Impact of Light Rail Implementation on Labor Market Accessibility: 
A Transportation Equity Perspective

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August 1, 2010
ABSTRACT
This study seeks to examine transit’s role in promoting social equity by assessing impacts of recent transit changes in the Twin Cities, including opening of the Hiawatha light rail line, on job accessibility among workers of different wage categories. Geo-spatial and descriptive analyses are employed to examine the magnitude of the accessibility changes and where changes occur. This study also uses regression analysis to estimate block-level before- and after-LRT accessibility as a function of the block’s locational characteristics and demographic composition. The analysis finds that proximity to light rail stations and bus stops offering direct rail connections are associated with large, statistically significant gains in accessibility to low-wage jobs. These gains stand out from changes in accessibility for the transit system as a whole. The paper concludes by discussing implications of the study results for informing more equitable transit polices in the future.
INTRODUCTION
Transit is more than just transportation: it helps to address poverty, unemployment, and equal opportunity goals (1, 2, 3). People with reliable, rapid transportation can easily commute between home and work even if the two are physically far apart: the issue of job access is often a problem of mobility. For low-income families, automobile ownership—particularly of reliable automobiles—is far from universal. Additionally, jobs that low-income urban residents are normally qualified for are often most common in suburban areas lacking either affordable housing or quality transit service. This is the basis of Kain’s spatial mismatch hypothesis: that lack of both affordable housing near employment centers and reliable, rapid transportation significantly harms employment outcomes for the urban poor (4).

Surveys of low-income individuals confirm transportation is a barrier to employment success (5, 6). Evidence shows low automobile ownership rates among low-income people and that existing transit typically fails to accommodate low-income job seekers’ travel needs—many entry-level jobs require working nights or weekends when service is often reduced or non-existent (3, 7, 8). Such uneven access to job opportunities have led to transit-related planning and policy efforts to address the job access problems of low-income people, including the famous Job Access and Reverse Commute (JARC) program established under the Transportation Equity Act for the 21st Century (TEA-21).

Despite expectations that transit improvements would positively affect employment status for the poor, empirical evidence is inconsistent. Employment benefits from transit improvements are often predicted but not empirically demonstrated (10). Out of the few rigorous studies examining employment impact of transit improvements, studies in Los Angeles find positive effects (11, 12, 13), but studies elsewhere show little or no association between transit and employment participation (10, 14, 15, 16, 17). Multiple explanations of this inconsistency have been suggested. Some cite difficulties in determining the effectiveness of transit programs for disadvantaged groups, including no accepted performance measures, inability to control for intervening factors affecting employability, etc. In addition, as low-wage workers benefit from increased job access, many purchase automobiles, ending their transit-dependency and increasing the difficulty of assessing transit’s employment outcome impacts. Many researchers also concede that inconsistencies in the literature partially reflect ineffectiveness of U.S. transit in meeting the needs of disadvantaged groups, especially unemployed single mothers. Chapple (2001) interviewed women on welfare in San Francisco, finding that low-income women with children generally seek jobs near home (11). On transit, such women face long commutes, incompatible with parental responsibilities and employment constraints. As a result, this lack of quality transit diminishes suburban jobs’ attractiveness to unemployed single mothers.

The review above seems to be sending a mixed message: while transit is important to low-income people, transit improvement may not help them. This message underscores the importance of evaluating major transit investments from a transportation equity perspective. Major transit capital projects—particularly rail transit lines—represent large, one-time expenditures, with total construction costs generally in the hundreds of millions of dollars. In the past, critics of transit improvements have often pointed out instances in which ridership gains were greatly overstated during planning while capital and operating costs were greatly understated. In addition to the frequently-touted criticism on Buffalo’s population-losing light rail line, projects from Baltimore, Miami, Pittsburgh, Sacramento and Portland have been criticized for the same reasons (18). In addition, rail transit investments have been characterized as serving mainly middle-class suburbanites, sometimes to the detriment of poorer, transit-
dependent urbanites; the landmark civil rights suit brought by the Bus Riders Union in Los Angeles provides a prime example (19). Given these circumstances, knowing the scope and size of job accessibility benefits associated with specific types of transit investments (e.g., light rail) for low-income residents will help policy makers make more informed investment decisions towards an equitable transportation system.

