Accessibility-based Evaluation of Transit Projects

Chelsey Palmateer¹, Alireza Ermagun², Andrew Owen³, David Levinson⁴

¹ Ph.D. Candidate, University of Minnesota, Department of Civil, Environmental, and Geo-Engineering, 500 Pillsbury Drive SE, Minneapolis, MN 55455 USA
Email: palma040@umn.edu

² Postdoctoral Fellow, Northwestern University, Department of Civil and Environmental Engineering, Technological Institute, 2145 Sheridan Rd, Evanston, IL 602088 USA
Email: alireza.ermagun@northwestern.edu (Corresponding Author)

³ Director of Accessibility Observatory, University of Minnesota, Department of Civil, Environmental, and Geo-Engineering, 500 Pillsbury Drive SE, Minneapolis, MN 55455 USA
Email: aowen@umn.edu

⁴ Professor, University of Sydney, School of Civil Engineering
Email: david.levinson@sydney.edu.au
ABSTRACT

This study uses the accessibility-based evaluation method to unpack the interaction effect of transit oriented development and a new transit hub, using the San Francisco Transbay Transit Center Development Plan project. We reveal both the transit oriented development and transit changes positively affect accessibility to jobs and accessibility to workers. However, the magnitude of effects for the transit changes alone are minimal in comparison to the effects of the anticipated transit oriented development changes. This indicates that in areas where there already is transit service, the development of land near the transit service can have a greater impact on accessibility levels than the improvement of connections between transit services. We also unravel the increase in accessibility at the project-level and determine that the increase is greater than the sum of the contributions of the individual portions of the project. This demonstrates that transit changes and transit oriented development have a superadditive effect, although it is negligible in our case.

**Keywords:** Transit-oriented development; Accessibility; Transit projects; San Francisco
1 Introduction

Transit Oriented Development (TOD) has become the focus of advocates and planners who are interested in creating multi-use facilities around transit hubs (Cervero and Duncan, 2002). TOD based design fosters benefits for communities that reach across the spectrum. For individuals, this “smart-growth” allows them to live in closer proximity or have a better accessibility to their valued destinations, and become less dependent on an automobile for transport. Cao and Ernagun (2016) used a quasi-longitudinal design on 597 residents who moved into the Hiawatha light rail transit in the Minneapolis-St. Paul metropolitan area, and revealed movers into the Hiawatha corridor increased their transit use and reduced their car use. For businesses, investing in land and development of TODs can increase profits. An example of this is shown in Santa Clara County, California, as business spaces within 400 meters from CalTrain witnessed an increased rental valuation of 120% compared to spaces outside of this zone (Weinberger, 2001). For transit agencies, planners, and advocates, TODs have the potential of solving 21st century problems of housing shortages, pollution, and traffic congestion (La Greca et al., 2011, Sung and Oh, 2011). They rank increasing transit ridership, promoting economic development and job growth, raising revenues for transit properties, enhancing livability, and widening housing choices as the top five goals for the transit oriented development (Cervero, 2004). For example, Ratner and Goetz (2013) analyzed 800m areas around current and proposed rail transit stations in Denver, Colorado, and acknowledged that TOD resulted in nearly 18,000 residential dwelling units, 492 thousands square meter of retail space, 502 thousands square meter of office space, and 576 thousands square meter of medical space between 1997 and 2010.

Transport analysts tackled assessing transport investments and transport dimensions of land-use developments, while focusing on mobility-based evaluation. They have commonly utilized traffic impact analysis as a primary tool for gauging the transport impact of land-use change, which is a mobility-based evaluation and overlooks the accessibility benefits of developments (Levine et al., 2017). When using mobility as an indicator, we are primarily looking at the speed and distance traveled by travel modes from their origin to their destination. However, mobility planning does not usually consider the individual, or their ability to easily get to their destination. To overcome this challenge, planners and advocates are changing the conversation from mobility to accessibility (Cervero et al., 1997). Accessibility analysis falls into two categories in which TODs are evaluated. The first category is regional analysis over time, which analyzes the benefits of a project on the region over time. Levinson et al. (2017), for example, implemented regional analysis over time discussing the accessibility of the Minneapolis-St. Paul region by automobile by examining TAZ data from 1995 to 2005. The second category is regional scenario analysis over space, which looks at the impact of a regional project in one region versus the impact of a project in a different region. In 2010, Grengs et al. (2010) used this method to evaluate the accessibility of transit among different socio-economic groups in Detroit for non-work based trips.

