

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

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1 **ABSTRACT**

2 This paper is a case study of the accessibility impacts of transit projects and nearby development
3 on transit accessibility in a region, which already has significant levels of accessibility via transit.
4 The project under consideration is the San Francisco Transbay Transit Center and the associated
5 planned development. Findings indicate that both portions of the project increase accessibility
6 via transit in the region. However, the contribution from the planned development is far greater.
7 Furthermore, the increase in accessibility from the project as a whole is greater than the sum of the
8 contributions of the individual portions of the project. This indicates that in areas where there is
9 already transit service, the development of land near the transit service can have a greater impact
10 on accessibility levels than the improvement of connections between transit services.

1 **INTRODUCTION**

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

8 **Case Study Description**

9 The San Francisco Transbay Transit Center Development involves the construction and use of the
10 new Transbay Transit Center and the redevelopment of Transbay Zone 1 and Transbay Zone 2,
11 which surround the new transit center, as well as the development of residential units in the nearby
12 Rincon Hill neighborhood. The project will result in a growth of approximately 21,500 jobs and
13 2,700 residential units in Transbay Zone 1 and 2 combined as well as 3,822 residential units in the
14 Rincon Hill neighborhood. In terms of accessibility, the primary impact of the relocation of the
15 transit services to the transit center will be an improved level of connection between various transit
16 services.

17 **LITERATURE REVIEW**

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

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

23 Where:

- 24 A_i = accessibility for location i
- 25 O_j = number of opportunities at location j
- 26 C_{ij} = time cost of travel from i to j
- 27 $f(C_{ij})$ = weighting function

28
29
30 Cumulative opportunities accessibility calculations are one form of gravity weighting sum-
31 mation in which one of the simplest weighting functions, a binary weighting function, is employed.
32 Basically opportunities that can be reached within a given threshold are weighted with a value of
33 one, and those that cannot are weighted with a value of zero [2].

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

34 Where:

- 35 t = travel time threshold

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

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

12 Where:

13 a_w = Weighted accessibility ranking metric for a single metropolitan area

14 a_t = Worker-weighted accessibility for threshold t

15 $\beta = -0.08$

16

17

18 DATA AND METHODOLOGY

19 Data

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

- 1 – 2013 California Household Travel Survey
- 2 – Census Transportation Planning Products – 2000 Workers per Household (provided by
- 3 US DOT)

4 **Project Area**

5 The project is defined by the combination Transbay Zone 1, Transbay Zone 2 and the Rincon Hill
6 neighborhood, however the accessibility impacts are assessed at the regional level.

7 **Land Use Estimates**

8 The *Transit Center District Plan Draft* describes growth of approximately 21,500 jobs and 2,700
9 residential units in Transbay Zone 1 and 2 combined. The *San Francisco General Plan: Rincon*
10 *Hill Area Plan* further describes growth of approximately 3,822 residential units in the Rincon Hill
11 neighborhood.

12 Finally, it was necessary to make an assumption about the number of workers per house-
13 hold in order to determine the expected growth in number of jobs based on assumed growth in the
14 number of residential units. To this end the San Francisco Bay Area Travel Survey 2000 (which is
15 mentioned in the project planning documents) was utilized to generate an estimate of 1.18 workers
16 per household which is reasonable in comparison to both the estimate of 1.22 workers per house-
17 hold at the national level as provided by the U.S. DOT Census Transportation Planning Products
18 and the estimate of 1.31 workers per household from the 2013 California Household Travel Sur-
19 vey. Due to its local relevance and mention in the planning documents, 1.18 workers per household
20 seems to be the most useful estimate for this analysis.

21 **Accessibility Calculation**

22 The accessibility results presented in this report were calculated using a *cumulative opportunities*
23 accessibility metric. In this approach, the accessibility level of a given origin location is determined
24 by the number of opportunities that can be reached within a given travel time threshold. This
25 analysis evaluated accessibility using travel time thresholds of 10, 20, 30, 40, 50, and 60 minutes.
26 The following sections provide a brief overview of this methodology.

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

32 *Origins and Destinations*

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

1 *Transit Travel Time Calculation*

2 Transit travel time calculations considered all components of travel by transit, including time spent
3 walking to a stop or station, time spent waiting for a trip departure, time spent traveling on a transit
4 vehicle, and time spent walking to a destination after alighting. An unlimited number of transfers
5 was allowed, and time spent walking to and waiting for transfers was included.