This study aligns with the research needs for quantifying job accessibility impacts of transit improvements among low income resident. We focus on a recent light rail implementation in the Twin Cities—the Hiawatha light rail line and examines how such an implementation have shaped job accessibility in the region. More specifically, we attempt to answer the following two questions: Does the light rail implementation make job opportunities more accessible to low-income individuals, contributing to improvements in transportation equity? How do the benefits for low-income individuals compare to those of high-income people?

The next section describes the study area and population. This is followed by an meaningful comparison and map analysis of before- and after-LRT job accessibility. Regression analysis follows, estimating accessibility at the census block level to low-wage, high-wage and all jobs as a function of proximity to LRT stations and other transit stops, as well as socioeconomic characteristics of blocks. The paper concludes with policy implications of the study findings.

**STUDY AREA AND POPULATION**

This paper centers on the Hiawatha light rail line, which connects downtown Minneapolis with numerous South Minneapolis residential neighborhoods, the Minneapolis-Saint Paul International Airport and the Mall of America in suburban Bloomington. The line attracts about 30,000 average weekday boardings, making it the most heavily used transit route in the Twin Cities metro area (20). Figure 1 shows the location of the light rail line relative to regional landmarks, as well as the bus routes in Metro Transit’s Hi-Frequency network (shown as bold yellow lines), which offers quarter-hourly (minimum) rail/bus service from 6:00am to 7:00pm weekdays and 9:00am to 6:00pm Saturdays, and the rest of the transit system.

Given the research’s transportation equity perspective, an important study population are low-wage workers (also can be referred as “working poor”) who maintain regular employment but remain in relative poverty. Quantitatively defining this population has proven to be a more difficult task. The national Working Poor Families Project (WPFP) simply defines working poor as low-income individuals and families that struggle to meet basic needs (21). WPFP uses incomes less than 200 percent of the Federal poverty threshold as a benchmark for low-income. In 2006, the poverty threshold for a family of three with one child under 18 was $16,227, meaning that families earning less than $32,454 would be considered low-income (22, 23). Based on this WPFP definition, there were approximately 9.6 million low-income working families in the United States in 2004, of which 2.5 million were considered to be in poverty based on official Federal government definitions (22).

Some define the working poor as families with a working head of household who earn less than the Federal poverty threshold for their household size/composition (23). Others, however, point out that the official poverty line does not consider taxes, in-kind transfer payments such as food stamps, working expenses including child care and transportation, disparities with average standards of living or income inequalities among the poor. The appropriate “poverty line” is the subject of considerable debate (24).
Existing definitions mentioned above (despite being inconsistent) have assisted various non-profit organizations and public agencies in identifying the work poor population and their specific needs. However, key challenges remain when it comes to practical applications of these definitions. The US Census Bureau only provides a limited amount of information on income and earning such as median household income at the census block group level and the percentage of families/children under the federal poverty line within the census block group, which cannot be easily translated into information on the number of working poor in the area. In this research, we employ the Census Bureau’s Longitudinal Employer and Housing Dynamics (LEHD) dataset. The nature of the dataset poses limitations on how we define our study population. This annually collected dataset counts individual incomes and wages in each of three categories (<$1,200/month, $1,200-$3,400/month and >$3,400/month) at block level (25). For the purposes of this research, jobs in the lowest category—equivalent to <$14,400 per year and accounting for roughly 25% of the jobs in the Twin Cities’ transit service area—are considered low-wage jobs, and used as indicators of the entry-level jobs the working poor are more likely to be qualified for. Jobs in the highest wage category are equivalent to >$40,800 per year and 42% of transit-served jobs. For context, 2006 per-capita income in the seven Twin Cities metro counties was $31,400. (26)
FIGURE 2 Locations of Low Wage Workers/Jobs Relative to LRT and Bus Connections.
Figure 2 locates low-wage jobs and low-wage workers before and after LRT implementation (which included other transit network changes) relative to the light-rail line and the connecting bus routes that offer LRT connections within 30 minutes. These maps make it clear that spatial mismatch exists in the Twin Cities. Though some areas that are home to many low-wage workers also offer large numbers of low-wage jobs, most have one and not the other, or neither. This pattern puts special emphasis on effective transit as means of promoting social equity in the region.

