**MAX Bus Rapid Transit**

**Las Vegas, Nevada**

# Do TOD's Make a Difference?


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6/13/2014

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## Acknowledgements

This project was funded by the Oregon Transportation Research and Education Consortium (OTREC) through a grant provided by the National Institute of Transportation and Communities (NITC). Cash match funding was provided by the Utah Transit Authority (UTA), Salt Lake County (SLCo), the Wasatch Front Regional Council (WFRC), and the Mountainlands Association of Governments (MAG). In-kind match was provided by the Department of City & Metropolitan Planning at the University of Utah, and by the Nohan A. Toulon School of Urban Affairs and Planning at Portland State University.

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PROJECT TITLE

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| Project Title:<br>**DO TODs MAKE A DIFFERENCE?** |

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# 1-INTRODUCTION

This analysis was intended to help answer the following policy questions:

**Q1: Are TODs attractive to certain NAICS sectors?**
**Q2: Do TODs generate more jobs in certain NAICS sectors?**
**Q3: Are firms in TODs more resilient to economic downturns?**
**Q4: Do TODs create more affordable housing measured as H+T?**
**Q5: Do TODs improve job accessibility for those living in or near them?**

The first question investigates which types of industries are actually transit oriented. Best planning practices call for a mix of uses focused around housing and retail, but analysis provides some surprises. The second question tests the economic development effects of transit—do locations provided with transit actually experience employment growth? The third question is intended to determine the ability of employers near transit to resist losing jobs; or having lost jobs, to rapidly regain them.

The fourth research question confronts the issue of affordable housing and transit. Transit is often billed as a way to provide affordable housing by matching low-cost housing with employment. Yet proximity to transit stations is also expected to raise land values. Proximity to transit, however, may increase actual affordability, regardless of increases in housing costs, because of the reduction in transportation costs.

The final research question considers the relationship between workplace and residential locations. To be able to commute by transit both the workplace and home must be near transit. Effective transit should increase both the number and share of workers who work and live along the transit corridor.

## Report Structure

The rest of the report is structured as follows. The following section details the study area and corridors used for analysis in all of the research questions with each research question given its own section. Each section contains a short review of relevant research as well as a description of additional data sources and analytical techniques. Each section then provides relevant analysis, discussion of the analysis, and relevant conclusions. The report concludes with a summary of outcomes from each.

# 2-DATA AND METHODS

Data from before and after the opening of a transit line were analyzed to determine if the advent of transit causes a significant change in area conditions. To control for exogenous factors (such as things affecting the entire metro area), changes in transit corridors were then compared to changes in comparable corridors located in the same metropolitan region, matching length, location, mix of land uses, and suitability for transit. As corridors differ primarily in their lack of transit, the corridor matching represents a 'natural experiment', where one corridor receives the treatment (a fixed guide-way transit line) and the comparable corridor acts as a control. Because of the need to perform this matching, this study used the corridor as its unit of analysis rather than station points. For most transit systems, stations lie within a mile of one another, so the areas are quite similar. Without a network analysis of walking paths, exact distances to transit are difficult to determine.

The remainder of this section describes the selection of existing transit (treatment) corridors, the creation of comparable corridors, and the data used for analysis. It also provides an overview of the transit corridor being analyzed.

## Selection of Treatment corridor

The process began with Center for Transit Oriented Development (CTOD)'s Transit Oriented Development (TOD) Database (July 2012 vintage). The database's unit of analysis is the station. For each station there is information about the station's location, providing both address and lat-long points. Station attributes include the transit agency for that station as well as the names of routes using that station. The database was enriched with the addition of transit modes for all stations since many transit stations serve more than one mode.

While the database contained routes, it did not identify the corridor for each station. Most transit routes make use of multiple corridors. While routes change in response to operational needs, a corridor consists of a common length of right-of-way that is shared by a series of stations on the corridor. Typically, all stations along a corridor begin active service at the same time. Transit systems grow by adding corridors to the network. Initial systems may consist of only a single corridor.

Distinct corridors for each system were identified on the basis of prior transportation reports (Alternative Analysis, Environmental Assessments, Environmental Impact Statements, Full Funding Grant Agreements) as well as reports in the popular media. Whenever possible, a corridor that started operation after 2002 but before 2007 was preferred. Stations relevant to analysis were then queried out, and imported into Google Earth as a series of points. Using aerial images, the path of the corridor was traced. The corridor was then exported as a KML file and imported into a geodatabase in ArcGIS.

## Creation of Comparable Corridors

Numerous draft corridors were created and then compared with the existing transit corridor. The following criteria were used while creating a comparable corridor:

## Comparable Corridors Criteria

1. Same MSA
2. Equal length
3. Existing transit route; express transit preferred
4. Direct; no doubling back
5. Anchored on both ends (unless the original line was not)
6. Anchors of equal magnitude; downtowns, transit centers, shopping centers, malls, etc.
7. Along a major corridor; major/minor arterial
8. Similar land use mix along the corridor; both corridors contain substantial commercial development
9. Conformity with existing rapid transit plans
10. Existing corridor; rail or highway
11. Similar relative nearness to a parallel freeway in both distance and degree
12. Commuter rail follows existing corridors; either rail or freeway

Keeping the comparable corridor in the same metropolitan area reduced a large number of confounding effects. Maintaining the same length meant a similar amount of area was included in the analysis. Bus routes in analogous locations were used to create draft corridors. Because of their high cost per mile, rapid transit corridors tend to be direct. They also tend to be ‘stretched’ until they reach a reasonable terminus to anchor each end. Whenever possible, the type and magnitude of each anchor used was matched.

For comparable corridors, the emphasis was placed on creating corridors that were contiguous and followed a continuous existing right-of-way that was viable as a transit corridor. Availability of right-of-way was the primary concern, and this dictated either existing major roads or existing railway right-of-way. For the former, highways and major arterials were preferred. For the latter, this meant the majority of right-of-way needed to follow an existing rail corridor. Whenever possible, proposed or future corridors from official planning documents were used, with some limitations.

For all commuter rail systems and most light rail corridors, the availability of right-of-way determines the location of the transit line. For many rail lines, this means that the transit corridor is located alongside incompatible or inappropriate uses, such as light industrial or low density single family residential units. These characteristics affect station accessibility. The mix of land uses along the corridor affects ridership in other ways. For instance, commercial locations generate more trips per acre than either residential or industrial uses, so similar levels of commercial exposure were sought in creating comparable corridors.

Finally, proximity to freeways was matched. The benefits ascribed to TOD are on the basis of the improved accessibility provided by transit. Because freeways also provide accessibility, the confounding effect of proximity to a competing mode can be considerable.

## Data Source and Extent

The data used originated from the Census Local Employment-Housing Dynamics (LEHD) datasets. Both the Local Employment Dynamics (LED) and LEHD Origin-Destination Employment Statistics (LODES) were used. Employment data are classified using the North American Industrial Classification System (NAICS), and data are available for each Census Block at the two-digit summary level. Data were downloaded for all years available (2002-2011). The geographic units of analysis are 2010 Census Blocks Points. The database contains information on employment within each block. The data were downloaded from http://onthemap.ces.census.gov/ for each metro area, using the CBSA (Core Based Statistical Area) definitions of Metropolitan/Micropolitan. In cases where either the transit or comparable corridor extended beyond a CBSA metro area, adjacent counties were included to create an expanded metropolitan area.

There is a vast difference between TOD, and Transit Adjacent Development (TAD). The latter refers to any development happens to occur within the Transit Station Area (TSA), or a 0.5-mile buffer around a fixed guide-way transit station, while the former refers to land uses and built environment characteristics hospitable to transit. This analysis assumes that while the existing development during the year of initial operations (YOIO) may not be TOD, land uses respond to changes in transportation conditions over time, phasing out TAD and replacing it with TOD. On this basis, the TOD is conflated with TSA for the purpose of this analysis.

## Data Processing

ArcGIS was used to create a series of buffers around each corridor in 0.25 mile increments. Those buffers were then used to select the centroid point of the LED block groups within those buffers, and summarize the totals. Because the location of census block points varies from year to year (for reasons of non-disclosure), it was necessary to make a spatial selection of points within the buffer for each year rather than using the same points each year. Figure 1 shows an example corridor, the buffers around the corridor, and the location of LED points in reference to both.