Transit projects involving the implementation or renovation of a hub for multiple transit services also incorporate plans for transit oriented development. As a result, planners and advocates are interested in evaluating the interaction effects, in addition to gauging the benefits of transport investment and land development independently. The interaction effect then takes on one of the following three forms. First, the effect is superadditive, if the joint benefits surpass the sum of the benefits, which are gained from development and transport investment. Second, the effect is subadditive, if the joint benefits reduce the sum of the benefits. Third, the effect is additive, if
the joint benefits equal the sum of the benefits (Kanchi et al., 2002). Although the existing body of literature on assessing transit projects supports the need for an accessibility-based evaluation on different portions of a transit project as a package, the research in this area still is in its infancy. We use the accessibility-based evaluation method to unpack the interaction effect of both transit oriented development and constructing a new transit hub in San Francisco, California. This allows planners and advocates to understand whether and to what extent the transit projects in accessibility terms benefit from both the transport investment and the land development.

The rest of the paper is organized as follows. First, we provide information on the San Francisco Transbay Transit project and its associated planned development. Second, we provide an in-depth discussion about accessibility measurement and calculation. Third, we represent the data used for the accessibility-based evaluation analysis along with data preparation and modification. Fourth, we illustrate the results of the accessibility-based evaluation. We conclude the paper by encapsulating the key findings and discussing the planning implementations.

2 Project Design Implementation

The San Francisco Transbay Transit Center Development includes two main project components: (1) the construction of the new Transbay Transit Center and Transit Tower to replace the existing Transbay Terminal as well as the relocation of transit services to the new Transbay Transit Center and extension of Caltrain from Fourth and King St. Station to the Transbay Transit Center, and (2) transit oriented development both within the Transit Center District and in the nearby Rincon Hill neighborhood.

The Transbay Transit Center and adjacent Transit Tower are shown in yellow in Figure 1. The Transbay Transit Center is intended as a replacement of the existing Transbay Terminal (the current temporary location of the Transbay Terminal is shown as a blue dot at the corner of Folsom St. and Main St.). However, the new Transbay Transit Center will be multimodal and is planned to incorporate an extension of Caltrain from the Fourth and King St. Station (shown as a green dot). Eventually the future California High-Speed Rail may also connect to the Transbay Transit Center.

The Transit Center will include a rooftop park and require a reconfiguration of local streets to accommodate anticipated changes in traffic patterns, such as increased pedestrian traffic. In addition, the Transit Tower, at a proposed height of 1072 feet 9 inches, will be built adjacent to the Transbay Transit Center. The Transit Tower is planned to include three floors of below-grade parking, four floors of retail space, and office space on the remaining floors. In terms of accessibility, the primary impact of the relocation of the transit services to the combined center will be an enhanced connection between various transit services (Department, 2008).

The Transit Center District and Rincon Hill Plans complement the new transit infrastructure. Figure 1 shows the boundary of the Transit Center District Plan with a dotted red line. The plan is for both private property and property owned by the Transbay Joint Powers Authority. As of 2008, the area is about 40 acres containing the temporary Transbay Terminal and access ramps and various vacant and underutilized properties. Many of the buildings within the project area are aging and in a state of deterioration, or simply do not meet modern construction standards.

New development within the Transit Center District will include office space and residences, primarily focused in Transbay Zone 2. To accommodate the taller building of the new development, the city of San Francisco plans for updated height restrictions in Zone 2. Efforts in
Transbay Zone 1 will largely be focused on streetscaping, with little land use or height changes. In Figure 1, Transbay Zone 1 and Transbay Zone 2 are shown with light purple and green shading, respectively (Department, 2008). In the nearby Rincon Hill neighborhood there is another plan encouraging high-density residential uses, with funding mechanisms to incorporate affordable housing and other public infrastructure.