**ACCESSIBILITY ANALYSIS**

This research applies a cumulative opportunity approach to calculate job accessibility. This method counts how many jobs can be reached within a predetermined travel time. This study uses 30 minutes as the threshold, since a 15- or 20-minute cutoff would mean the majority of the cutoff time being spent waiting for a bus to arrive, and since long cutoff times would likely seriously skew results given our ≤1 transfer assumption and that longer transit trips often require multiple transfers. As transit service levels change throughout the day, the analysis employs weighted average accessibility figures including the early-morning off-peak, morning peak, mid-day off-peak, evening peak and late-evening off-peak periods of the service day. Weights stem from percentages of transit rides from peak and off-peak periods, reported in a 2006 on-board survey of riders conducted by Metro Transit (27). Separate averages were produced for low-wage, high-wage and all jobs; each category received weights based on the travel behavior of riders in that income group—54.88% peak, 45.12% off-peak for low-income riders; 80.05% peak, 19.95% off-peak for high-income riders; 69.74% peak, 30.26% off-peak for all riders. To show changes in job accessibility by transit before and after LRT, we describe the pre-Hiawatha condition using the 2000 transit network and 2002 employment, and the post-Hiawatha condition using the 2005 transit network and 2006 employment.

**Map Analysis**

Figure 3 shows pre- and post-LRT accessibility to low-wage jobs via transit, along with changes in accessibility between observations. It is immediately apparent that major low-wage employment accessibility gains occurred both along the Hiawatha LRT corridor and other high-frequency bus corridors, particularly University Avenue (which will be the alignment of the planned Central Corridor LRT scheduled to open in 2014);

While most of downtown Minneapolis gains accessibility, the large gains along routes connecting with LRT outside downtown are particularly striking. Many of these gains occur along cross-town and suburban local bus routes, with the effect of broadening accessibility gains beyond the LRT corridor. Other large gains occur along outer portions of local routes continuing downtown after their connections; these trips are often better served by a rail transfer than a one-seat bus ride. Areas not adjacent to the LRT stations, bus stops with bus-LRT connections, or along Hi-Frequency bus routes mostly show either no change or a slight decline in accessibility to low-wage jobs.
FIGURE 3  Transit Accessibility to Low-Wage Jobs, Comparing 2000/2002 and 2005/2006.
Statistical Analysis
In all of the accessibility models, the dependent variable describes census-block-level 30-minute cumulative accessibility by transit (with a maximum of one route-transfer) to low-wage, high-wage, or all jobs. Changes in low-wage job accessibility are the main focus. The high-wage and all jobs categories are included for comparison. Only blocks served by transit (defined by a 0.25-mile [400m] maximum walking distance) were considered. Independent variables can be broken into two groups: those describing locations of blocks, and those describing socio-demographic characteristics within blocks. These two groups serve different functions. In the case of the spatial variables, it is easy to form reasonable hypotheses about their relationships to transit job accessibility—one expects accessibility to increase as distance to downtown Minneapolis decreases, for example: these variables are primarily included to test expected relationships.

In terms of the demographic variables, however, it is harder to make even educated guesses about what relationships with transit job accessibility to expect, as many are unlikely to be causal. This second group of variables, in other words, is included to shed light on general trends about which relatively little is known, but which may impact how well populations with great needs for quality transit are served.

