The Synergistic Effects of Transit Oriented Development and Transit Hubs on Accessibility in the San Francisco Bay Area

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ABSTRACT

This paper is a case study of the accessibility impacts of transit projects and nearby development on transit accessibility in a region, which already has significant levels of accessibility via transit. The project under consideration is the San Francisco Transbay Transit Center and the associated planned development. Findings indicate that both portions of the project increase accessibility via transit in the region. However, the contribution from the planned development is far greater. Furthermore, the increase in accessibility from the project as a whole is greater than the sum of the contributions of the individual portions of the project. This indicates that in areas where there is already 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.

INTRODUCTION

Frequently transit projects involving the implementation or renovation of a hub for multiple transit services also incorporate plans for transit oriented development. This study seeks to parse the effects of transit hubs and nearby transit oriented development on accessibility via transit. In order to do so, a case study project is considered, in which both a new transit hub and nearby development are planned for a region. The case study project under consideration is he San Francisco Transbay Transit Center and the associated planned development.

Case Study Description

The San Francisco Transbay Transit Center Development involves the construction and use of the new Transbay Transit Center and the redevelopment of Transbay Zone 1 and Transbay Zone 2, which surround the new transit center, as well as the development of residential units in the nearby Rincon Hill neighborhood. The project will result in 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. In terms of accessibility, the primary impact of the relocation of the transit services to the transit center will be an improved level of connection between various transit services.

LITERATURE REVIEW

Accessibility is the ease with which users may reach opportunities. It is important to distinguish accessibility from mobility, which is concerned with ease of movement, rather than ease of reaching opportunities. In 1959 Walter Hansen introduced the modern understanding of accessibility;y in an article regarding the relationship between accessibility and land use [1]. Hansen describes accessibility as a summation of gravity-weighted potential destinations:

$$A_i = \Sigma_j O_j f(C_{ij})$$

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 opportunities 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 are weighted with a value of zero [2].

$$f(C_{ij}) = \begin{cases} 1 & \text{if } \mathrm{C}_{ij} \leq t \\ 0 & \text{if } \mathrm{C}_{ij} > t \end{cases}$$

Where:
t = travel time threshold

The cumulative opportunities measure of accessibility is used for multiple threshold times in the Access Across America report by Owen and Levinson. In addition several techniques allowing for comparison of accessibility by transit across systems are utilized. The first is the introduction of time averaged accessibility in order to account for the variability in accessibility associated with transit scheduling. This methodology requires the measurement of accessibility on a minute by minute bases during the time frame of interest [2]. Second is the use of a person-weighted accessibility in order to aggregate the accessibility measurements at the census block level to a region. Basically, the accessibility is averaged over all census blocks with each blocks accessibility weighted by the population of workers in the census block. Finally, in order to provide an overall ranking which takes into account the accessibility at each of the measured thresholds a weighted accessibility is determined as follows [2]:

$$a_w = \Sigma_t(a_t - a_{t-10})e^{\beta t}$$

Where:
a_w = Weighted accessibility ranking metric for a single metropolitan area
a_t = Worker-weighted accessibility for threshold t
β = -0.08

DATA AND METHODOLOGY

Data

- U.S. Census TIGER 2010 datasets: blocks, core-based statistical areas (CBSAs)
- U.S. Census Longitudinal Employer-Household Dynamics (LEHD) 2013 Origin-Destination Employment Statistics (LODES)
- OpenStreetMap (OSM) North America extract, retrieved January 2016
- Planning documents which describe the anticipated growth in residential units and jobs.
  - Transit Center District Plan Draft (November 2009)
  - San Francisco General Plan: Rincon Hill Area Plan
- Baseline Transit Network:
  - San Francisco Municipal Transportation Agency (SMFTA) GTFS release for November 2015
  - Caltrain GTFS release for November 2015
- Travel Surveys:
  - San Francisco Bay Area Travel Survey 2000 (mentioned in the project planning documents)

- 2013 California Household Travel Survey
- Census Transportation Planning Products – 2000 Workers per Household (provided by US DOT)

Project Area

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.

Land Use Estimates

The *Transit Center District Plan Draft* describes growth of approximately 21,500 jobs and 2,700 residential units in Transbay Zone 1 and 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.