Between these two planning efforts a growth of approximately 21,500 jobs and 2,700 residential units in Transbay Zone 1 and 2 combined as well as 3,822 residential units in the Rincon Hill neighborhood is anticipated. The project is defined by the combination Transbay Zone 1, Transbay Zone 2 and the Rincon Hill neighborhood, however the accessibility impacts are assessed at the regional level.

**FIGURE 1**: Transit Center District Plan and Transit Tower (Department, 2008)
3 Accessibility Measurement and Calculation

Hansen (1959) introduced the modern understanding of accessibility in an article regarding the relationship between accessibility and land use. He describes accessibility as a summation of gravity-weighted potential destinations as in Equation 1:

\[ A_i = \sum_j O_j f(C_{ij}) \]  

Where:
- \( A_i \) = accessibility for location \( i \)
- \( O_j \) = number of opportunities at location \( j \)
- \( C_{ij} \) = time cost of travel from \( i \) to \( j \)
- \( f(C_{ij}) \) = weighting function

Cumulative opportunity accessibility calculations are one form of gravity weighting summation in which one of the simplest weighting functions, a binary weighting function, is employed. Basically, opportunities that can be reached within a given threshold are weighted with a value of one, and those that cannot be reached are weighted with a value of zero as in Equation 2 (Owen and Levinson, 2014).

\[ f(C_{ij}) = \begin{cases} 
1 & \text{if } C_{ij} \leq T \\
0 & \text{if } C_{ij} > T 
\end{cases} \]  

Where:
- \( T \) = travel time threshold

The cumulative opportunities measure of accessibility is used for multiple threshold times in Access Across America (Owen and Levinson, 2014). In addition, several techniques allowing for comparison of accessibility by transit across systems are utilized. The first is the introduction of time averaged accessibility to account for the variability in accessibility associated with transit scheduling. This methodology requires the measurement of accessibility on a minute by minute basis during the period of interest (Owen and Levinson, 2014). Second is the use of person-weighted accessibility in order to aggregate the accessibility measurements at the census block level to a region. In other words, the accessibility is averaged over all census blocks with each block’s accessibility weighted by the population of workers in the census block. Finally, to provide an overall ranking, which takes into account the accessibility at each of the measured thresholds, a weighted accessibility is determined as in Equation 3 (Owen and Levinson, 2014).

\[ a_w = \sum_T (a_T - a_{T-10})e^{\beta T} \]  

Where:
- \( a_w \) = Weighted accessibility ranking metric for a single metropolitan area
- \( a_T \) = Worker-weighted accessibility for threshold \( t \)
- \( \beta = -0.08 \)

The accessibility results presented in this study were calculated using a cumulative oppor-
tunities accessibility metric. In this approach, the accessibility level of a given origin location is determined by the number of opportunities that can be reached within a given travel time threshold. This analysis evaluates accessibility using the travel time thresholds of 10, 20, 30, 40, 50, and 60 minutes. The following discussion describes two fundamental steps in measuring accessibility: (1) origin and destination selection and (2) transit travel time calculation.

3.1 Origins and Destinations

Census blocks were used as origin and destination points for this analysis. In urban areas, as defined in 2010 by the U.S. Census bureau, a Census block typically corresponds to a “city block” – a small area enclosed by roads. The origin sets are comprised of the centroid points of all Census blocks in the areas of interest for a given case study. To avoid understating the accessibility of blocks at the edge of this area, the destination sets included blocks in a slightly wider area.

3.2 Transit Travel Time Calculation

Transit travel time calculations consider all components of travel by transit, including access time, time spent waiting for a trip departure, time spent traveling on a transit vehicle, and egress time. An unlimited number of transfers was allowed, and time spent walking to and waiting for transfers was included. This analysis used the assumption that all walking portions of a trip take place at a speed of 5.0 kilometers per hour (3.1 miles per hour). On-vehicle travel time was derived directly from published transit timetables, under an assumption of perfect schedule adherence. Jobs that can be accessed by walking only are included in the accessibility totals; a transit component is not strictly required. This allows the most consistent application and interpretation of the travel time calculation methodology. The shortest walking path from an origin to a transit station in some cases passes through potential destinations where job opportunities exist; these destinations were included even though transit is not required to access them.