The location-based independent variables included in this research are as follows:

- **Distance to nearest stop**—Distance in miles to nearest transit stop, regardless of type. (measured from block centroids.)
- **Downtown**—Dummy variable identifying blocks to which the nearest transit stop is an LRT station in downtown Minneapolis. The maps show large localized accessibility gains around LRT stations—in which case we expect positive coefficients.
- **North**— Dummy variable identifying blocks to which the nearest transit stop is the Cedar—Riverside, Franklin Avenue or Lake Street—Midtown LRT station. Positive coefficients expected.
- **South**— Dummy variable identifying blocks to which the nearest transit stop is the 38th Street, 46th Street, 50th Street—Minnehaha Park or VA Medical Center LRT station. Positive coefficients expected.
- **Suburb**— Dummy variable identifying blocks to which the nearest transit stop is an LRT station in the suburbs. Positive coefficients expected.
- **Connection**—Dummy variable identifying blocks to which the nearest transit stop is a bus stop offering a direct connection (<30 min.) to LRT. Positive coefficients expected.
- **Hi-Frequency**— Dummy variable identifying blocks to which the nearest transit stop is a bus stop served by a Hi-Frequency bus route with no LRT connection. Positive coefficients expected. (Regular bus service is omitted as the reference category. Regression incidence rate ratios show percentage differences from blocks with only regular bus service.)

This research breaks the LRT station areas into four groups: downtown, north, south, and suburb. The classification is not only based upon differences in urban forms and built environments (i.e., downtown versus suburb), but also upon differences in socioeconomic characteristics across station area. There is a significant divide between the Cedar—Riverside, Franklin Avenue and Lake Street—Midtown station areas (i.e., the north category) and the 38th Street, 46th Street, 50th
Street—Minnehaha Park and VA Medical Center station areas (i.e., the south category). The north neighborhood station areas are surrounded by dense, urban neighborhoods including significant amounts of public housing and numbers of low-income residents. The south neighborhoods, however, though still in Minneapolis, take on a more suburban feel, and are dominated by single-family housing and more middle-class residents.

The demographic-based independent variables included in this research are as follows:

- **African American**—Percentage of block residents who are African-American.
- **Latino**—Percentage of block residents who are Latino.
- **Asian**—Percentage of block residents who are Asian.
- **Single Parent**—Percentage of families in a block headed by a single parent with children present.
- **College Degree**—Percentage of block-group residents over the age of 25 with a bachelor’s or higher degree.
- **Owner Occupied**—Percentage of occupied housing units in a block-group which are owner-occupied.
- **Zero Vehicle HH**—The percentage of households in the block-group with no automobile.
- **Median HH Income**—Median household income, in thousands of dollars, of the block-group.

### Descriptive Statistics

Table 1 shows descriptive statistics for the variables:

| TABLE 1 Descriptive Statistics |
|--------------------------------|
| N=22588 blocks                |
| Mean                         |
| Std. Dev.                    |
| Min                          |
| Max                          |
| Pre-LRT  | Post-LRT | Pre-LRT | Post-LRT | Pre-LRT | Post-LRT | Pre-LRT | Post-LRT |
|--------------------------|
| Low-Wage Job Accessibility | 7610      | 8826    | 8285     | 10223   | 0        | 0       | 64622   | 85899   |
| High-Wage Job Accessibility| 16848     | 21924   | 20199    | 27152   | 0        | 0       | 132106  | 167735  |
| All Job Accessibility      | 36532     | 436189  | 42051    | 52737   | 0        | 0       | 301646  | 373635  |
| Distance to nearest stop (mi)| 0.114     | 0.114   | 0.058    | 0.058   | 0.001    | 0.001  | 0.25    | 0.25    |
| Downtown                  | 0.004     | 0.004   | 0.060    | 0.060   | 0        | 0       | 1       | 1       |
| North                     | 0.003     | 0.003   | 0.052    | 0.052   | 0        | 0       | 1       | 1       |
| South                     | 0.003     | 0.003   | 0.056    | 0.056   | 0        | 0       | 1       | 1       |
| Suburb                    | 0.001     | 0.001   | 0.023    | 0.023   | 0        | 0       | 1       | 1       |
| Connection                | 0.393     | 0.393   | 0.488    | 0.488   | 0        | 0       | 1       | 1       |
| Hi-Frequency              | 0.145     | 0.145   | 0.352    | 0.352   | 0        | 0       | 1       | 1       |
| African American (%)      | 0.056     | 0.056   | 0.129    | 0.129   | 0        | 0       | 1       | 1       |
| Latino (%)                | 0.033     | 0.033   | 0.080    | 0.080   | 0        | 0       | 1       | 1       |
| Asian (%)                 | 0.041     | 0.041   | 0.095    | 0.095   | 0        | 0       | 1       | 1       |
| Single Parent (%)         | 0.179     | 0.179   | 0.136    | 0.136   | 0        | 0       | 1       | 1       |
| College Degree (%)        | 0.334     | 0.334   | 0.191    | 0.191   | 0        | 0       | 0.93    | 0.93    |
| Owner-Occupied (%)        | 0.639     | 0.639   | 0.407    | 0.407   | 0        | 0       | 1       | 1       |
| Zero Vehicle HH (%)       | 0.107     | 0.107   | 0.123    | 0.123   | 0        | 0       | 0.877   | 0.877   |
| Median HH Income (K)      | 51.579    | 51.579  | 21.975   | 21.975  | 0        | 0       | 200     | 200     |