6 This analysis used the assumption that all walking portions of a trip take place at a speed
7 of 5 kilometers per hour (3.1 miles per hour). On-vehicle travel time was derived directly from
8 published transit timetables, under an assumption of perfect schedule adherence.

9 Jobs that can be accessed by walking only are included in the accessibility totals; a transit
10 component is not strictly required. This allows the most consistent application and interpretation
11 of the travel time calculation methodology. The shortest walking path from an origin to a transit
12 stop/station in some cases passes through potential destinations where job opportunities exist; these
13 destinations were included even though transit is not required to access them.

14 Accessibility by transit depends strongly on departure time because of the scheduled nature
15 of transit service. For example, if a transit route's service frequency is 20 minutes, then immedi-
16 ately after a vehicle departs all destinations become 20 minutes "farther away." To address this and
17 to reflect the influence of transit service frequency on accessibility, travel times were calculated
18 repeatedly for each origin-destination pair using each minute between 7:00 and 8:59 AM as the
19 departure time.

20 Using the travel time calculations described above, a set of destinations reachable within
21 each travel time threshold was identified for each origin and departure time, and the jobs located
22 at the reachable destinations were aggregated to arrive at a single accessibility data point for that
23 origin and departure time. For each origin, the accessibility data for all 120 departure times were
24 then averaged to provide a single accessibility value indicating the number of jobs that can be
25 reached from that origin within a given travel time threshold, on average, between 7 and 9 AM.
26 These are the values presented and discussed in the following sections.

27 **GTFS Modification**

28 In order to generate GTFS for the network after the Transbay Transit Center is complete, the
29 baseline GTFS network needed to be modified according to the proposals made in the planning
30 documents. The following sections describe the GTFS format and the implementation of modifi-
31 cations.

32 **General Transit Feed Specification**

33 GTFS requires a minimum of six text files in order to sufficiently describe a transit network. These
34 files include: `agency.txt`, `stops.txt`, `routes.txt`, `trips.txt`, `stop_times.txt`,
35 and `calendar.txt`. GTFS also allows for the addition of numerous optional text files in order to
36 provide additional information. Five of these files are affected by the modifications to the network
37 and a brief description of each follows.

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

- 1 • `routes.txt` lists all routes in the network, providing a unique id for each route, as
2 well as a short name and other basic information. New routes are added to the file as part
3 of the modifications.
- 4 • `trip.txt` lists all trips in the network providing a unique trip id, the associated route
5 id, and other basic information about the trips. New trips are added to this file, and the
6 data for rescheduled trips is changed to reflect the modifications.
- 7 • `stop_times.txt` contains the scheduling information. This file lists the time that
8 each trip is at an associated stop, as well as the associated trip id and stop id. Whether
9 a trip is rescheduled or completely new, all of the stops in the trip and the times at those
10 stops are added to this file as part of the modifications (old stop times for rescheduled
11 trips are deleted). However, in some cases a single trip can be used as a representative
12 for many trips. In that case, the stop times are only included once, and the frequency of
13 the trip is indicated in in the `frequencies.txt` file.
- 14 • `frequencies.txt` includes the desired headway of the trip, as well as information
15 about the duration of that headway, and the id of the associated trip.

16 *Route Adjustment*

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

22 **Land Use Modifications**

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

27 **LEHD - 2013 LODES Data**

28 The U.S. Census Longitudinal Employer-Household Dynamics (LEHD) 2013 Origin-Destination
29 Employment Statistics (LODES) consists of three files. The first is a file of origins and destinations
30 of commutes to work, which is not used as part of this analysis. The second is a file containing
31 workplace area characteristics (WAC). This file details the number of jobs by category in each
32 census block. The third and final file contains residential area characteristics (RAC). This file
33 details the number of workers by category that live in each census block.

34 *Updating the LEHD Data*

35 In case studies with anticipated development, the planning documents are reviewed to determine
36 the geographic extents of the project and anticipated growth in residential units and commercial
37 space. The anticipated growth in total workers can then be estimated by multiplying the typical

1 number of workers per household by the anticipated number of new residential units. Similarly,
2 the anticipated growth in jobs is determined as the multiplication of the commercial usage factor
3 (number of workers per square foot of commercial space) by the anticipated increase in commer-
4 cial square feet. In the case of the San Francisco Transbay development, this was not necessary
5 because the planning documents indicated an anticipated growth in number of jobs rather than an
6 anticipated growth in commercial square feet. The total increase in workers and jobs for the project
7 extents are then distributed to all potential census blocks within the project extents based on the
8 percentage of the total project area within each census block. So for example a census block which
9 has twenty percent of the total land area of the project is receives twenty percent of the projected
10 growth in jobs and workers. These increases are added to the baseline total number of workers
11 in the RAC file and total number of jobs in the WAC file to generate digitized representations of
12 the proposed land use. Finally, it is assumed that the relative ratio of total jobs to any category of
13 jobs (i.e. jobs with earnings \$1250/month or less, etc.) and the relative ratio of total workers to
14 any given category of workers (i.e. workers of race: white alone, etc.) remain constant so that the
15 predictions for these categories of jobs and workers can be populated based on the predicted total
16 jobs and total workers.