Accessibility by transit depends strongly on departure time because of the scheduled nature of transit service. For example, if a transit route’s service frequency is 20 minutes, then immediately after a vehicle departs all destinations become 20 minutes “farther away.” To address this and to reflect the influence of transit service frequency on accessibility, travel times were calculated repeatedly for each origin-destination pair using each minute between 7:00 AM and 8:59 AM as the departure time. Using the travel time calculations described above, a set of destinations reachable within each travel time threshold was identified for each origin and departure time, and the jobs located at the reachable destinations were aggregated to arrive at a single accessibility data point for that origin and departure time. For each origin, the accessibility data for all 120 departure times were then averaged to provide a single accessibility value indicating the number of jobs that can be reached from that origin within a given travel time threshold, on average, between 7:00 AM and 9:00 AM.

4 Data Preparation and Modification

For the purpose of accessibility-based evaluation analysis, we use six particular data sets as follows:
1. U.S. Census TIGER 2010 datasets: blocks, core-based statistical areas (CBSAs)


5. Baseline Transit Network, which includes the San Francisco Municipal Transportation Agency (SMFTA) GTFS release for November 2015 and the Caltrain GTFS release for November 2015.

6. Three travel surveys consist of San Francisco Bay Area Travel Survey 2000, which mentioned in the project planning documents, the 2013 California Household Travel Survey, and the Census Transportation Planning Products – 2000 Workers per Household provided by US department of transportation.

In the following subsections, we provide an in-depth discussion over the data preparation and modification.

### 4.1 Land Use Estimates

The *Transit Center District Plan Draft* describes the growth of approximately 21,500 jobs and 2,700 residential units in Transbay Zone 1 and zone 2 combined. The *San Francisco General Plan: Rincon Hill Area Plan* further describes growth of approximately 3,822 residential units in the Rincon Hill neighborhood. It is necessary to make an assumption about the number of workers per household to determine the expected growth in number of workers based on assumed growth in the number of residential units. We utilized the San Francisco Bay Area Travel Survey 2000, which is mentioned in the project planning documents, to generate an estimate of 1.18 workers per household. This rate is reasonable in comparison to both the estimate of 1.22 workers per household at the national level as provided by the U.S. DOT Census Transportation Planning Products and the estimate of 1.31 workers per household from the 2013 California Household Travel Survey. Due to its local relevance and mention in the planning documents, 1.18 workers per household seems to be the most useful estimate for this analysis.

### 4.2 GTFS Modification

To generate General Transit Feed Specification (GTFS) for the network after the Transbay Transit Center is complete, the baseline GTFS network needed to be modified according to the proposals made in the planning documents. GTFS requires a minimum of six text files to sufficiently describe a transit network. These files include: agency.txt, stops.txt, routes.txt, trips.txt, stop_times.txt, and calendar.txt. GTFS also allows for the addition of numerous optional
text files to provide additional information. Five of these files are affected by the modifications to the network and a brief description of each follows:

• **stops.txt** lists all stops in the transit network, providing a unique ID as well as latitude and longitude of each stop base on the WGS 84 datum. New stops are added to this file as part of the modifications.

• **routes.txt** lists all routes in the network, providing a unique ID for each route, as well as a short name and other basic information. New routes are added to the file as part of the modifications.

• **trip.txt** lists all trips in the network providing a unique trip ID, the associated route ID, and other basic information about the trips. New trips are added to this file, and the data for rescheduled trips is changed to reflect the modifications.

• **stop_times.txt** contains the scheduling information. This file lists the time that each trip is at an associated stop, as well as the associated trip ID and stop ID. Whether a trip is rescheduled or completely new, all the stops in the trip and the times at those stops are added to this file as part of the modifications (old stop times for rescheduled trips are deleted). However, in some cases a single trip can be used as a representative for many trips. In that case, the stop times are only included once, and the frequency of the trip is indicated in in the frequencies.txt file.

• **frequencies.txt** includes the desired headway of the trip, as well as information about the duration of that headway, and the id of the associated trip.

As part of the modifications for the Transbay Transit Center implementation, it was necessary to define the alignment for all trips that would terminate at the new Transbay Transit Center. As such, the former terminals of these routes were adjusted to reflect their new location at the Transbay Transit Center, by simply changing the stop location. It was assumed that travel times would remain the same for all routes.