All three dependent variables’ mean values (jobs by category within 30 minutes by transit) increase substantially after the implementation of LRT and reconfiguration of the bus network, showing an overall gain in regional employment accessibility. Though the three wage
groups increase by different amounts, bear in mind they have different starting points and that the low- and high-wage categories are not thirds of the metropolitan job market—high wage jobs in general greatly outnumber low-wage jobs. Standard deviations for the accessibility variables are invariably greater than means, showing considerable variation in transit-based employment accessibility based on one’s home location within the transit service area. Figure 4 shows percent change in accessibility before and after the LRT implementation, by types of closest transit service: LRT, rail-connecting bus, regular bus and the overall system. Once again, strong accessibility gains appear for all wage levels. For all three wage groups, LRT station areas experience the greatest relative gains by far, followed by connecting bus routes and the system as a whole, with regular bus routes showing relatively minor accessibility gains. When compared by wage categories, high-wage jobs experience larger gains than low-wage jobs.

![FIGURE 4 Percent Changes in Low-, High-, and All-Wage Job Accessibility by service type.](image)

Among the independent variables (which are constant across all models), while mean values for LRT station-area dummies are very small, in sum accounting for only 1.1% of the transit service area, the mean for Connection shows that 38.5% of the transit service area is most closely served by a bus stop offering a direct LRT connection.

**Regression Analysis**

The regression analysis employs a negative binomial model. Negative binomial regression is better suited to count outcomes than ordinary least squares regression, particularly when zero values are involved. In addition, negative binomial models are better suited than linear models to the positively-skewed distribution of dependent variables present in this study. However, as negative binomial regression is a non-linear function, interpreting its coefficients is considerably
more complex than interpreting OLS regression coefficients. Therefore, results provide an Incidence Rate Ratio (IRR) for each variable, as well as a coefficient. The IRR represents the percentage change in the dependent variable associated with one unit of change in the independent variable as follows: (IRR*100%)-100% =% change in dependent variable. Put simply, an IRR of 1.1 predicts a 10% increase in the dependent variable for each unit increase in the independent variable, while an IRR of 0.9 predicts a 10% decrease in the dependent variable for each unit increase in the independent variable. In interpreting the regression results, our primary interest is not in the raw coefficients or IRRs themselves, but in the difference between the pre-Hiawatha and post-Hiawatha models-including the effects of the constant terms. Separate models were estimated for each wage category before and after LRT.