17 **ACCESSIBILITY RESULTS**

18 The San Francisco Transbay Transit Center Development access to jobs and access to workers
19 calculations have been performed, and the access to jobs and access to workers results have been
20 processed, the output for total jobs and total workers is below.

21 The maps in [Figure 5.1](#) illustrate the accessibility by transit to jobs ,averaged between 7 AM
22 and 9 AM, in the baseline scenario. The maps in [Figure 5.2](#) illustrate the change in the number of
23 jobs and workers respectively that can be reached from each block based on the development of
24 the Transbay Transit Center. ¹

25 **Decomposing the Accessibility Changes**

26 As can be seen in [Table 1](#) both the land use changes and the transit changes impact accessibil-
27 ity levels. However, the impacts of the transit changes alone are minimal in comparison to the
28 effects of the anticipated land use changes. For example given only the new land changes the typ-
29 ical worker can reach an additional 1,647 jobs in thirty minutes. However, given only the transit
30 changes the typical worker can reach an additional 5 jobs. When the two changes are both taken
31 into account, the typical worker can reach only an additional 1,655 jobs which is more than the
32 sum of the benefits of the individual projects (1,652 additional jobs). A similar case can be made
33 for the increase in the access to workers, see [Table 2](#). Therefore, this case study indicates that
34 transit projects and land use development can have a synergistic effect on accessibility via transit,

¹When 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.

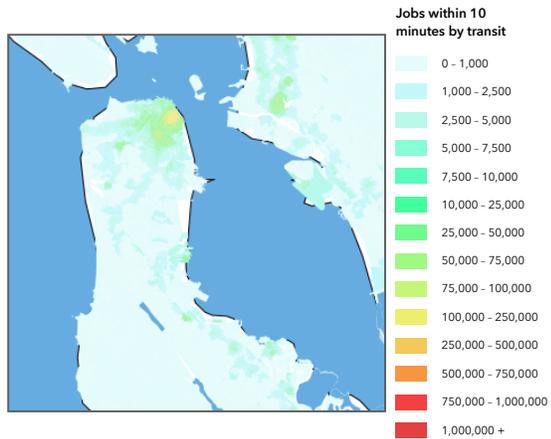
TABLE 1 : Regional Worker - Weighted Accessibility to Jobs using 2013 LEHD Data vs. Worker estimates based on the Transit Center District Plan and the Rincon Hill General Plan (Growth of 6,522 Residential Units and 1.18 workers/household from the 2000 San Francisco Bay Area Travel Survey) and Employment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

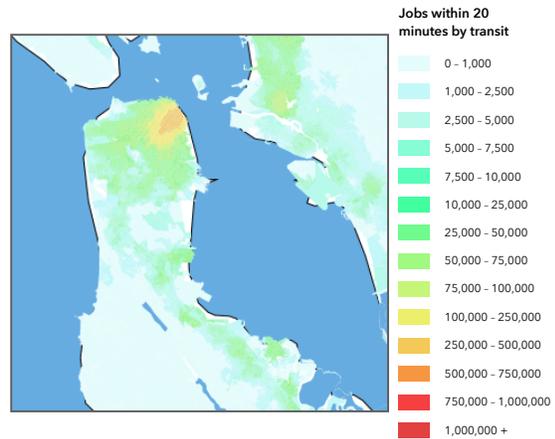
TABLE 2 : Regional Job - Weighted Accessibility to Workers using 2013 LEHD Data vs. Worker estimates based on the Transit Center District Plan and the Rincon Hill General Plan (Growth of 6,522 Residential Units and 1.18 workers/household from the 2000 San Francisco Bay Area Travel Survey) and Employment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