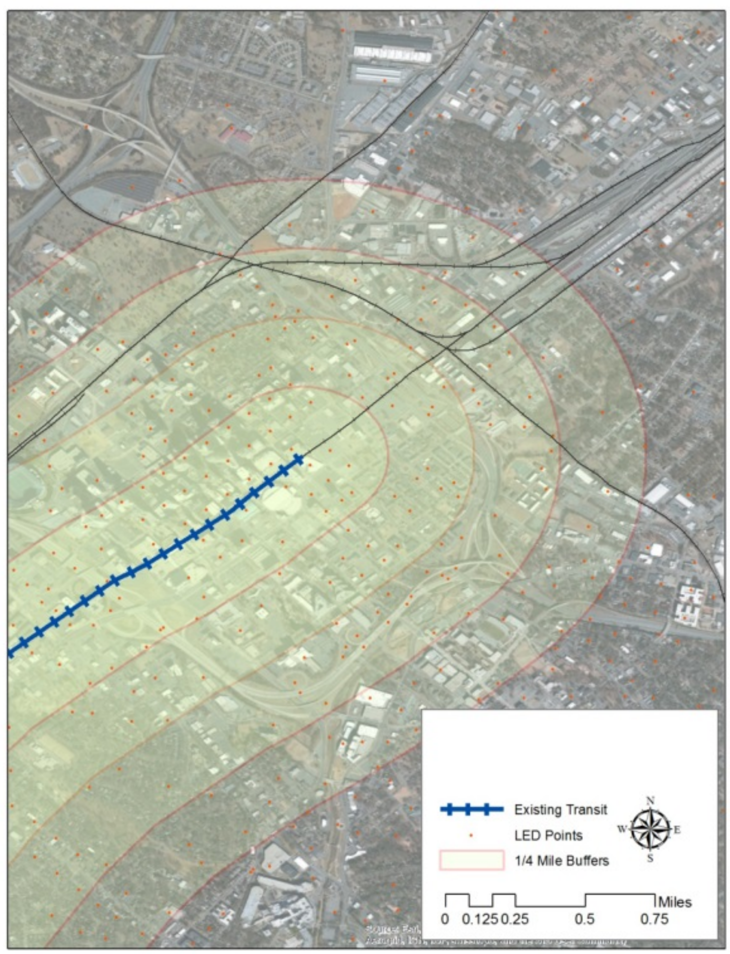


**Figure 1: Example corridor, buffers, and LED census block points**

## Study Area

This study examines the Ace/MAX Bus Rapid Transit (BRT) system in Las Vegas, Nevada. It runs along a 7.5-mile corridor anchored at one end by the Downtown Transit Center, and at the other by a super-WalMart. It began operations in 2004. At both ends, to reach a series of nearby destinations, the system corridor creates two several block loops. The comparable corridor starts from the new transit center in downtown Las Vegas, then runs south along Main Street before heading west along Sahara Avenue (following the route of the Sahara Express bus and planned BRT). The comparable corridor shares the dumbbell loops structure, with a large loop through downtown, and a smaller loop on the far end. It connects to the monorail/casinos at north end of strip and its terminus is at a large retail center. Figure 2 shows the transit and comparable corridors, as well as the location of LED points.

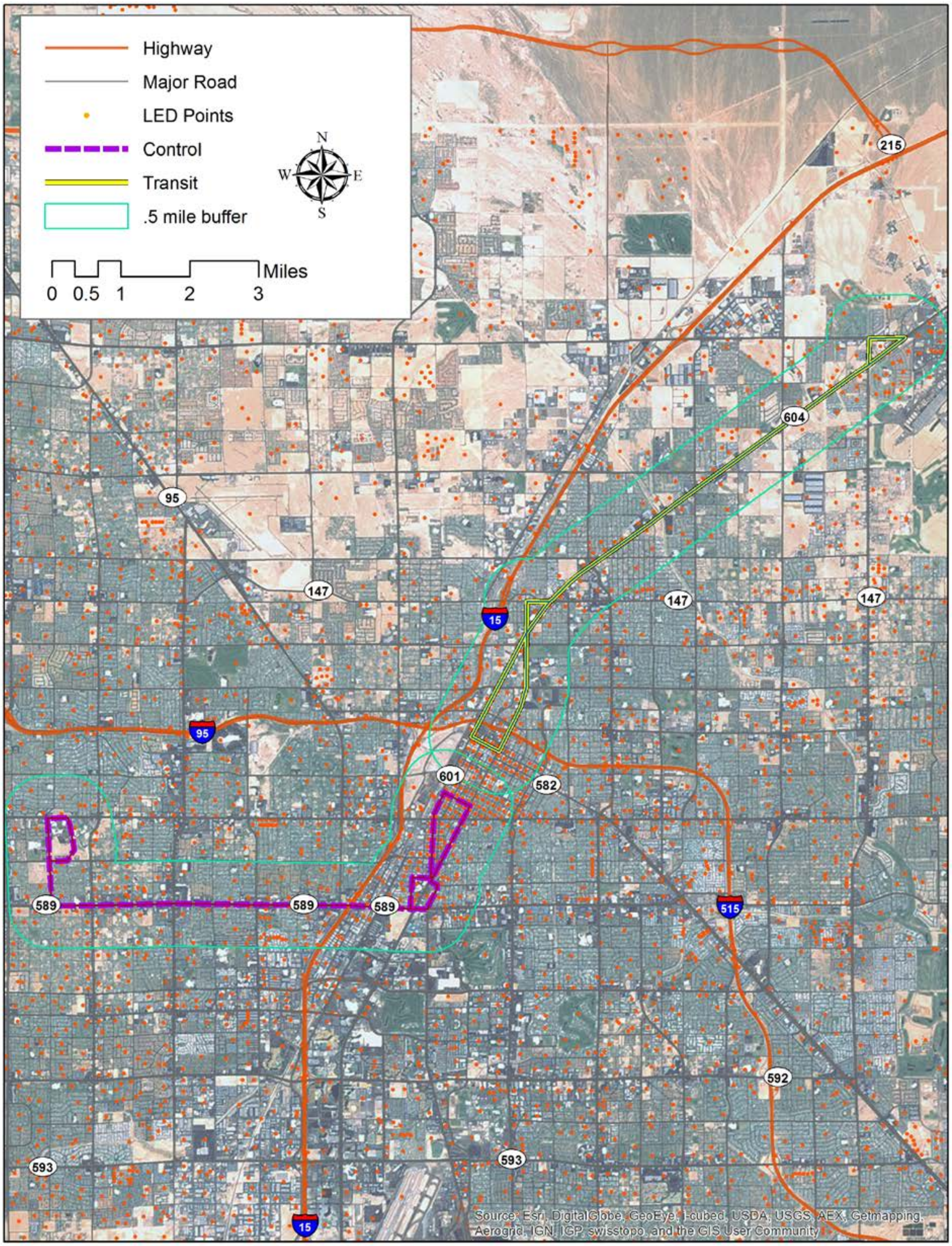


Figure 2: Transit and comparable corridor locations

# 3-EMPLOYMENT CONCENTRATION

## Introduction

This section is intended to determine if TODs are more attractive to certain NACICS industry sectors. Case studies indicate that economic development and land use intensification are associated with heavy rail transit (HRT) development (Cervero et al. 2004; Arrington & Cervero 2008). Case studies associated with light rail transit (LRT) have inconsistent results, suggesting that much of the employment growth associated with transit stations tends to occur before a transit station opens (Kolko 2011). A study by CTOD (2011) examined employment in areas served by fixed guide-way transit systems, and explored how major economic sectors vary in their propensity to locate near stations, finding high capture rates in the Utilities, Information, and Art/Entertainment/Recreation industry sectors.

## Data & Methods

To analyze the difference in the attractiveness of TODs, location quotient was used to analyze the concentration of different industries over time. Location quotient is a calculation that compares the number of jobs in each industry in the area of interest to a larger reference economy for each corridor. The analysis then compares the location quotients of each industry between each corridor. A 0.5-mile buffer around each corridor was used as the unit of analysis.

## Results

The location quotients within a 0.5-mile buffer for the transit corridor is shown in Table 1. Location quotients are shown for the first and final years, with a sparkline to show trends between the years. Changes in location quotient between the 2002 and the advent of transit are calculated, as well as the advent of transit and 2011. The final column is the difference between the changes in the two periods.

Both corridors are located in a pre-existing, built-up urban area, so additional growth must occur through redevelopment of existing urban land, while the urban area that forms the denominator of the location quotient continues to grow through both development and redevelopment. With an expanding urban area, the location quotient for a fixed area would be expected to fall over time. Any increase in location quotient for a corridor should indicate locational advantage.

| Industry | Location Quotient | | | Changes | | Differences in Changes |
|---|---|---|---|---|---|---|
| | 2002 | 2002-2011 | 2011 | Δ 2002-2004 | Δ 2004-2011 | Δ 2002-2004 & Δ 2004-2011 |
| Utilities | 0.15 | | 0.14 | 0.00 | -0.01 | 0.00 |
| Construction | 0.39 | | 0.30 | 0.04 | -0.12 | -0.16 |
| Manufacturing | 0.62 | | 0.82 | 0.33 | -0.13 | -0.46 |
| Wholesale | 0.81 | | 0.39 | -0.51 | 0.10 | 0.61 |
| Retail | 0.53 | | 0.52 | 0.11 | -0.12 | -0.24 |
| Transportation | 0.48 | | 0.23 | 0.14 | -0.39 | -0.52 |
| Information | 0.73 | | 0.82 | 0.39 | -0.30 | -0.69 |
| Finance | 0.43 | | 0.51 | 0.05 | 0.03 | -0.02 |
| Real Estate | 0.55 | | 0.65 | -0.02 | 0.11 | 0.13 |
| Professional | 0.78 | | 0.88 | -0.01 | 0.11 | 0.12 |
| Management | 0.25 | | 0.30 | 0.03 | 0.01 | -0.02 |
| Administrative | 0.29 | | 0.27 | 0.15 | -0.17 | -0.32 |
| Education | 0.03 | | 1.08 | 0.03 | 1.01 | 0.98 |
| Health Care | 0.98 | | 0.69 | -0.01 | -0.28 | -0.28 |
| Arts, Ent. Rec. | 1.52 | | 2.19 | 0.10 | 0.57 | 0.47 |
| Lodging & Food | 1.17 | | 0.86 | -0.20 | -0.11 | 0.08 |
| Other Services | 1.79 | | 1.20 | 0.00 | -0.58 | -0.58 |
| Public Admin | 7.23 | | 7.58 | 1.09 | -0.75 | -1.84 |

**Table 1: Location quotients comparison for transit corridor**

In the transit corridor, industries with the highest location quotients include Public Administration at 7.58, followed by Arts/Entertainment/Recreation at 2.10, and Education at 1.08.

