>.820</td>
<td>.850</td>
<td>.823</td>
</tr>
</tbody>
</table>

**DISCUSSION**

This proposed eTOD Rating System operates at the level of the station area or neighborhood surrounding a transit station and provides important information about attributes of the station area that affect its suitability for equitable TOD. The rating system allows planners, policymakers, developers and community stakeholders to assess and compare station areas based on how well they provide accessibility to transit-reliant populations, promote higher transit ridership and reduce household vehicle miles traveled (VMT). The highest-rated “transit-oriented” station areas share a combination of built, social and transit attributes.
that reduce driving, increase transit ridership, and promote equity. Given the rating system’s strong
correlation with average daily household VMT within station areas, the combined eTOD Score provides a
holistic measure of those conditions that contribute to less driving and more transit ridership both now and
likely into the future.

While the combined scores provide important information about the suitability of the station area for
high performing equitable TOD, the three separate sub-scales on Transit, Orientation and Development can
be used to better understand the strengths and weaknesses of different station areas and help focus attention
on the types of measures that can improve an area’s eTOD Score and thereby the performance and equity of
TOD in that station area.

One desired use of an equitable TOD rating system is for the evaluation of specific TOD projects
that are in the planning stage, so that such projects can be “scored” and different ideas for specific
development projects (such as the proposed mix of uses) can be compared. While this rating system focuses
on transit station areas rather than individual TOD projects or proposals, it can be used to better inform the
evaluation of proposed TOD projects.

While considering the development of a complementary rating system for equitable TOD projects,
we came to realize that there is no single answer to the question of whether a proposed TOD project is or is
not a “good” equitable TOD project. Instead, the answer is context-specific and depends in part on whether a
TOD project provides what is “missing” in a station area. The eTOD Score sub-scores can be used to
understand which station area attributes to focus on in order to improve the eTOD Score and thereby the
performance and equity of TOD in a given station area.

In order to better visualize the resulting overall eTOD score as well as the sub-scores, the score can
be presented in the form of a “radar graph”. Each axis of the radar graph represents one of the three sub-
scores: transit, orientation, and development. Transit and development are on scales with a maximum of 15
points; orientation is on a scale with a maximum of 20. The theoretical maximum possible score (15/20/15)
is shown with the outside triangle; the filled-in shape inside the triangle shows how much of the possible
score the station receives. This representation allows for a quick analysis of the strengths and weaknesses in
the transit station area.

Figure 4 presents several different radar graphs representing the eTOD Scores of different MBTA
bus, rapid transit and commuter rail stations. The transit-oriented example is a busy bus station at Dudley,
the transit-supportive example is a commuter rail station in the Lynn urban center and the transit-related and
transit-adjacent stations are rapid transit stations in lower density urban/suburban communities. The radar
graphs and sub-scores provide a more detailed view than the combined score alone. For example, the Lynn
station area is well-oriented toward core transit riders but scores poorly on transit (as it is commuter rail
rather than more frequent bus or rapid transit service) and has a mixed record with respect to
development/built environment attributes.
FIGURE 4  Examples of eTOD Score Categories

Transit-Oriented  Transit-Supportive  Transit-Related  Transit-Adjacent

Dudley  Lynn  North Quincy  Newton Center

By using the sub-scores, the eTOD rating system can help planners, policymakers and community
groups both design and assess specific TOD projects (as well as transportation investments) to assess the
extent to whether they add a missing component to a station area and thus improves its suitability for
equitable TOD. This rating system may underestimate the value of a TOD project in areas where the project
is proposed in a vacant or under-developed (and therefore low-scoring) area and is likely to create a
significant change in the score. In the future it may be possible to develop a complementary project-level
equitable TOD rating system that builds from the eTOD Score station area system and more explicitly
weighs and scores different components of TOD projects and the extent to which they are responsive to the
strengths and weaknesses of their host station area as presented in the eTOD Score for that station area. Such
a system could take into account the likely effect of the proposed TOD project on the station area score.

CONCLUSION

This research was designed to create a specific and quantitative method for assessing the relative suitability
of different transit station areas for high performing, equitable transit-oriented development. The resulting
eTOD Score methodology was built using nationally-available datasets so that it can be replicated and
applied to other transit systems and metropolitan areas. By providing a specific measurement system for
equitable TOD station areas, this rating system can be used by planners, policymakers and developers to
direct TOD projects and TOD funding and other resources toward high performing station areas.

Local officials, developers and community stakeholders face numerous challenges when trying to
ensure that transit-oriented development succeeds in simultaneously achieving transportation, land use and
social equity goals. The process of developing and validating this equitable TOD rating system helped
illuminate a number of these challenges.

Station areas that succeed from the perspectives of both transportation (as measured by lower daily
household vehicle miles) and social equity are those full of people who are likely to use transit, including
households without automobiles, renters and low-income households. Orienting equitable TOD toward these
core riders or “transit-oriented neighbors” is an effective strategy for creating TOD which is both high
performing and equitable.

The eTOD Score system also addresses a longstanding debate in the TOD community about the
extent to which neighborhoods served solely by high frequency bus service can support TOD. Some of the
highest scoring transit areas in our analysis were those served by the MBTA’s high frequency key bus routes,
in large part because those neighborhoods scored well on the transit, orientation and development sub-scales.

Finally, the process of developing this station area rating system provided an important insight into
ongoing efforts to develop similar rating systems for individual proposed or completed TOD developments.
We came to the conclusion that it is difficult to provide a single answer to the question of whether a proposed
TOD project is or is not a “good” equitable TOD project. The answer is context-specific and therefore a
system like this that quantifies key attributes of the station area context can be helpful. A “good” equitable is one that addresses weaknesses as identified by lower scores on one or more of the sub-scales; such a project should “rate” highly as equitable transit-oriented development for purposes of receiving permitting preference or funding subsidies, for example. The transit, orientation and development sub-scores developed as part of this station area rating system can therefore be used to better understand which station area attributes to focus on in order to improve the eTOD Score and thereby the performance and equity of TOD in a given station area.

The eTOD Score system needs to be further validated by application in different regions. While the system performs well in the Boston area, limitations to the system may be uncovered when multiple transit systems have been scored.

REFERENCES


11. Blumenberg, E., M. Donahue, S. L. Handy, K. Lovejoy, C. J. Rodier, S. Shaheen, and J. Volker. Travel of diverse populations: Literature review. California PATH Program of the University of California,