Table 2 shows the results of the six regression models. Of the LRT station area dummy's, only Downtown achieves statistical significance before LRT for all wage levels and produce strongly positive coefficients, meaning that before the LRT implementation, out of all the LRT station areas, only downtown station areas have higher accessibility to all job categories than areas served by regular bus service. In contrast, all LRT station area dummy's are significant in the post-LRT models, suggesting that after the LRT implementation all areas adjacent to the LRT stations have higher accessibility to low- and high-wage jobs than areas served by regular bus service. This indicates significant before-after improvement in transit-based job accessibility in LRT station areas, especially in North, South, and Suburban station areas. Similarly, areas on the Hi-Frequency Bus network also have higher accessibility.

### TABLE 2 Regression Results

| Dependent = ln(Number of Jobs by Type within 30 minutes by Transit) | Low-Wage Jobs | High-Wage Jobs | All Jobs |
|---|---|---|---|
| N=22588 | Before | After | Before | After | Before | After |
| LR Chi2 | 9199.43 | 12175.04 | 9515.03 | 12292.18 | 9596.2 | 12998.32 |
| Probability > Chi2 | 0.0028 | 0.027 | 0.0203 | 0.0254 | 0.0189 | 0.026 |
| Pseudo R2 | 0.565*** | 0.403*** | 0.562*** | 0.456*** | 0.562*** | 0.456*** |

| Coeff. | IRR | Coeff. | IRR | Coeff. | IRR | Coeff. | IRR |
|---|---|---|---|---|---|---|---|
| Distance to nearest stop (mi) | -3.252*** 0.039 | -2.695*** 0.809 | 0.068 | 3.836*** 0.022 | -3.365*** 0.035 | -3.581*** 0.028 | -3.079*** 0.046 |
| Downtown | 0.441*** 1.554 | 0.618*** 1.694 | 1.855*** 0.527*** 1.694 | 0.496*** 1.643 | 0.511*** 1.666 | 0.570*** 1.768 |
| North | 0.078 1.081 | 0.336** 1.225 | 1.400 0.203 | 3.74** 1.453 | 0.154 | 1.166 | 0.366** 1.442 |
| South | -0.21 0.811 | 0.830*** 0.872 | 2.292 -0.137 | 1.158*** 3.184 | -0.163 | 0.849 | 1.032*** 2.807 |
| Suburb | -0.096 0.909 | 0.552* 0.834 | 1.737 -0.182 | 0.921** 2.511 | -0.124 | 0.883 | 0.782** 2.186 |
| Connection | 0.712*** 2.039 | 0.837*** 2.578 | 2.310 0.947*** | 1.117*** 3.057 | 0.859*** 2.362 | 1.014*** 2.757 |
| Hi-Frequency | 0.421*** 1.524 | 0.446*** 1.377 | 1.562 0.320*** | 0.358*** 1.431 | 0.358*** 1.430 | 0.393*** 1.481 |
| African-American (%) | 0.393*** 1.481 | 0.337*** 1.913 | 1.400 0.649*** | 0.648*** 1.913 | 0.558*** 1.748 | 0.536*** 1.710 |
| Latino (%) | 1.418*** 4.130 | 1.396*** 5.455 | 4.040 1.916*** | 1.696*** 5.455 | 1.735*** 5.667 | 1.587*** 4.887 |
| Asian (%) | 0.858*** 2.358 | 1.009*** 3.350 | 2.743 1.187*** | 1.209*** 3.350 | 1.053*** 2.866 | 1.108*** 3.030 |
| Single Parent (%) | 0.391*** 1.479 | 0.425*** 1.935 | 1.530 0.660*** | 1.935 0.668*** 1.951 | 0.563*** 1.756 | 0.589*** 1.802 |
| College Degree (%) | 1.634*** 5.124 | 2.008*** 7.327 | 7.447 1.578*** | 4.845 1.997*** 7.368 | 1.581*** 4.860 | 1.025*** 7.579 |
| Owner Occupied (%) | -0.039* 0.961 | -0.042** 0.959 | 0.083*** 0.921 | -0.101*** 0.904 | -0.070*** 0.933 | -0.082*** 0.921 |
| Zero Vehicle HH (%) | 1.812*** 6.122 | 1.530*** 4.859 | 4.617 1.855*** | 6.391 1.581*** 4.859 | 1.846*** 6.335 | 1.573*** 4.821 |
| Med. HH Income (K) | -0.012*** 0.988 | -0.015** 0.985 | 0.013*** 0.987 | -0.016*** 0.984 | -0.013*** 0.988 | -0.016*** 0.984 |
| Constant | 8.348*** | 8.383*** | 9.051*** | 9.189*** | 8.859*** | 9.000*** |
| In Alpha Cons. | 0.319*** | 0.124*** | 0.565*** | 0.403*** | 0.456*** | 0.242*** |