After the advent of transit (2004-2011), significant increases in location quotient occur in the Education industry, followed by the Arts/Entertainment/Recreation industry. Wholesale, Real Estate and Professional all experience increases in location quotient of 0.10 or greater. In contrast, the Public Administration and Other Services industries experience substantial declines within the transit corridor. Decreases in the location quotient may indicate that either the amount of employment within the corridor has shrunken, or that employment in that industry has grown outside the transit corridor.

The difference in changes shows difference in trends between the two time periods (2002-2004 and 2004-2011). The most substantial difference in changes is for the Public Administration industry. Prior to 2004, it experienced a substantial increase in location quotient, but a substantial decrease afterward. The difference in changes is also notable for the Education industry, which experiences a substantial increase in location quotient after the advent of transit. The difference in changes is also large for the Arts/Entertainment/Recreation industry. While the Wholesale industry has a large difference in changes, the difference is largely due to a significant fall prior to the advent of transit.

For both the transit and comparable corridors, changes in location quotient for the time period after the advent of transit are shown in Figure 3. Only some industries benefit from proximity to the transit corridor. Industries that benefit from proximity to transit should experience larger increases in location quotient in the transit corridor than in the comparable corridor. The y-axis is numeric change in location quotient.

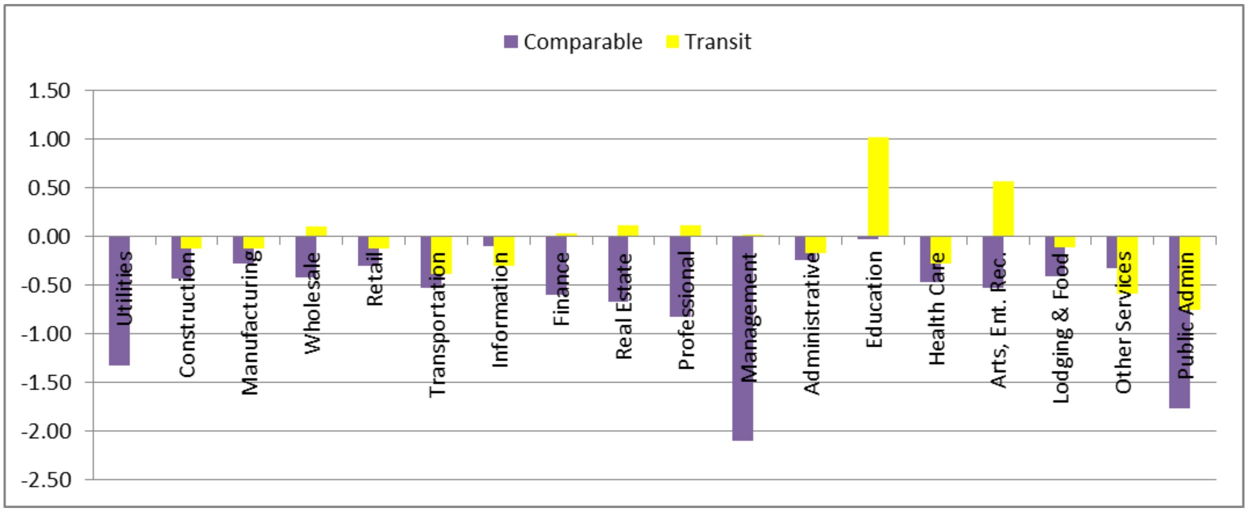


**Figure 3: Changes in location quotient by corridor for the time period after the advent of transit**

The graph shows industries where the transit corridor did better than the comparable corridor, with a greater increase in location quotient after the advent of transit (2004). Overall, the transit corridor experiences less reduction in location quotient then the comparable corridor, with the notable exceptions of Information and Other Services industries. While the transit corridor experiences a considerable reduction in the location quotient of the Public Administration Industry, the drop is even more severe for the comparable corridor. The minor increases in location quotient for the Real Estate and Professional Industries in the transit corridor become more significant in the context of the comparable corridor, which expereinces steep drops in the location quotient for both. The difference is even more notable for the Arts/Entertainment/Recreation industry, which experiences a major increase in the transit corridor and a major drop in the comparable corridor. The changes in location quotient of Education in the transit quarter, in comparison to a minor reduction in the comparable corridor, is also notable.

## Discussion & Implications

Attributing causal effect to transit lines is always problematic. Designing successful transit networks is largely a game of connect-the-dots, linking together major employment centers with employee housing along congested corridors. Many stations are co-established with new campuses for major institutions, so increases in the location quotient for Education could be expected. The increase in Arts/Entertainment/Recreation is expectable, given that the southern end of the BRT corridor loops around the Fremont Street experiences. For the same reason, the rise in the location quotient for the Lodging/Food industry makes sense.

The increase in the Wholesale indsutry remains puzzling, but which industry sectors do well near transit corridors is not simply a function of proximity to a transit corridor. Increases in location quotients near transit may be confounded by the effect of freeway proximity, which is far more important to most industries than transit access.

A 0.5-mile buffer around a corridor is an inappropriate analytical geography for transit analysis. The buffer distance has been established less by empirical evidence than a by custom and by data limitations. That some people walk distances greater than 0.5 miles to transit has been rigorously established, so any buffer distance is somewhat arbitrary. The 0.5-mile buffer is expected to capture the majority of transit effect; yet there is a negative binomial relationship between distance and number of walkers, so that the number of people willing to take a walk of a given distance falls off exponentially. This also suggests that the strongest effect will be found nearest to transit, and should be most observable there. Using a smaller buffer would reduce the number of confounders. This is especially important for BRT, because the accessibility provided by BRT may not provide the level of premium associated with rail rapid transit. BRT systems are less legally regulated than rail transit, thus they are the mode most prone to suffer from corner cutting.

The location quotient of the Finance, Real Estate and Professional industries all increased after the opening of the MAX BRT line. All are office uses, and are likely tied to broader efforts to revitalize Las Vegas's historic downtown. It is likely that the location of the transit center which is the southern terminus of the MAX BRT is also a result of that process. While transit may be an amenity which offers competitive advantage to some industries, that does not mean that that transit is the only necessary requisite. Transit may enhance a good location, but may not be able to change a bad location into an acceptable one.

# 4-EMPLOYMENT GROWTH BY SECTOR

## Introduction

This section is intended to determine if TODs generate more jobs in certain NAICS sectors. To determine if the new jobs are actually created as a result of proximity to transit, it is necessary to determine what portion of changes in employment can be attributed to transit and what portion of changes is determined by other factors.

In theory, employment in different NAICS sectors should be variable depending on the NAICS code, as some industry sectors are better able to take advantage of the improved accessibility offered by transit. For example, industries in which employment is characterized by low-income workers in need of affordable transportation or salaried office workers with long distance commutes are more likely to make use of transit. Likewise, arts and entertainment venues prone to serious congestion (due to their high peaks of visitors) would also benefit. Finally, institutions with large parking demands (universities, colleges, hospitals, and some government offices) could be expected to find proximity to transit valuable.

It is difficult to determine to what degree employment growth is caused by location near transit, and what is a product of self-selection, as rapidly growing industry sectors locate next to transit. Shift-Share analysis helps answer this question.

## Data and Methods

A shift-share analysis attempts to identify the sources of regional economic changes to determine industries where a local economy has a competitive advantage over its regional context. Shift-share separates the regional economic changes within each industry into different categories and assigns a portion of that the change to each category. For the purpose of this analysis, these categories are Metropolitan Growth Effect, Industry Mix, and the Corridor Share Effect.

1. Metropolitan Growth Effect is the portion of the change attributed to the total growth of the metropolitan economy. It is equal to the percent change in employment within the area of analysis that would have occurred if the local area had changed by the same amount as the metropolitan economy.
2. Industry Mix Effect is the portion of the change attributed to the performance of each industrial sector. It is equal to the expected change in industry sector employment if employment within the area of analysis had grown at the same rate as the industry sector at the metropolitan scale (less the Metropolitan Growth Effect).
3. Corridor Share Effect is the portion of the change attributed to location in the corridor. The remainder of change in employment (after controlling for metropolitan growth and shifts in the industry mix) is apportioned to this variable. Within regions, some areas grow faster than others, typically as a result of local competitive advantage. While the source of competitive advantage cannot be exactly identified, the methods of analysis used suggest that the cause of

competitive advantage can be directly attributed to the presence of transit, or factors leveraged by the presence of transit.