### 4.3 Land Use Modifications

In the San Francisco Transbay Development the primary change of concern is the development of land. To represent an implementation of the development proposed in these projects, changes are made to the baseline LEHD data from each case study. The U.S. Census Longitudinal Employer-Household Dynamics (LEHD) 2013 Origin-Destination Employment Statistics (LODES) consists of three files. The first is a file of origins and destinations of commutes to work, which is not used as part of this analysis. The second is a file containing workplace area characteristics (WAC). This file details the number of jobs by category in each census block. The third and final file contains residential area characteristics (RAC). This file details the number of workers by category that live in each census block.

In case studies with anticipated development, the planning documents are reviewed to determine the geographic extents of the project and anticipated growth in residential units and commercial space. The anticipated growth in total workers can then be estimated by multiplying the
the anticipated number of workers per household by the anticipated number of new residential units. Similarly, the anticipated growth in jobs is determined as the multiplication of the commercial usage factor, which is the number of workers per floor area of commercial space, by the anticipated increase in commercial floor area. In the case of the San Francisco Transbay development, this was not necessary because the planning documents indicated an anticipated growth in the number of jobs rather than an anticipated growth in commercial square feet. The total increase in workers and jobs for the projects are then distributed to all potential census blocks within the projects based on the percentage of the total project area within each census block. For example, a census block that has twenty percent of the total land area of the project will receive twenty percent of the projected growth in jobs and workers. These increases are added to the baseline total number of workers in the RAC file and total number of jobs in the WAC file to generate digitized representations of the proposed land use. Finally, it is assumed that the relative ratio of total jobs to any category of jobs (i.e. jobs with earnings $1250/month or less, etc.) and the relative ratio of total workers to any given category of workers (i.e. workers of race: white alone, etc.) remain constant so that the predictions for these categories of jobs and workers can be populated based on the predicted total jobs and total workers.

5 Accessibility-based Evaluation

The San Francisco Transbay Transit Center Development access to jobs and access to workers calculations have been performed, and the access to jobs and access to workers results have been processed. The maps in Figure 2 illustrate the accessibility by transit to jobs, averaged between 7:00 AM and 9:00 AM, in the baseline scenario. The maps in Figure 3 illustrate the change in the number of jobs and workers respectively that can be reached from each block based on the development of the Transbay Transit Center. When interpreting these maps, it is important to note that they show percentage, rather than absolute, accessibility changes. Across all blocks in the region the range of accessibility values is wide: from some blocks no jobs can be reached by transit, while from others, hundreds of thousands of jobs can be reached. When a transit service is added to an area that previously had little or no service, the low original accessibility value can produce a very high percentage change, even if the absolute number of new jobs that can be reached is relatively low. This can also result in anomalous blocks if an area having very low accessibility experiences slightly more or less walking distance due to rounding in the accessibility calculation program.

Figure 3 portrays that the development of the Transbay Transit Center and Rincon Hill results in increases in accessibility to jobs. In addition, it is interesting to note that there is a high percentage change in accessibility to workers, who are localized within or near the project area, for thresholds at or below 30 minutes, with little or no change in higher thresholds. This localization is likely due to the already high levels of accessibility experienced by areas surrounding the project. A similar phenomenon occurs for access to jobs, however at higher thresholds the areas impacted are further from the project area. This is likely due to the larger growth in jobs than workers coupled with the lower accessibility to jobs in the areas showing higher percent increases than in the areas near the project at thresholds at or above 40 minutes, as demonstrated in Figure 2. Table 1 and Table 2 further illustrate that the San Francisco Bay Area as a whole experience increases in accessibility to both jobs and workers respectively at all thresholds due to the development directly,
FIGURE 2: Total jobs reachable by threshold (Baseline network and 2013 land use)
FIGURE 3: Change in number of total jobs reachable by threshold
with an additional benefit of a lower magnitude associated with the relocation of transit services to the Transbay Transit Center and thereby closer to the planned development.

To give the reader a quantitative sense of how the accessibility is changed following the San Francisco Transbay Transit Center redevelopment plan, we outline the weighted accessibility to jobs in Table 1 and weighted accessibility to workers in Table 2 for different scenarios.