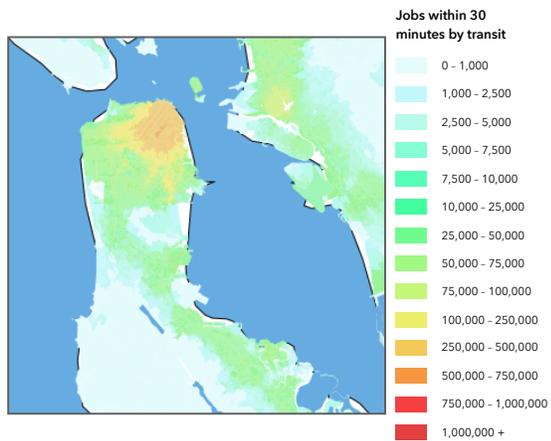
- 1 but the effects of land use development may be far greater than the effects of transit changes. This
2 is especially true in the case where transit changes are made in an area with pre-existing service.



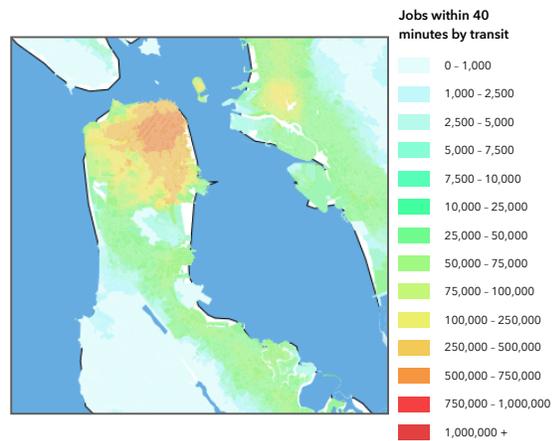
(a) 10 Minute Threshold



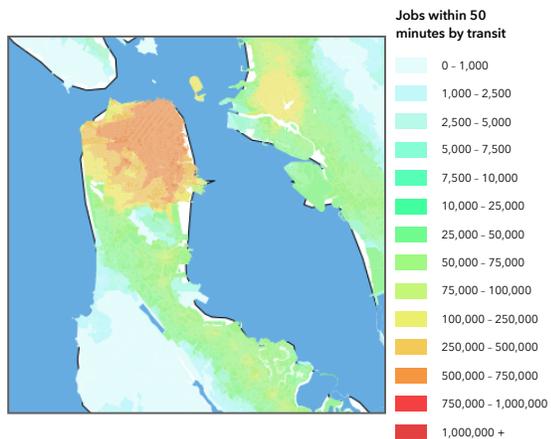
(b) 20 Minute Threshold



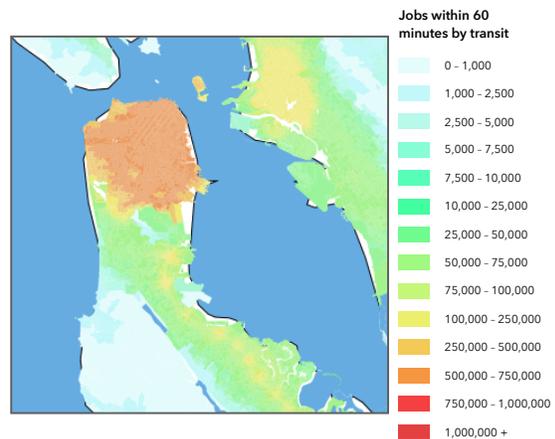
(c) 30 Minute Threshold



(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)