## Results

A shift-share analysis of changes in employment within a 0.5-mile buffer of the transit corridor is presented in Table 2. The first batch of columns shows numeric and percentage changes in the metropolitan area, and the second batch of columns shows the numeric and percentage changes in the buffer around the transit corridor. The third batch of columns is the actual shift-share analysis, and apportions the numeric change in the buffer around the corridor.

| NAICS Sector | Metro | | | | Transit Corridor | | | | Sources of Employment Change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2004 | 2011 | # Change | % Change | 2004 | 2011 | # Change | % Change | Metro Share | Industry Mix Share | Corridor Effect |
| Utilities | 3,929 | 3,594 | (335) | -9% | 26 | 21 | (5) | 0% | 1 | (2) | (4) |
| Construction | 81,870 | 37,844 | (44,026) | -54% | 1,557 | 475 | (1,082) | -69% | 65 | (837) | (310) |
| Manufacturing | 23,723 | 19,854 | (3,869) | -16% | 1,015 | 676 | (339) | -33% | 43 | (166) | (216) |
| Wholesale | 22,408 | 21,657 | (751) | -3% | 296 | 350 | 54 | 18% | 12 | (10) | 52 |
| Retail | 85,564 | 94,196 | 8,632 | 10% | 2,463 | 2,018 | (445) | -18% | 103 | 248 | (797) |
| Transportation | 26,097 | 31,857 | 5,760 | 22% | 725 | 304 | (421) | -58% | 30 | 160 | (611) |
| Information | 11,583 | 10,256 | (1,327) | -11% | 579 | 346 | (233) | -40% | 24 | (66) | (191) |
| Finance | 29,404 | 23,482 | (5,922) | -20% | 634 | 499 | (135) | -21% | 27 | (128) | (34) |
| Real Estate | 17,806 | 17,454 | (352) | -2% | 426 | 467 | 41 | 10% | 18 | (8) | 32 |
| Professional | 33,513 | 35,967 | 2,454 | 7% | 1,164 | 1,315 | 151 | 13% | 49 | 85 | 17 |
| Management | 8,815 | 16,014 | 7,199 | 82% | 113 | 197 | 84 | 74% | 5 | 92 | (13) |
| Administrative | 56,261 | 57,558 | 1,297 | 2% | 1,115 | 652 | (463) | -42% | 47 | 26 | (535) |
| Education | 44,853 | 57,323 | 12,470 | 28% | 128 | 2,551 | 2,423 | 1893% | 5 | 36 | 2,382 |
| Health Care | 54,864 | 72,939 | 18,075 | 33% | 2,393 | 2,082 | (311) | -13% | 100 | 788 | (1,200) |
| Arts, Ent. Rec. | 18,009 | 17,245 | (764) | -4% | 1,305 | 1,557 | 252 | 19% | 55 | (55) | 253 |
| Lodging & Food | 222,004 | 247,112 | 25,108 | 11% | 9,646 | 8,731 | (915) | -9% | 404 | 1,091 | (2,410) |
| Other Services | 17,053 | 20,137 | 3,084 | 18% | 1,365 | 1,001 | (364) | -27% | 57 | 247 | (668) |
| Public Admin | 27,499 | 33,829 | 6,330 | 23% | 10,258 | 10,590 | 332 | 3% | 430 | 2,361 | (2,459) |
| **Total** | **785,255** | **818,318** | **33,063** | **4%** | **35,208** | **33,832** | **(1,376)** | **-4%** | **1,476** | **3,862** | **(6,714)** |

**Table 2: Shift-share analysis for 0.5 mile buffer of transit corridor**

For the time period after the advent of transit in 2004, the entire metropolitan area enjoys an increase in employment of 4 percent. In contrast, the transit corridor suffers a decline in employment of about 4 percent. This still represents a loss of over 1,300 jobs. In numeric terms, the industry to enjoy the most significant numeric increases is Education. Public Administration, Arts/Entertainment/Recreation, and Professional all add over 100 employees. Employment in the Arts/Entertainment/Recreation industry increases by 19 percent, and Professional by 13 percent. Management enjoys a significant percentage increase in employment of almost 75 percent, although from a low base. Serious declines occur in the Construction and Lodging/Food industries.

After using Shift-Share analysis to disaggregate the cause of change in employment, different patterns emerge. Any gains in employment contributed by the Metro Share or due to Industry Mix are entirely wiped out by the Corridor Effect, so that the net effect of the transit corridor on employment is strongly negative. The only exceptions are in the Education industry, which prospers, and the Arts/Entertainment/Recreation industry.

The differences between the expected positive changes in employment due to Metropolitan Share of Growth and Industry Mix are in Health Care, Lodging/Food, and Other Services, and Public Administration. All do substantially less well than would otherwise be expected, due to the Corridor Effect. Construction, a declining industry, does not benefit from being located in the corridor.

Information about the Corridor Effect is presented for both the transit and comparable corridor in Table 3. Differences between the corridors are also presented. It is intended to confirm that the corridor effects attributed to transit are specific to the transit corridor, and not the result of another effect. The 'Corridor Benefit' relates the change employment in employment totals to the change due to the Corridor Effect. It is calculated as the corridor effect divided by the absolute value of employment change. A value of 1 indicates that almost all the change can be attributed to the Corridor Effect, while a value of 0 means that the corridor has almost no effect.

| Industry | Comparable | | | Transit | | | Transit Advantage | |
|---|---|---|---|---|---|---|---|---|
| | # Change | Corridor Effect | Corridor Benefit | # Change | Corridor Effect | Corridor Benefit | Employment Change | Corridor Effect |
| Utilities | -213 | -173 | -0.8 | -5 | -4 | -0.8 | 208 | 169 |
| Construction | -3315 | -1005 | -0.3 | -1082 | -310 | -0.3 | 2233 | 695 |
| Manufacturing | -422 | -320 | -0.8 | -339 | -216 | -0.6 | 83 | 104 |
| Wholesale | -467 | -478 | -1.0 | 54 | 52 | 1.0 | 521 | 530 |
| Retail | 449 | -404 | -0.9 | -445 | -797 | -1.8 | -894 | -393 |
| Transportation | 222 | -471 | -2.1 | -421 | -611 | -1.5 | -643 | -141 |
| Information | 17 | 50 | 3.0 | -233 | -191 | -0.8 | -250 | -241 |
| Finance | -1054 | -563 | -0.5 | -135 | -34 | -0.3 | 919 | 529 |
| Real Estate | -645 | -678 | -1.1 | 41 | 32 | 0.8 | 686 | 709 |
| Professional | -753 | -1266 | -1.7 | 151 | 17 | 0.1 | 904 | 1283 |
| Management | -863 | -2329 | -2.7 | 84 | -13 | -0.2 | 947 | 2316 |
| Administrative | 1 | -207 | -207.2 | -463 | -535 | -1.2 | -464 | -328 |
| Education | 54 | -25 | -0.5 | 2423 | 2382 | 1.0 | 2369 | 2407 |
| Health Care | -72 | -1529 | -21.2 | -311 | -1200 | -3.9 | -239 | 329 |
| Arts, Ent. Rec. | -515 | -514 | -1.0 | 252 | 253 | 1.0 | 767 | 767 |
| Lodging & Food | -2767 | -4852 | -1.8 | -915 | -2410 | -2.6 | 1852 | 2442 |
| Other Services | 175 | -106 | -0.6 | -364 | -668 | -1.8 | -539 | -562 |
| Public Admin | -49 | 2287 | -46.7 | 332 | -2459 | -7.4 | 381 | -172 |
| **Total** | **-10223** | **-17161** | **-1.7** | **-1374** | **-6712** | **-4.9** | **8841** | **10449** |

Table 3: Shifts by corridor and comparison between corridors

Contrast with the comparable corridor shows that the transit corridor emphasizes the negative magnitude of the Corridor Effect. The 'Corridor Benefit' for the transit corridor has a value of -4.9, compared to a value of -1.7 for the comparable corridor. The Corridor Effect benefitted neither corridor, but was substantially worse for the transit corridor. The Transit Advantage columns suggest that the transit corridor does substantially better. While the transit corridor experiences substantial losses in employment that can be attributed to the corridor effect, the losses are yet worse in the comparable corridor. The Wholesale, Education, and Arts/Entertainment/Recreation industries all have corridor benefits of 1.0.

## Discussion & Implications

Drawing any conclusion for the MAX BRT is difficult due to confounding factors. Metropolitan Las Vegas is still suffering from the Great Recession, including a housing market had still not found its bottom in 2011. The biggest loss of employment along the corridor was in the Construction industry. While Las Vegas is built on tourism (Arts/Entertainment/Recreation & Lodging/Food), the Construction industry has been serving as a second 'primary industry' for Las Vegas, providing a mechanism to bring outside money into the city, by converting cheap land and local labor into vacation and retirement homes. This created an indirect stimulus to the local economy, as the need for materials boosted local manufacturing, and an induced stimulus, as wages and profits were spent within the metropolitan area. The expansion of housing had an especially strong effect, because a house requires furnishings, 'white goods', appliances, as well as an array of domestic implements. As construction ceased, the cycle turned from virtuous to vicious, resulting in a savage economic decline.

One of the side effects of a housing boom was rapidly rising property prices, forcing locals and newcomers alike to locate cheaper housing at the periphery of the metro area, requiring long commuters in the face of rapidly rising gas prices. The road network failed to expand as rapidly as population, so that additional development clustered around existing roadways, such as the corridor for the MAX BRT. The MAX BRT links central Las Vegas with an outlying area, along a congested state highway that had become a primary arterial. The employment that had sprung up along it to take advantage of cheap land and good access proved to be fleeting.

Having grown so fast it outstripped its road network capacity, and yet with a population too small and too sprawled for rail, the Las Vegas metropolitan area has been forced to become a leader in both bus and BRT. The MAX BRT was developed to meet a transportation need, providing a 'commuter bus' to outlying areas. As such, the focus was not on TOD, and not transportation. Correspondingly, of the trifecta of land uses associated with TOD ('Eds, Meds and Feds') it is proximate only to education employment, and misses out on the employment growth in Public Administration and Health Care industries elsewhere in the region.

Yet even with all of the limitations and caveats, the transit corridor still does notably better than the comparable corridor. Unlike the comparable corridor, there are industries for which the Corridor Effect is positive, and for those industries, the corridor benefit is about 1, indicating that the majority of employment change can be attributed to the Corridor Effect.