**TABLE 1 : Results of the Weighted Accessibility to Jobs**

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Accessibility Calculation</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>2013 LEHD</td>
<td>1,500</td>
<td>10,290</td>
<td>28,248</td>
<td>52,674</td>
<td>78,602</td>
<td>100,995</td>
</tr>
<tr>
<td>TOD</td>
<td>1,698</td>
<td>11,156</td>
<td>29,895</td>
<td>55,161</td>
<td>81,828</td>
<td>104,748</td>
</tr>
<tr>
<td>Transit</td>
<td>1,500</td>
<td>10,291</td>
<td>28,253</td>
<td>52,688</td>
<td>78,638</td>
<td>101,124</td>
</tr>
<tr>
<td>TOD and Transit</td>
<td>1,699</td>
<td>11,156</td>
<td>29,903</td>
<td>55,181</td>
<td>81,880</td>
<td>104,917</td>
</tr>
</tbody>
</table>

| Accessibility Changes | TOD          |          |          |          |          |          |
|                       | 198          | 866      | 1,647    | 2,487    | 3,226    | 3,753    |
|                       | Transit      | 0        | 1        | 5        | 14       | 36       | 129      |
|                       | TOD + Transit| 198      | 867      | 1,652    | 2,501    | 3,262    | 3,882    |
|                       | TOD and Transit| 199    | 867      | 1,655    | 2,507    | 3,278    | 3,922    |

| Interaction Effects   | Superadditive | Superadditive | Superadditive | Superadditive | Superadditive | Superadditive |

As shown in Table 1 both the TOD and the transit changes impact accessibility levels. However, the impacts of the transit changes alone are minimal in comparison to the effects of the anticipated TOD changes. For example, given only the land use changes the typical worker can reach an additional 1,647 jobs in 30 minutes. However, given only the transit changes the typical worker can reach an additional 5 jobs in the same time threshold. When the two changes are both taken into account, the typical worker can reach only an additional 1,655 jobs. This is more than the sum of the benefits of the individual projects, which is 1,652 additional jobs. This demonstrates that transit projects and TOD can have a superadditive effect. A similar pattern is observed for the increase in the access to workers. As shown in Table 2, the impacts of the transit changes alone are less than the effects of the anticipated TOD changes. Considering only the new land changes, the additional regional workers that a typical company can reach within 30 minutes of travel is 1,509

**TABLE 2 : Results of the Weighted Accessibility to Workers**

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Accessibility Calculation</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>2013 LEHD</td>
<td>1,460</td>
<td>10,167</td>
<td>27,088</td>
<td>49,319</td>
<td>73,491</td>
</tr>
<tr>
<td>TOD</td>
<td>1,642</td>
<td>10,977</td>
<td>28,597</td>
<td>51,485</td>
<td>76,250</td>
</tr>
<tr>
<td>Transit</td>
<td>1,617</td>
<td>10,169</td>
<td>27,105</td>
<td>49,379</td>
<td>73,595</td>
</tr>
<tr>
<td>TOD and Transit</td>
<td>1,642</td>
<td>10,978</td>
<td>28,618</td>
<td>51,555</td>
<td>76,374</td>
</tr>
</tbody>
</table>

| Accessibility Changes | TOD          |          |          |          |          |          |
|                       | 182          | 810      | 1,509    | 2,166    | 2,759    | 3,174    |
|                       | Transit      | 157      | 2        | 17       | 60       | 104      | 206      |
|                       | TOD + Transit| 339      | 812      | 1,526    | 2,226    | 2,863    | 3,380    |
|                       | TOD and Transit| 182    | 811      | 1,530    | 2,236    | 2,883    | 3,423    |

| Interaction Effects   | Subadditive | Subadditive | Superadditive | Subadditive | Superadditive | Superadditive |