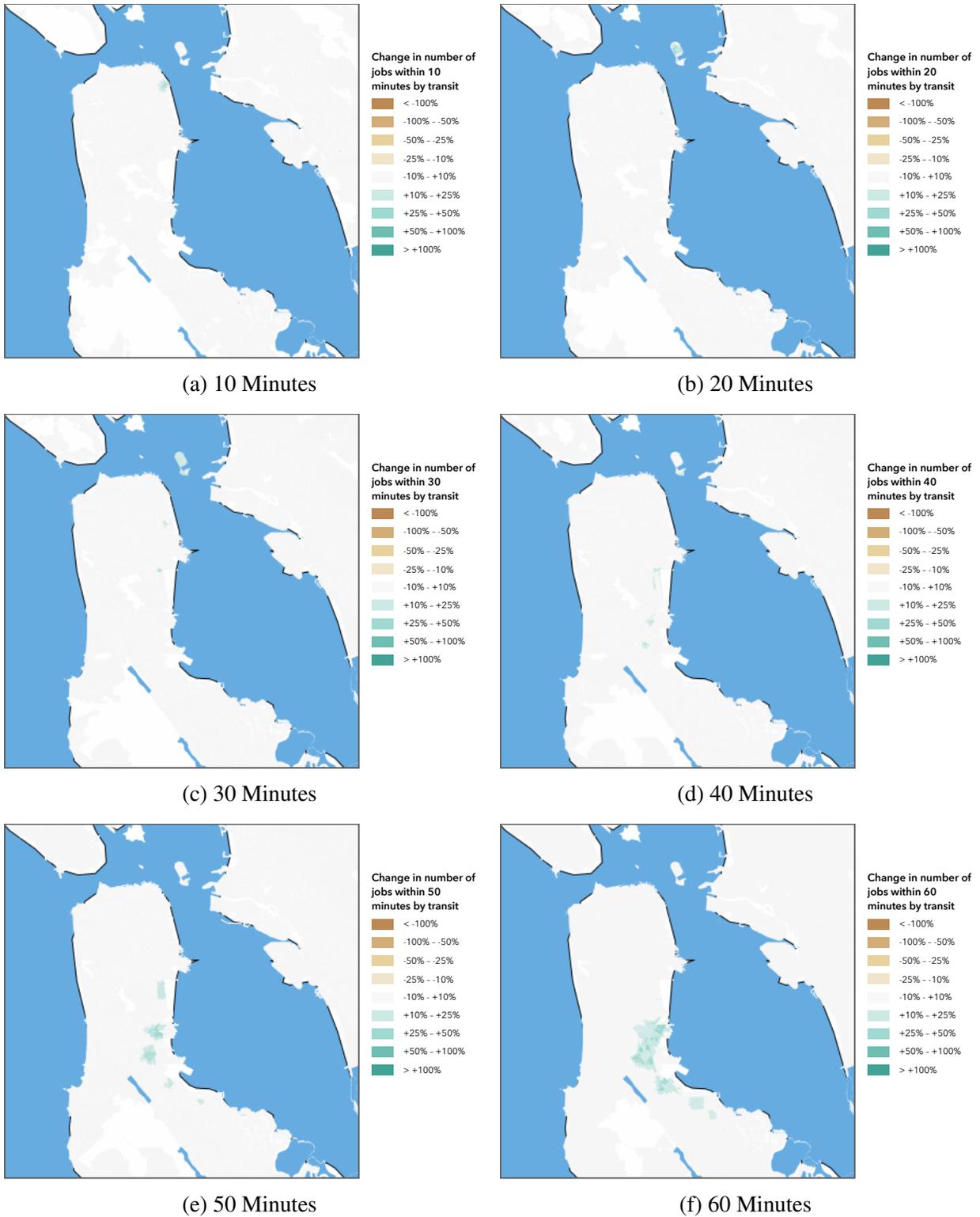


FIGURE 5.2 : Change in number of total jobs reachable by threshold (employment estimates based on the Transit Center District Plan (Growth of 21,500 jobs vs. 2013 LEHD land use)

1 **CONCLUSION**

2 As can be seen in [Figure 5.2](#) the development of the Transbay Transit Center and Rincon Hill
3 results in increases in accessibility to jobs. Furthermore it is interesting to note that high percent
4 changes in accessibility to workers are localized within or near the project area, for thresholds at
5 or below 30 minutes, with little or no change in higher thresholds. This localization is likely due
6 to the already high levels of accessibility experience by areas surrounding the project. A similar
7 phenomena occurs for access to jobs, however at higher thresholds the areas impacted are further
8 from the project area. This is likely due to the larger growth in jobs than workers coupled with
9 the lower accessibility to jobs in the areas showing higher percent increases than in the areas near
10 the project at thresholds at or above 40 minutes, see [Figure 5.1](#). [Table 1](#) and [Table 2](#) further
11 illustrate that the San Francisco Bay Area as a whole experiences increases in accessibility to both
12 jobs and workers respectively at all thresholds due to the development directly, with an additional
13 benefit of lower magnitude associated with the relocation of transit services to the Transbay Transit
14 Center and thereby closer to the planned development. This then indicates that transit hub projects
15 and transit oriented development have a synergistic effect on accessibility via transit. However,
16 in areas which already have significant existing transit service, transit oriented development will
17 likely produce a far greater impact than the implementation of a transit hub.

18 **ACKNOWLEDGEMENTS**

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20 like to thank FHWA for their support. All opinions and results presented in this paper are the
21 responsibility of the authors.

1 **REFERENCES**

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3 *planners*, 25(2):73–76, 1959.

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