# 5-EMPLOYMENT RESILIENCE

## Introduction

Resilience is defined as the ability to absorb and recover from shocks or disruptions. Resilient systems are characterized by diversity and redundancy. The resilience of employment is a critical factor in community economic health. For many communities, the loss of a single primary employer can be catastrophic, resulting in a state of sustained collapse. Employment resilience is the capacity to recover from such disruptions, due to locational characteristics.

Access to transit can help improve employment resilience because proximity to transit is a source of competitive advantage for some industries. Firms located near transit also benefit from reduced employee and visitor parking needs. This translates into an ability to economize on the size of parcels required, both reducing costs and increasing the number of viable sites for business locations.

Transit provides a mechanism to meet transportation needs and usual or unexpected conditions, such as an automobile breakdown or lower income, and it provides alternate transportation options during conditions that impair other modes, such as weather, construction projects, or accident-induced delay. It also provides accessibility to a population unable to drive such as the young, the elderly, and the poor (VPTI 2014). These factors act to reduce tardiness and absenteeism, thus reducing employment turnover.

Transit also helps create 'thick' markets for employment, whereby employees can match themselves to numerous different employment opportunities. This reduces the time necessary to find matches, unemployment duration, and the unemployment rate.

## Data and Methods

An interrupted time series was used to compare the resilience of employment in both areas to determine if proximity to transit represents a locational advantage. An interrupted time series divides a time series dataset into two time series with the datasets separated by an 'interruption' and compares the differences. For the purpose of this analysis, the interruption is the Great Recession, considered to have begun in 2007.

If an interruption has a causal impact, the second half of the time series will display a significantly different regression coefficient than the first half. Failure to be adversely affected by a severe economic shock indicates employment resilience. A low R-squared ($R^2$) represents larger variability in total employment. Industry sectors with a high $R^2$ demonstrate robust trends, indicating that employment failed to change regardless of the effects on the larger economy. The regression coefficient represents the relationships between the change in variables, and the $R^2$ explains how much of the variance in the data is explained by the regression equation—a measure of the 'goodness' of the regression.

## Results

A line graph of the employment by industry time series is presented in Figure 4. The time series (2002-2011) for each is interrupted in 2008. The vertical axis shows total employment in each industry sector along the corridor. Illustrative regression lines with $R^2$ values have been added for some of the industries. The trend lines and associated $R^2$ values for all industry sectors can be found in Table 4.

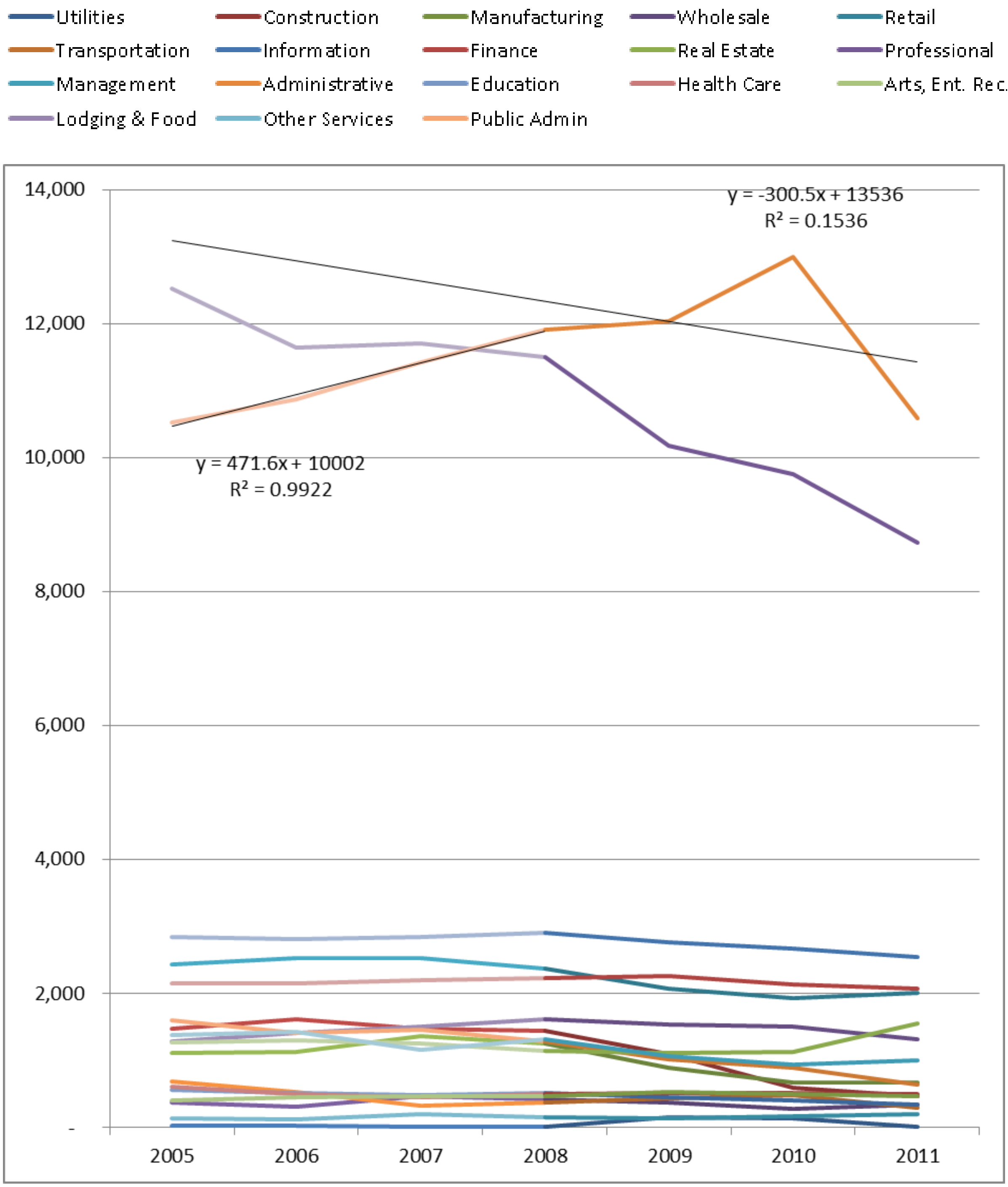


Figure 4: Regression trend lines and R-squared values for different industries

As the graph shows, industry employment varies by year, with many industries affected by substantial fluctuations in employment, both before and after the recession. While visual inspection is valuable, more rigorous interpretation is necessary.

Resilience by industry is presented in Table 4. It highlights the resilience of different industries between 2002-2008 and 2008-2011. The trend number is the linear regression line on industry employment over time. Trend indicates whether total employment increases or decreases during each time period. A negative trend indicates sustained loss of employment while a positive trend indicates a sustained gain. The trend number is the slope of the regression line. However, industries with larger total employment will have larger slopes. To normalize trend numbers for comparison between industries, the trend percent is presented. It is calculated by dividing the trend number for a time period by the average employment for that period. Finally, the $R^2$ column indicates how strong a trend is. Industry sectors with a high $R^2$ demonstrate robust trends—trends in employment change that are consistent over time with less tendency to fluctuate.

The change in the trend between the two time periods is given in the differences column. A positive value for the trend number represents a change from employment loss to employment gain, or a reduction in the rate of decline in employment for that industry. The change in strength of trend is given by the R2 column. A positive value indicates that a previously erratic trend has become more consistent. A negative value means a previously consistent trend has become more erratic.

| Industry | 2005-2008 | | | 2008-2011 | | | Differences | | |
|---|---|---|---|---|---|---|---|---|---|
| | Trend # | Trend % | R2 | Trend # | Trend % | R2 | Trend # | Trend % | R2 |
| Utilities | -6 | -25% | 0.80 | 0 | 0% | 0.00 | 6 | 25% | -0.80 |
| Construction | -26 | -2% | 0.17 | -344 | -38% | 0.95 | -318 | -36% | 0.78 |
| Manufacturing | 63 | 5% | 0.50 | -197 | -22% | 0.86 | -260 | -28% | 0.35 |
| Wholesale | 31 | 8% | 0.32 | -33 | -9% | 0.52 | -64 | -17% | 0.20 |
| Retail | -17 | -1% | 0.09 | -124 | -6% | 0.67 | -108 | -5% | 0.58 |
| Transportation | -111 | -23% | 0.80 | -20 | -5% | 0.11 | 92 | 18% | -0.69 |
| Information | -16 | -3% | 0.39 | -58 | -13% | 1.00 | -42 | -10% | 0.61 |
| Finance | -40 | -8% | 0.56 | 0 | 0% | 0.00 | 40 | 8% | -0.55 |
| Real Estate | 22 | 5% | 0.75 | -4 | -1% | 0.03 | -26 | -6% | -0.72 |
| Professional | 113 | 8% | 1.00 | -95 | -6% | 0.88 | -208 | -14% | -0.12 |
| Management | 14 | 9% | 0.26 | 16 | 10% | 0.71 | 3 | 1% | 0.45 |
| Administrative | -91 | -6% | 0.80 | -205 | -21% | 0.98 | -114 | -15% | 0.18 |
| Education | 24 | 1% | 0.54 | -118 | -4% | 0.99 | -142 | -5% | 0.46 |
| Health Care | 27 | 1% | 0.93 | -57 | -3% | 0.75 | -83 | -4% | -0.17 |
| Arts, Ent. Rec. | -44 | -4% | 0.69 | 125 | 10% | 0.58 | 169 | 14% | -0.12 |
| Lodging & Food | -299 | -3% | 0.71 | -873 | -9% | 0.97 | -574 | -6% | 0.26 |
| Other Services | -47 | -4% | 0.26 | -106 | -10% | 0.71 | -59 | -6% | 0.45 |
| Public Admin | 472 | 4% | 0.99 | -301 | -3% | 0.15 | -772 | -7% | -0.84 |
| Total | 66 | 0% | 0.08 | -2392 | -6% | 0.95 | -2459 | -6% | 0.87 |

**Table 4: Changes in employment trends for 0.5 mile buffer of the transit corridor**

During the 2008 to 2011 period, overall employment fell, and most industries had falling employment. Only the Management and Arts/Entertainment/Recreation industries saw increases, both of about 10 percent, although the increase was only numerically significant for the latter. Lodging/Food saw the largest numerical decline, and Construction had the steepest percentage decline.