As shown in Table 1 both the TOD and the transit changes impact accessibility levels. However, the impacts of the transit changes alone are minimal in comparison to the effects of the anticipated TOD changes. For example, given only the land use changes the typical worker can reach an additional 1,647 jobs in 30 minutes. However, given only the transit changes the typical worker can reach an additional 5 jobs in the same time threshold. When the two changes are both taken into account, the typical worker can reach only an additional 1,655 jobs. This is more than the sum of the benefits of the individual projects, which is 1,652 additional jobs. This demonstrates that transit projects and TOD can have a superadditive effect. A similar pattern is observed for the increase in the access to workers. As shown in Table 2, the impacts of the transit changes alone are less than the effects of the anticipated TOD changes. Considering only the new land changes, the additional regional workers that a typical company can reach within 30 minutes of travel is 1,509
workers. This value equals 17, in the only transit change scenario. When the two changes are both taken into account, the typical company can reach an additional 1,530 workers. This is slightly more than the sum of the benefits of the individual projects, which is 1,526 additional jobs. Unlike the accessibility to jobs that is superadditive in all minutes of travel, the accessibility to workers is superadditive in greater than 20 minutes of travel. Although we reveal that transit projects and transit-oriented development can have a superadditive effect on accessibility via transit, the effects of transit oriented development may be far greater than the effects of transit changes. This is especially true in the case where transit changes are made in an area with pre-existing service.

6 Summary and Conclusions

Accessibility, as an indicator to evaluate transit projects, can replace or complement traditional indicators, including roadway level-of-service, traffic speeds, and vehicle operating costs evaluated under the umbrella of mobility paradigm. Consequently, a paradigm shift from the mobility-based evaluation to accessibility-based evaluation is occurring in assessing transit projects. However, accessibility-based evaluation of transit projects is still in its infancy. Much of previous research has focused on regional-scenario evaluation, and little is known about accessibility-based evaluation of transit projects at the project-level. The two umbrellas these projects fall under are transport investment and land development. Transit oriented development has become a means for planners to address 21st Century, big-city issues such as traffic congestion, affordable housing, air pollution from vehicles, and urban sprawl, to name a few. Transport investments, such as the creation of a multi-modal transit hub by connecting multiple systems under one roof, promises to enhance regional connections to transit for residents, workers, and visitors, and boosts accessibility to valued destinations. This drives planners and advocates into examining the interaction effect of project parts for transit project evaluation.

We evaluated the interaction effect of transit oriented development and transit hubs in the Transbay Transit Center Project underway in San Francisco, California. Enhancing the accessibility to jobs and workers is a promising regional economic benefit of the Transbay Transit Center Project. For companies, the widening talent pool should expand productivity. For workers, particularly low-income households, access to affordable transportation is the biggest impediment to employment. Many low-income households do not have easy access to public transit and thereby increase the time spent on their commute to and from work. The Transit Center, and by extension the downtown rail, is not only tasked with creating better access to affordable transit to all of San Francisco, but to focus explicitly on residents in the poorer southern neighborhoods and the Peninsula corridor. We encapsulate the key remarks of the accessibility-based evaluation in the following annotations:

- The transit-oriented development has a significant impact on enhancing accessibility to workers. The number of regional workers that a could be reached from typical job within 30 minutes of travel, between 7:00 and 9:00 AM using transit, increases by about 5.5%. Akin to access to regional workers, the transit-oriented development has a significant impact on enhancing accessibility to jobs. The number of regional jobs that a typical worker residing in the region can reach within 30 minutes of travel, between 7:00 and 9:00 AM using transit, increases by 6.0%.
• Although this transit hub enhances accessibility to jobs and workers, the impact is negligible. The number of regional jobs and workers that a typical worker residing in the region can reach within 30 minutes of travel, between 7:00 and 9:00 AM using transit, increases by less than one percent.

• The interaction effect analysis revealed that the joint accessibility benefit of the transit-oriented development and creating transit hubs, generally in this case, exceed the sum of the accessibilities, which gain from each development independently. This pinpoints that transit-oriented development and transit hubs can have a superadditive effect. However, this effect is minimal. We speculate that the slight interaction effect drives from the fact that the area is already benefiting from a decent transit service.

Planners and transit officials might use the findings of the current research to properly invest in transit projects. Evaluation of transit projects at the project-level aligns the planning strategies with expectations, which increases the effectiveness of investments. Planners also can use accessibility-based evaluation used in this study to detect project quality weaknesses and strengths. This leads them to allocate corporate resources to the important parts of the project and properly fulfill their targets.

7 Acknowledgment

This research was funded by the Federal Highway Administration (FHWA). The authors would like to thank FHWA for their support. All opinions and results presented in this paper are the responsibility of the authors.

References