Finally, it was necessary to make an assumption about the number of workers per household in order to determine the expected growth in number of jobs based on assumed growth in the number of residential units. To this end the San Francisco Bay Area Travel Survey 2000 (which is mentioned in the project planning documents) was utilized to generate an estimate of 1.18 workers per household which is reasonable in comparision 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.

Accessibility Calculation

The accessibility results presented in this report were calculated using a *cumulative opportunities* 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 evaluated accessibility using travel time thresholds of 10, 20, 30, 40, 50, and 60 minutes. The following sections provide a brief overview of this methodology.

The analysis for transit accessibility is modified to accomodate the effects of scheduling and is derived from the basic methodology used to evaluate transit accessibility to jobs in the Accessibility Observatory's *Access Across America* series of reports, with data sources updated to reflect the case studies in consideration. This modification is described more fully in *Access Across America: Transit 2014 Methodology.* [**? ?**]

Origins and Destinations

Census blocks, defined in 2010 by the U.S. Census bureau, were used as origin and destination points for this analysis. In urban areas, Census blocks typically correspond to "city blocks" – small areas 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.

Transit Travel Time Calculation

Transit travel time calculations considered all components of travel by transit, including time spent walking to a stop or station, time spent waiting for a trip departure, time spent traveling on a transit vehicle, and time spent walking to a destination after alighting. 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 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 stop/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 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 and 9 AM. These are the values presented and discussed in the following sections.

GTFS Modification

In order to generate 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. The following sections describe the GTFS format and the implementation of modifications.

General Transit Feed Specification

GTFS requires a minimum of six text files in order 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 in order 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 of 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 of 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.

Route Adjustment

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 where 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.

Land Use Modifications

In the San Francisco Transbay Development the primary change of concern is the development of land. In order to represent an implementation of the development proposed in these projects, changes are made to the baseline LEHD data from each case study. The sections below describe the contents of LEHD data, and how they can be modified to reflect proposed changes in land use.

LEHD - 2013 LODES Data

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.

Updating the LEHD Data

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 than be estimated by multiplying the typical

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 (number of workers per square foot of commercial space) by the anticipated increase in commercial square feet. In the case of the San Francisco Transbay development, this was not necessary because the planning documents indicated an anticipated growth in number of jobs rather than an anticipated growth in commercial square feet. The total increase in workers and jobs for the project extents are then distributed to all potential census blocks within the project extents based on the percentage of the total project area within each census block. So for example a census block which has twenty percent of the total land area of the project is receives 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.

ACCESSIBILITY RESULTS

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 output for total jobs and total workers is below.

The maps in Figure 5.1 illustrate the accessibility by transit to jobs ,averaged between 7 AM and 9 AM, in the baseline scenario. The maps in Figure 5.2 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. [1]

Decomposing the Accessibility Changes

As can be seen in Table 1 both the land use changes 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 land use changes. For example given only the new land changes the typical worker can reach an additional 1,647 jobs in thirty minutes. However, given only the transit changes the typical worker can reach an additional 5 jobs. When the two changes are both taken into account, the typical worker can reach only an additional 1,655 jobs which is more than the sum of the benefits of the individual projects (1,652 additional jobs). A similar case can be made for the increase in the access to workers, see Table 2. Therefore, this case study indicates that transit projects and land use development can have a synergistic effect on accessibility via transit,

[1] 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 very wide: from some blocks no jobs can be reached by transit, while from others, hundreds of thousands of jobs can be reached. When the 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.

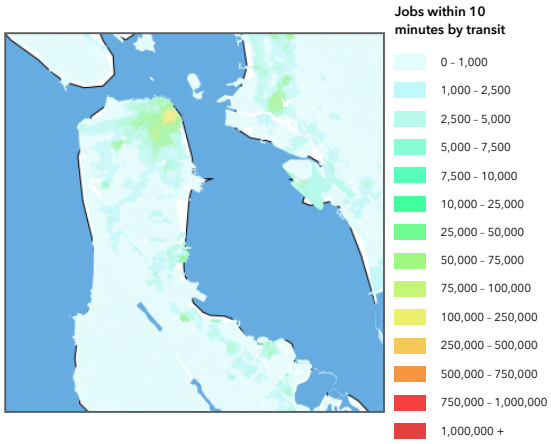
TABLE 1 : Regional Worker - Weighted Accessibility to Jobs using 2013 LEHD Data vs. Worker estimates based on the Transit Center District Plan and the Rincon Hill General Plan (Growth of 6,522 Residential Units and 1.18 workers/household from the 2000 San Francisco Bay Area Travel Survey) and Employment estimates based on the Transit Center District Plan (Growth of 21,500 jobs)