*p<0.1; **p<0.05; ***p<0.01
When looking at the pre- and post-LRT models of accessibility to low-wage jobs, the positive before-after difference in IRR is visible across all station area dummies and the connection dummy. The highest before-after changes are seen with the South and Suburban dummies. IRR of the South dummy increases from 0.81 (p>0.1) to 2.29 (p<0.001) after LRT implementation, meaning that the south LRT station areas’ accessibility to low-wage jobs is originally similar to that of regular bus service area in the before period but the areas’ accessibility becomes 129% higher than regular service area in the after period. To summarize, LRT-associated accessibility benefits for low-wage workers are highest in south and suburban LRT station areas, followed by downtown and north station areas as well as bus-LRT connection areas.

Model results can also be compared across wage categories. Low-wage models produce a higher post-LRT IRR for Downtown (1.86) than the downtown IRRs produced by the post-LRT high-wage model (1.64). This suggests that, after controlling for bus service frequency and area socio-demographics, downtown LRT station areas’ access to low-wage jobs is 86% than regular bus service area, and the areas’ access to high-wage jobs is only 64% higher than regular service area. In other words, low-wage workers who live in downtown LRT stations areas relatively benefited more from the LRT implementation than than the areas’ high-wage workers. However, comparison across other station area dummies and the connection area dummy show that low-wage workers in other LRT station areas relatively benefited less from the LRT implementation than high-wage workers in those areas.

Overall, the trend for the dummy variables dealing with light rail is one of improved accessibility after the introduction of light rail: station area dummies which are significant before implementation always produce higher IRR’s after, while the station areas which are not significant before LRT all become significant after, and produce high IRR’s showing significant accessibility benefits compared with the study area as a whole. It is particular important to note the consistency and strength of this trend for Connection. The behavior of this variable not only is a indication of the Hiawatha LRT’s success but also underscores the importance of good bus-LRT connections in broadening the impact scope of LRT lines. In other words, we should not attribute the positive and significant accessibility increase observed in the connection areas to the Hiawatha LRT, but the good integration of the Hiawatha LRT with the existing transit system in the Twin Cities.

Note that the limits of one connection and ≤0.25mi (400m) walking used in the accessibility calculations likely understate the actual importance of light rail connections for routes which connect outside downtown. Since the employment centers at either end of the light rail line are both considerably larger than the walking distance assumption, many commutes to these areas would either require more than a 0.25mi (400m) walk, or an additional, short bus ride at the destination end. Given our maximum-one-transfer assumption, such trips would not be captured by the analysis.

The three demographic variables describing racial/ethnic minorities invariably show positive relationships between minority percentages of block populations and employment accessibility by transit. While African-Americans, Latinos and Asians show different changes in their ability to access jobs by transit compared with other races/ethnicities—African American IRR’s either decline slightly or show no change, Latino IRR’s show either slight (for low-wage jobs) or significant (for high-wage and all jobs) declines, while Asian IRR’s all increase slightly—the high, postive IRR values for the racial variables before and after the LRT implementation (ranging from 1.4 to 7.6), show that members of these important minority groups consistently enjoy high relative transit accessibility both before and after light rail. Finally, the
variable for percentage of households without a motor vehicle always, as one might expect, shows a strongly positive relationship with transit accessibility before and after light rail as well.