Differences in trends (number and percent) and the strength of trends ($R^2$) indicate which industries in the corridor did better after 2008, as the recession reached its trough and the recovery began. The most substantial positive difference in trends is for the Transportation industry, followed by the Arts/Entertainment/Recreation industry.

The trend for the Management industry is much stronger after the recession, while Arts/Entertainment/Recreation sees a minor reduction in trend strength. The trend strength falls dramatically for Transportation, indicating an erratic improvement, with substantial year on year fluctuations.

The same trend information for a comparable corridor is presented **Table 5**. Industries with similar trends and trend strengths in both corridors are likely due to factors affecting both corridors, such as metropolitan scale trends.

| Industry | Differences | | | | | | Differences in Differences | | |
|---|---|---|---|---|---|---|---|---|---|
| | Transit | | | Comparable | | | | | |
| | Trend # | Trend % | R2 | Trend # | Trend % | R2 | Trend # | Trend % | R2 |
| Utilities | 6 | 25% | -0.80 | -16 | -2% | 0.10 | 21 | 27% | -0.90 |
| Construction | -318 | -36% | 0.78 | -621 | -29% | 0.53 | 303 | -7% | 0.25 |
| Manufacturing | -260 | -28% | 0.35 | -124 | -22% | 0.76 | -136 | -6% | -0.41 |
| Wholesale | -64 | -17% | 0.20 | -25 | -4% | 0.73 | -39 | -13% | -0.52 |
| Retail | -108 | -5% | 0.58 | 171 | 3% | -0.38 | -279 | -8% | 0.96 |
| Transportation | 92 | 18% | -0.69 | -139 | -5% | -0.45 | 231 | 23% | -0.24 |
| Information | -42 | -10% | 0.61 | 4 | 1% | 0.02 | -46 | -11% | 0.59 |
| Finance | 40 | 8% | -0.55 | 144 | 5% | -0.44 | -103 | 3% | -0.12 |
| Real Estate | -26 | -6% | -0.72 | -93 | -12% | -0.05 | 67 | 6% | -0.68 |
| Professional | -208 | -14% | -0.12 | -218 | -5% | 0.83 | 10 | -9% | -0.95 |
| Management | 3 | 1% | 0.45 | -132 | -15% | 0.11 | 135 | 16% | 0.34 |
| Administrative | -114 | -15% | 0.18 | 75 | 2% | -0.19 | -189 | -17% | 0.37 |
| Education | -142 | -5% | 0.46 | 12 | 4% | 0.50 | -154 | -9% | -0.04 |
| Health Care | -83 | -4% | -0.17 | -277 | -7% | -0.24 | 193 | 3% | 0.06 |
| Arts, Ent. Rec. | 169 | 14% | -0.12 | -79 | -10% | 0.88 | 248 | 24% | -1.00 |
| Lodging & Food | -574 | -6% | 0.26 | -153 | -2% | 0.17 | -421 | -4% | 0.09 |
| Other Services | -59 | -6% | 0.45 | -122 | -8% | -0.37 | 62 | 2% | 0.82 |
| Public Admin | -772 | -7% | -0.84 | -593 | -7% | 0.82 | -179 | 0% | -1.66 |
| Total | -2459 | -6% | 0.87 | 10070 | 16% | -0.22 | -12528 | -23% | 1.09 |

**Table 5: Comparison of resilience by corridor**

Comparison of the two corridors suggests that the transit corridor has the advantage in a large number of industries. The difference in trends is greatest for the Utilities industry, followed by the Arts/Entertainment/Recreation industry, followed by the Transportation industry, although the trend for the Utilities industry is not numerically significant. Management has a slightly lower difference in difference for trend percent, but a much better one for Trend number.

All industries win the comparable corridor with positive trends display lowered trend strengths, as measured by the differences in $R^2$ values. Contrast with the comparable corridor only compounds this, as the decline in $R^2$ values tends to be larger for the transit corridor.

## Discussion & Implications

To be resilient is to have the capacity to endure shocks and recover to a previous equilibrium. That equilibrium may refer to a prior employment level, or to a prior employment trend.

In the transit corridor, only the Management and Arts/Entertainment/Recreation industries did better than their prior trend. The positive trend for the Management industry can likely be attributed to development adjacent to the I-15/I-515 interchange, although there is notable growth within the southern loop of the MAX BRT. In contrast, employment in the Arts/Entertainment/Recreation industries is directly adjacent to the MAX BRT route, so access to the BRT route likely represents a competitive advantage for that industry.

Some caveats are necessary. Employment in any industry sector is variable over time, and the amount of variability increases with smaller geographic units of analysis. Because the geographic unit of analysis is small, the amount of fluctuation is larger. Changes might 'average out' over a larger unit of geographic aggregation have may have significant effects. In a given year, the relocation of a single firm, or the addition of a new building, would be sufficient to dramatically change employment trends in any industry. Finally, the area within a half-mile buffer is fixed, so new development requires the displacement of existing development. The new development may employ workers in different industries, or new residential development may replace existing employment.

# 6-HOUSING AFFORDABILITY

## Introduction

It is not always possible to maintain a supply of affordable housing for a growing population by adding housing at the urban periphery. Such locations are the furthest from employment and services, requiring long distance travel to meet basic needs. Total cost of automobile ownership is considerable, given not only the cost of the automobile itself, but also the operations and maintenance costs associated with fuel, insurance, and repairs. Housing in exurban locations may be cheap without actually being affordable.

It is necessary for housing affordability to include both housing and transportation costs (H + T). Housing costs do not exist in isolation but within the context of transportation costs. While housing in an urban location with transit access may cost more than suburban housing, it may still be more affordable once the effect of associated transportation costs has been taken into account. Low-income households tend to spend a high proportion of their income on basic transportation (VPTI 2012). Faced with high transportation costs, close proximity to public transit networks is an effective solution. Populations in poverty remain concentrated in central cities partially because such locations enjoy high quality public transit (Glaeser et al 2008).

While the effects of heavy rail transit on housing affordability has been extensively researched, the effects of non-heavy rail TOD on housing affordability is mixed. Matching low-income employment to high-income housing fails to improve housing affordability, and matching high-income employment to low-income housing may actually decrease affordability through gentrification-induced displacement. Maintaining affordable housing through TODs may require the allocation of affordable housing resources (NAHB 2010). A review of the hedonic literature reporting the price effects of transit stations on housing suggests that TODs may be an anathema to the provision of affordable housing, given their propensity to increase housing values (Bartholomew and Ewing 2011).

Calthorpe (1993) initially proposed a ten-minute walk, or about a 0.5 mile radius, as the ideal size for a TOD. Empirical studies confirm that while the majority of walk trips occur for distances of or equal to 0.5 miles, the effects of proximity to transit can be detected out to 1.5 miles away (Nelson 2011). Access to fixed guide-way transit systems is frequently by non-walk modes such as bicycle, bus, and automobile. The characteristics of the built environment within a 1.0 buffer of a station can still affect transit ridership (Guerra, Cervero, & Tischler 2011).

## Data and Methods

This section describes the data used for analysis, and the techniques used to process and analyze the data. Unlike all other analysis contained in this report, the housing affordability analysis included data from multiple 0.25-mile buffers, not just a single 0.5-mile buffer. Doing so makes it possible to relate the magnitude of the effect of proximity to transit. Near things are more related than distant things (Tobler 1970). This makes it possible to track the relationship between magnitude of effect and proximity to transit. The area within the smallest buffers should show the strongest effect from transit.

## Data Source and Geography

This study uses the Location Affordability Index (LAI). The Location Affordability Index was developed under the aegis of the Sustainable Communities, an inter-agency partnership between the Housing and Urban Development, US Department of Transportation, and the Environmental Protection Agency. The LAI is an effort to use statistical modeling to determine the factors which underlie the causes of housing and transportation costs. It controls for a number of factors known to influence transportation and housing costs, such as income and number of workers. The full methodology for the LAI can be found at: http://lai.locationaffordability.info/methodology.pdf.

The LAI provides an estimate of the total cost of housing plus transportation for different locations. The LAI offers eight different household profiles of different family types. For this analysis, type 1 household (hh_type1) was used. It represents the Regional Typical household, with average household size, median income, and an average number of commuters per household for the region. A full data dictionary can be found at: http://lai.locationaffordability.info/lai_data_dictionary.pdf

The unit of analysis for the dataset is the 2010 Decennial Census Block Group. The data extent is the Census 2010 Core-Based Statistical Area (CBSA). When transit lines crossed the boundary into adjacent statistical areas, both statistical areas were included.