Threshold	2013 LEHD Jobs	Estimated Jobs	Transit Changes	Estimated Jobs and Transit Changes
10 Minutes	1,500	1,698	1,500	1,699
20 Minutes	10,290	11,156	10,291	11,156
30 Minutes	28,248	29,895	28,253	29,903
40 Minutes	52,674	55,161	52,688	55,181
50 Minutes	78,602	81,828	78,638	81,880
60 Minutes	100,995	104,748	101,124	104,917

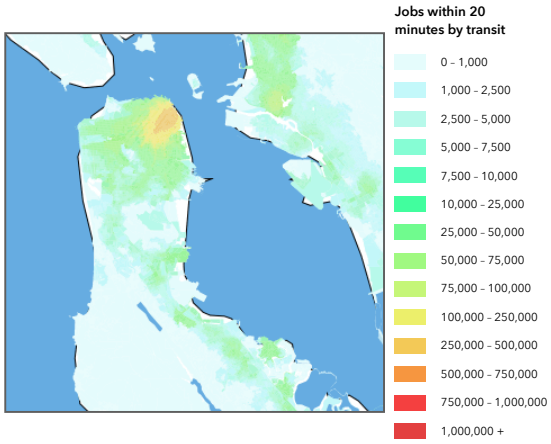
TABLE 2 : Regional Job - Weighted Accessibility to Workers using 2013 LEHD Data vs. Worker estimates based on the Transit Center District Plan and the Rincon Hill General Plan (Growth of 6,522 Residential Units and 1.18 workers/household from the 2000 San Francisco Bay Area Travel Survey) and Employment estimates based on the Transit Center District Plan (Growth of 21,500 jobs)

Threshold	2013 LEHD Workers	Estimated Workers	Transit Changes	Estimated Workers and Transit Changes
10 Minutes	1,460	1,642	1,617	1,642
20 Minutes	10,167	10,977	10,169	10,978
30 Minutes	27,088	28,597	27,105	28,618
40 Minutes	49,319	51,485	49,379	51,555
50 Minutes	73,491	76,250	73,595	76,374
60 Minutes	95,216	98,390	95,422	98,639

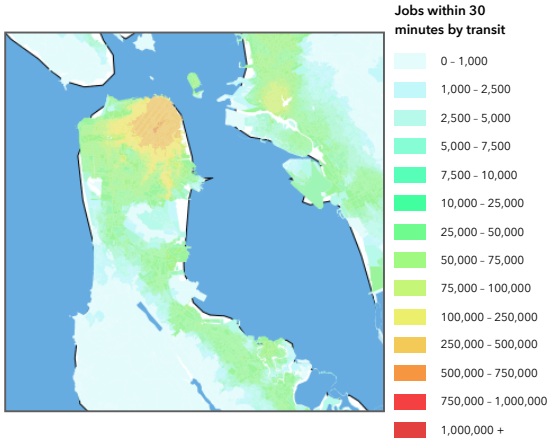
but the effects of land use development may be far greater than the effects of transit changes. This is especially true in the case where transit changes are made in an area with pre-existing service.