**Marginal Effects**

In addition to IRR’s, the marginal effects of the models were estimated at various values of transit stop distance, and graphs of the predicted behavior of the accessibility variables with respect to distance from transit stops were produced in Figure 5. Predicted values are shown at various values of the Nearest transit stop distance variable, with the value of the connection dummy variable set to 1, the values of all other dummy variables set to 0, and all other independent variables held at their mean values. This means that the graphs in Figure 5 illustrate predicted before and after accessibility values in areas with direct bus-LRT connection.

![FIGURE 5a Predicted Accessibility](chart1)

![FIGURE 5b Percent Change](chart2)

**FIGURE 5 Marginal Effects.**

All three income groups show increases in predicted accessibility after light rail (see Fig. 5a.) As one would expect, accessibility is predicted to be highest at a distance of zero from the
nearest stop, declining out to the 0.25mi (400m) limit of the service area definition. However, differences in starting-point values and total numbers of jobs available make direct comparisons difficult. Figure 5b shows the relative changes in accessibility for the three wage categories studied. While accessibility to high-wage jobs shows the greatest gain in accessibility, percentage-wise, accessibility to low-wage jobs shows gains more similar to those observed for accessibility to all jobs, meaning that a low-income job seeker living in bus-LRT connection areas can be expected to have gained a similar amount of transit accessibility to the average job seeker living in those areas.

It is also interesting to note that relative gains in accessibility actually increase with distance to the nearest transit stop. Though, in part, this pattern simply underscores the lower starting-point accessibility values predicted for blocks farther from stops, it also reinforces the regional scale of the accessibility gains found. Rather than taking the form of extremely localized gains that disappear with distance from stops, increases in accessibility extend to the maximum walking distance considered, shifting the entire absolute-prediction line up the graph without significantly changing its slope.

The disparity between predicted accessibility to low- and high-wage jobs indicates the Twin Cities’ transit network is better at serving high wage than low wage jobs, and that the changes have reinforced that disparity. However, it is clear that accessibility by transit to low-wage jobs did improve significantly between the two observations of the study. Overall, the marginal effects paint a picture of benefits for all, including low-wage workers.

CONCLUSIONS AND DISCUSSION
Overall, the Hiawatha light rail line has benefitted transit dependent and low-wage workers, though not as much as high-wage workers, whose jobs tend to be more concentrated in downtown. Careful consideration of both what the Hiawatha line does well for low-wage workers and what it could possibly do better should inform both the planning of future transit corridors and ongoing planning for areas and connecting transit services surrounding Hiawatha stations. A summary of key findings of this study, and discussion of their policy implications follows:

Spatial mismatch exists in the Twin Cities—As can be seen in Figure 2, major concentrations of low-wage workers and low-wage jobs often do not match up. In addition, both are scattered throughout the metropolitan area. Both of these observations—combined with both relatively high rates of transit dependency among low-wage workers and the large cost-of-living savings that can be realized by low-wage workers by depending on transit—underscore the importance of transit service as a provider of economic opportunity for low-wage workers.

The Hiawatha light rail line, being well-connected with the rest of the transit system in the Twin Cities, has significantly improved accessibility to both low-wage and high-wage jobs—Both the map analysis and regression analysis conducted in this study show significant, positive changes in low- and high-wage employment accessibility by transit after the introduction of light rail transit. By offering frequent, rapid, all-day services, premium transit services such as light rail and bus rapid transit hold special significance for low-wage workers and the transit dependent, as they are much more likely than others to use transit at off-peak times. In planning future transit development in the Twin Cities region, it will be important to keep in mind that high quality transit service (both bus and rail) can be a powerful tool for improving the lives of the poor.
Good connections are essential in broadening the impact scope of transit implementations—One of the most interesting findings of the study are the large areas of accessibility gains found along bus routes that connect with light rail in addition to areas with high-frequency bus service and along the LRT. They suggest enormous importance of a fully integrated transit network (as opposed to a single transit corridor) in realizing the maximum benefits from major transit investments. The effective and efficient planning of feeder/distributor services will be critical to ensuring low-wage workers reap the greatest benefits possible from existing and future transit services. Accessibility should be an important performance measure for assessing transit investments.
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