## Data Processing

The data were downloaded from: http://www.locationaffordability.info/lai.aspx?url=download.php as CSV (Comma Separated Values) files. It was then joined to a shapefile of the 2010 Decennial Census Block Groups from https://www.census.gov/geo/maps-data/data/tiger.html

Census Block Groups represent an unacceptably large geography for transit relevant analysis. It was necessary to devise an alternative to determining buffer membership by selecting a centroid. Instead, ArcGIS was used to create a series of buffers around each corridor, in 0.25-mile increments, out to 2 miles. Those buffers were then used to clip the block groups. The characteristics of each block were then weighted by geographic ratio, which is the ratio between the area of the block group, and the area of the portion of the block group that was within a buffer. For instance, if a block group represented 3 percent of the area in the buffer, H+T characteristics for that block group received a weight of 3 percent. The weighted variables were then summed to obtain a geographically weighted value for the buffer.

For the purpose of comparison, a metro index was devised. Because the metropolitan area contains all census blocks, not just urban blocks, weighting the blocks by area was deemed inappropriate. Census block groups are intended to contain similar amounts of population, rather than volumes of area, so the size of Census block groups varies by orders of magnitude. Consequently, the comparison value for the metro area was calculated by weighting the block group characteristics by Census 2012 block group population. This weighted average is intended to provide a referent for what are normal values for the metropolitan area.

This analysis makes use of seven characteristics from the location affordability index: housing costs as a percent of income and transportation costs as a percent of income, for owners, renters, and all households in the region. Additionally, it makes use of the median income to translate percentages into dollar amounts.

## Results

The change in housing and transportation (H+T) costs are presented below with three results presented:

1. Housing, Transportation, and H+T dollar costs for the transit corridor
2. Housing costs by tenure, by percent of income
3. Change in LAI H+T costs for transit and comparable corridors

For interpreting the Location Affordability Index, housing is considered affordable if total housing and transportation costs do not exceed 46 percent of income.

The 2009 combined housing, transportation, and H+T dollar costs for the transit corridor are shown in **Figure 5**. The vertical axis shows the dollar cost of housing and transportation. The horizontal axis shows how the total varies by buffer distance from the transit corridor. A stacked graph has been used to display the disaggregated effects of housing and transportation on H+T affordability.

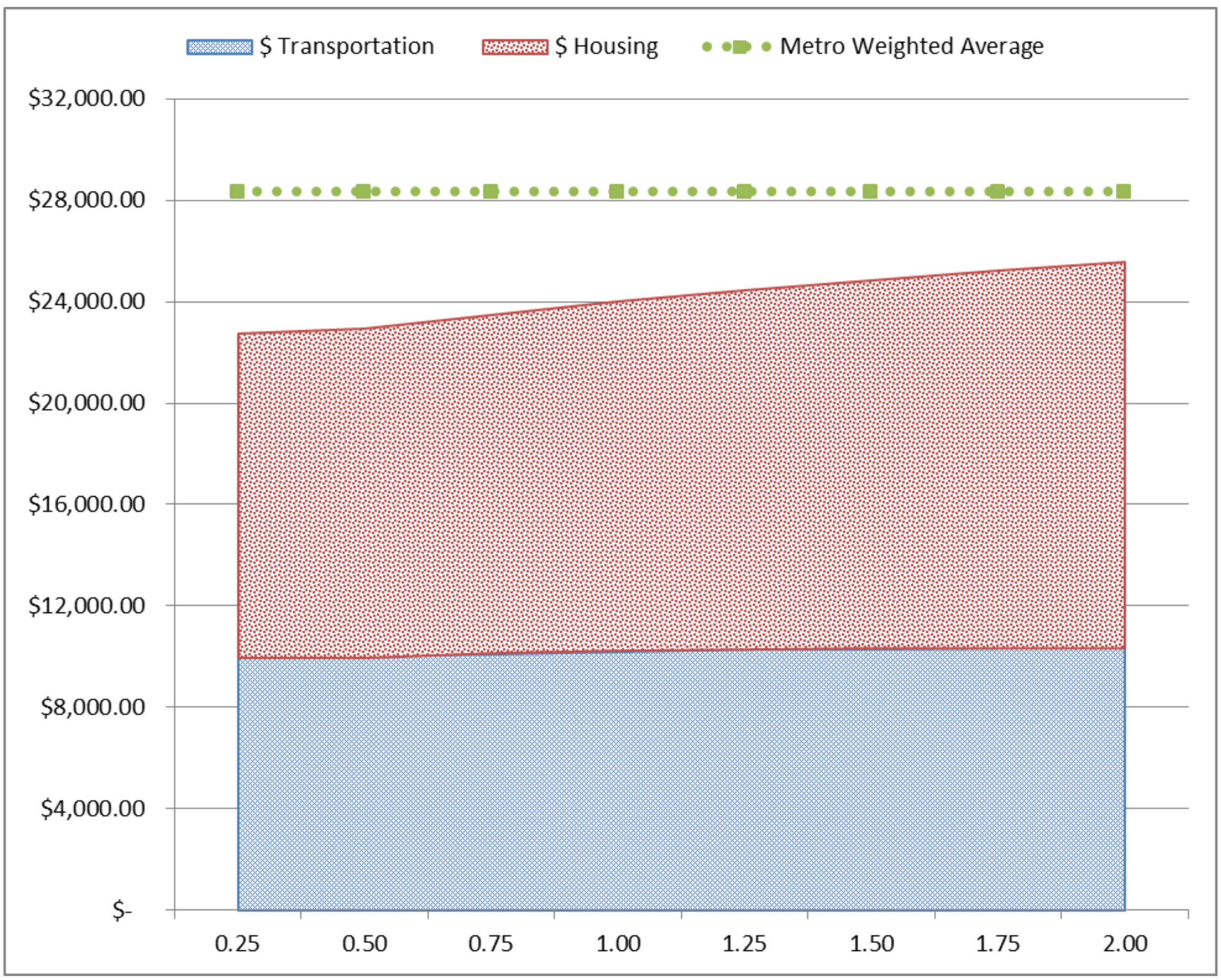


**Figure 5: Housing, transportation, and H+T costs for the transit corridor, 2009, by buffer distance**

As the above graph shows, H+T costs near the transit line are lower than the metropolitan average. Housing costs are lower nearer to the transit line, with a steady drop between 2.0 miles and 0.25 miles. While differences in transit costs are not as significant as differences in housing cost, they are perceptibly lower nearer the transit corridor.

Transportation costs, and housing costs by tenure are shown in **Figure 6**. The vertical axis shows the percent of income needed to meet housing costs. The horizontal axis shows how the total varies by buffer distance from the transit corridor. The response to transit should be more significant nearer to the transit line.

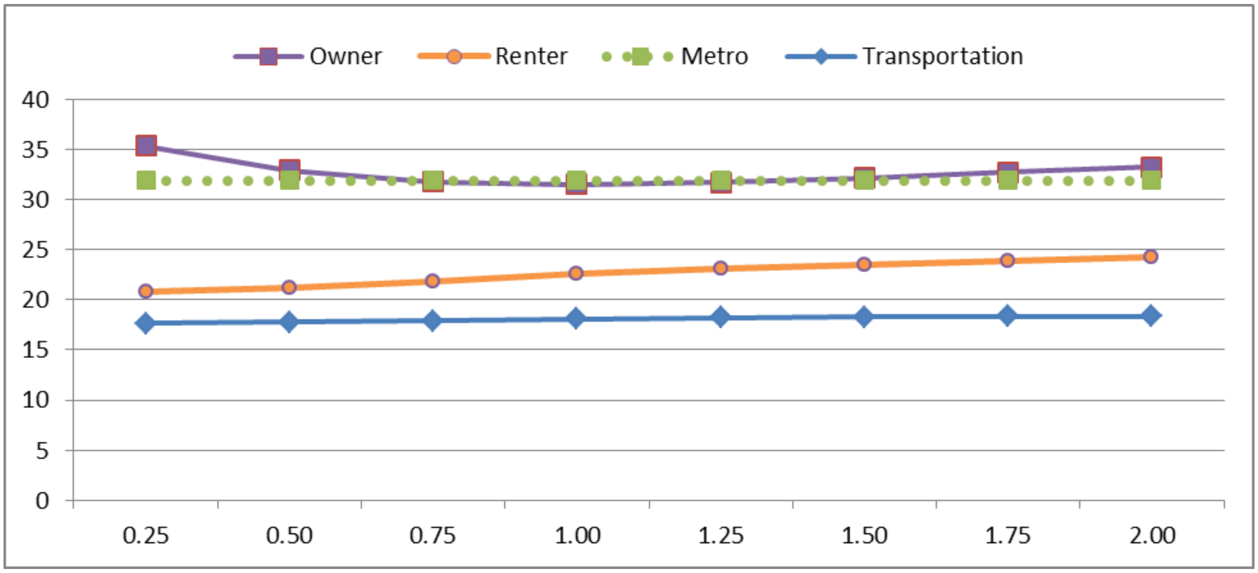


**Figure 6: Transportation costs & Housing costs by tenure, by buffer distance.**

Housing costs for owners near the transit corridor are similar to the metropolitan area as a whole, while the housing costs for renters are substantially lower. However, the housing costs for owners are notably higher than the metropolitan average for the area within a 0.25 mile buffer of the transit line. The housing costs of renters show an inverse relationship, with higher costs further away from the transit line. Transportation costs are slightly lower nearer to the transit corridor.

Dollar amount H+T costs for the transit corridor, comparable corridor, and metropolitan area are shown below in **Figure 7**. The vertical axis shows dollar amounts, and the horizontal axis shows how the total varies by buffer distance from the transit corridor.