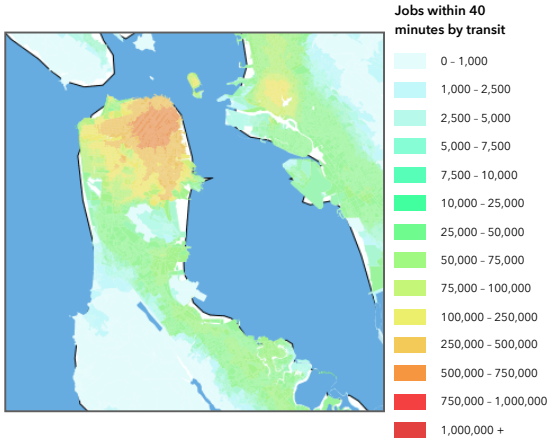
(a) 10 Minute Threshold



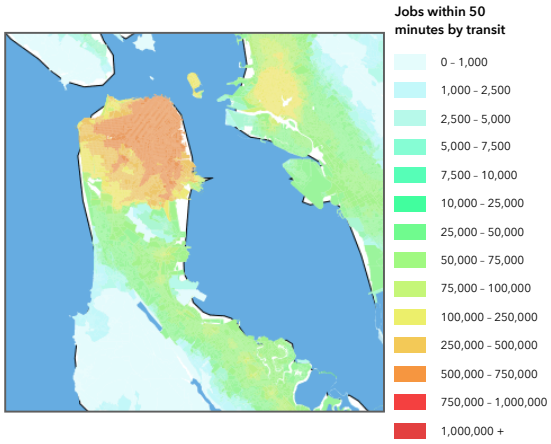
(b) 20 Minute Threshold



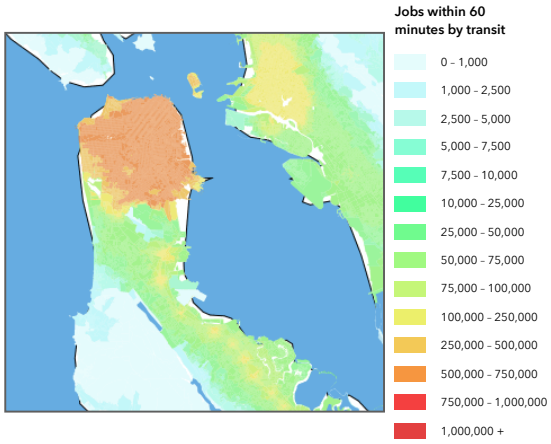
(c) 30 Minute Threshold



(d) 40 Minute Threshold

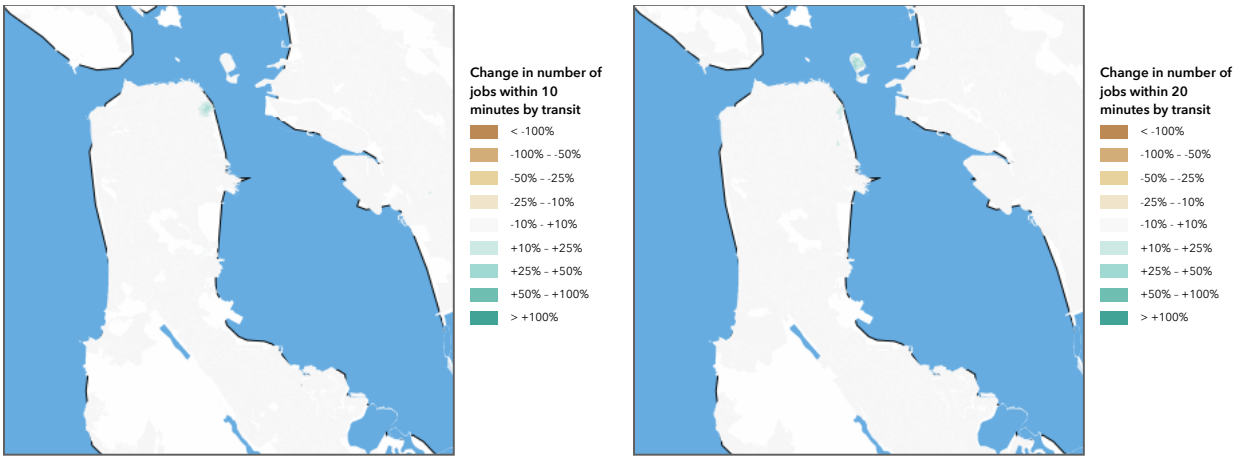


(e) 50 Minute Threshold



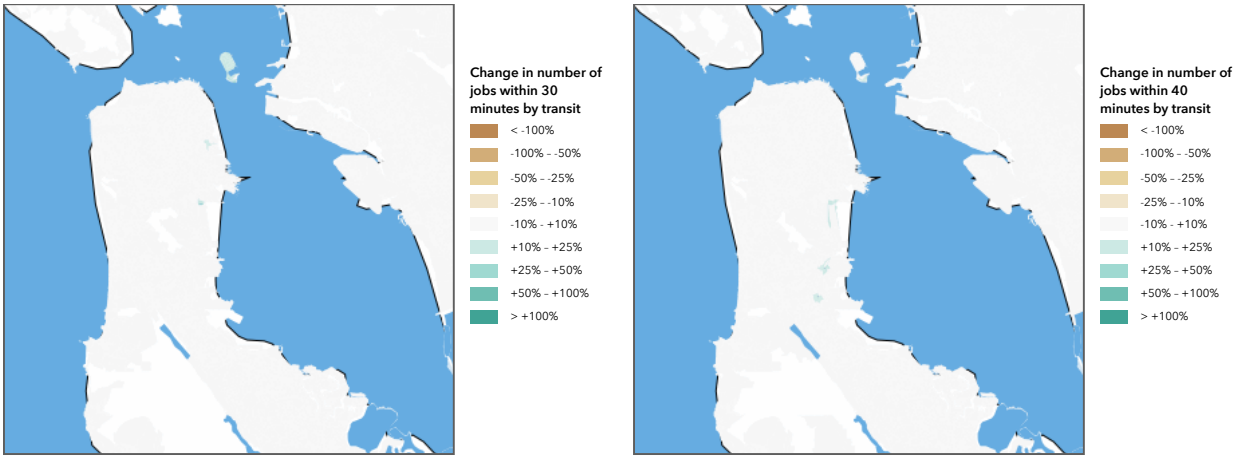
(f) 60 Minute Threshold

FIGURE 5.1 : Total jobs reachable by threshold (Baseline network and 2013 land use)



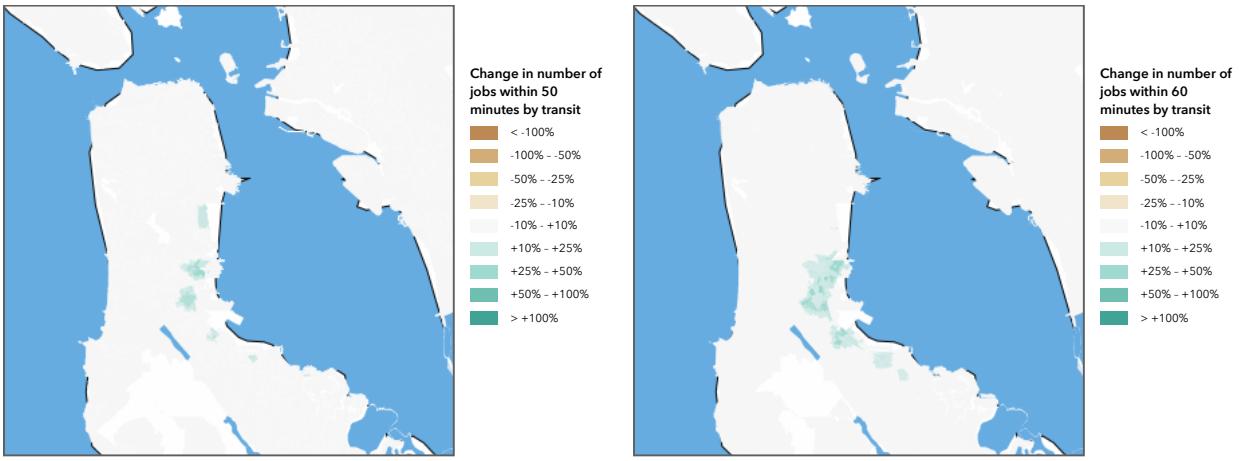
(a) 10 Minutes

(b) 20 Minutes



(c) 30 Minutes

(d) 40 Minutes



(e) 50 Minutes

(f) 60 Minutes

FIGURE 5.2 : Change in number of total jobs reachable by threshold (employment estimates based on the Transit Center District Plan (Growth of 21,500 jobs vs. 2013 LEHD land use)

CONCLUSION

As can be seen in Figure 5.2 the development of the Transbay Transit Center and Rincon Hill results in increases in accessibility to jobs. Furthermore it is interesting to note that high percent changes in accessibility to workers 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 experience by areas surrounding the project. A similar phenomena 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, see Figure 5.1. Table 1 and Table 2 further illustrate that the San Francisco Bay Area as a whole experiences increases in accessibility to both jobs and workers respectively at all thresholds due to the development directly, with an additional benefit of lower magnitude associated with the relocation of transit services to the Transbay Transit Center and thereby closer to the planned development. This then indicates that transit hub projects and transit oriented development have a synergistic effect on accessibility via transit. However, in areas which already have significant existing transit service, transit oriented development will likely produce a far greater impact than the implementation of a transit hub.

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[2] Andrew Owen and David Levinson. Access across america: Transit 2014. 2014.