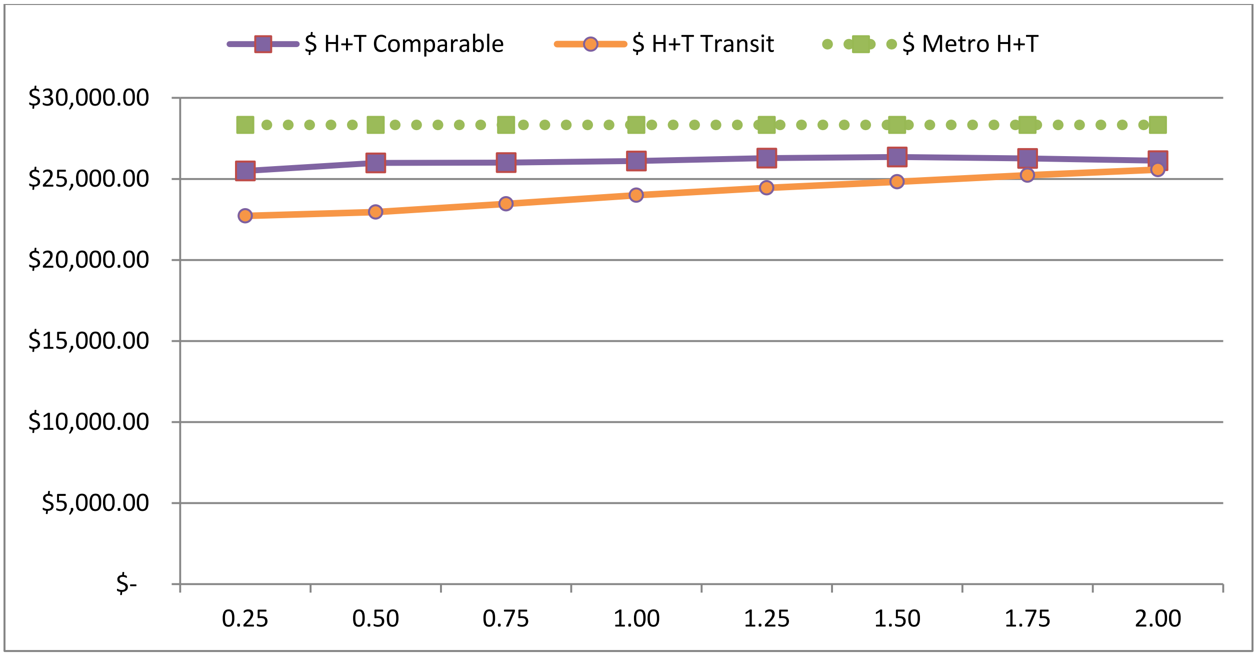


Figure 7: H+T costs for transit and comparable corridors, by buffer distance

Transit displays significantly different patterns in H+T costs from the metropolitan area. It is lower than the metropolitan average for all distances. H+T costs for the transit corridor are lower nearer the transit corridor. The transit corridor experiences much lower H+T costs than the comparable corridor for all buffer distances, with the greatest difference nearest to the corridor.

## Discussion & Implications

TOD is typically planned on the basis of 0.5-mile circles, which are supposed to represent the maximum acceptable walk radius. The reality is more complex. While some people are willing to walk much further for access to high quality transit, up to 2 miles, the majority walk far less. This shows an inverse relationship: the greater the distance, the fewer people are willing to walk to transit. Correspondingly, the strongest response to transit should be in the areas closest to the transit station. Theoretically, the value of the additional accessibility generated by proximity to transit should be capitalized into property value, resulting in rising housing costs. Within the 0.25 mile buffer of the line, the rise in housing costs for owners may be reflecting this.

Transit is expected to increase affordability overall, presuming that higher housing costs could be offset by lower transportation costs, with a lower overall H+T costs. The pattern of increases in H+T costs fails to match this relationship. While housing costs are lower nearer the transit line, transportation costs are not. Almost all of the lower H+T costs associated with proximity to the MAX BRT MAX can be assigned to lower housing costs.

The pattern of housing costs for the transit corridor shows a consistent relationship with the transit corridor, but does so for distances far beyond a normal walk radius. It is unlikely that the local population is willing to walk significantly further than normal.

# 6-JOB ACCESSIBILITY

## Introduction

Commuters have the ability to travel long distances more rapidly by fixed guide-way transit, making it possible to connect to destinations that are otherwise too distant. TOD is based on the premise that locating housing and employment in close proximity to transit stations will significantly enhance the accessibility of those locations. Because each transit line connects multiple stations, it creates a Transit Oriented Corridor (TOC) where people can live or work near any station and use the rapid transit system to access destinations at any other station along the corridor. Therefore, TOD should significantly enhance employment accessibility along the corridor.

To achieve jobs-housing balance, there should be a rough proportionality between the amount of employment and the amount of housing. However, merely matching the total number of jobs and housing along a corridor is not enough. In recent years, the jobs-housing balance has been refined to include how well jobs (by income) are matched to housing (by income), to ensure that people working in the corridor can afford to live in the corridor. Proximity to light rail stations and bus stops offering rail connections is associated with low-wage job accessibility, but proximity to bus networks alone does not show the same correlation (Fan 2012). To check the degree of match between employment and residence, this analysis controls for both low and high wages. To further check for the degree of match, it compares the occupation balance of how well the number of people employed in the corridor matches the number of people residing in the corridor. If an industry is making heavy use of transit along the corridor, the numbers should be near equivalent.

If transit has a positive effect on jobs-housing balance, there should be a detectable change in the employment resident balance for both wage categories and for all occupation categories. Comparing the changes in these balances to the comparable corridor will ensure that the effect is contingent upon the transit corridor rather than metropolitan trends.

## Data & Methods

The data used comes from the Census Local Employment-Housing Dynamics (LEHD) data source, using the Local Employment Dynamics (LED) datasets. Because the LODES data contain both place of employment and place of residence, it is possible to aggregate data to obtain both workplace area characteristics (WAC) and residential area characteristics (RAC). The ratio between the total workers at these different geographies was used as the jobs-housing balance. Corridors with better jobs-housing balance were presumed to have better job accessibility.

Three analyses were performed to determine job accessibility within the corridors: overall jobs-housing balance, jobs-housing balance by earnings category, and jobs-housing balance by industry. In addition to providing total number of employees per Census Block, the LED employment data are classified by earnings category. The LED classifies income by monthly earnings, into the following categories:

- $1250/month or less
- $1251/month to $3333/month

- Greater than $3333/month

The categories have been treated as low-medium-high income classifications. The actual monthly values are less significant than changes over time in the distribution of each of the categories in proximity to the transit corridor. LED employment data are also classified by industry using NAICS at the two-digit summary level.

ArcGIS was used to create a series of buffers around each corridor in 0.25-mile increments. Those buffers were then used to select the centroid point of the LED block groups within those buffers, and summarize the totals. Because the location of census block points varies from year to year (for reasons of non-disclosure), it was necessary to make a spatial selection of points within the buffer for each year, rather than using the same points each year. For this analysis, the 0.5-mile buffer was used.

## Results

Overall jobs-housing balance for the existing transit and comparable corridor are presented below in Table 6 for each year. The ratio column indicates the ratio of workers who are employed within the corridor to the number of workers residing in the corridor. The year-on-year change for ratios is also presented. Sparklines at the bottom show the trend for each column. Years for which the transit system is in operation are shaded.

## Overall Balance

The jobs-housing ratio at the metropolitan level represents a balanced level of jobs to workers. Comparing that value to the jobs-housing ratio for each corridor demonstrates how far out of balance both corridors are. Ideally, the addition of transit (years of operation highlighted in pink) should make the jobs-housing ratio more similar to the metropolitan level ratio.

| Year | Metro | | | Comparable | | | | Transit | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Work, 000's | Home, 000's | Jobs-Housing Ratio | Work, 000's | Home, 000's | Jobs-Housing Ratio | Year on Year Change | Work, 000's | Home, 000's | Jobs-Housing Ratio | Year on Year Change | |
| 2002 | 714 | 699 | 1.02 | 54.9 | 22.5 | 2.44 | 0.00 | 36.5 | 20.8 | 1.76 | 0.00 | 2002 |
| 2003 | 739 | 725 | 1.02 | 55.5 | 21.9 | 2.54 | 0.09 | 36.4 | 20.4 | 1.78 | 0.02 | 2003 |
| 2004 | 786 | 773 | 1.02 | 59.1 | 22.1 | 2.68 | 0.14 | 35.2 | 20.8 | 1.69 | -0.09 | 2004 |
| 2005 | 851 | 834 | 1.02 | 60.5 | 23.7 | 2.55 | -0.13 | 41.5 | 23.4 | 1.77 | 0.07 | 2005 |
| 2006 | 897 | 878 | 1.02 | 61.4 | 25.6 | 2.40 | -0.16 | 40.8 | 25.3 | 1.61 | -0.16 | 2006 |
| 2007 | 918 | 899 | 1.02 | 58.5 | 22.8 | 2.57 | 0.17 | 41.4 | 22.3 | 1.85 | 0.24 | 2007 |
| 2008 | 901 | 879 | 1.02 | 58.4 | 20.8 | 2.80 | 0.24 | 41.5 | 20.0 | 2.07 | 0.22 | 2008 |
| 2009 | 823 | 804 | 1.02 | 52.2 | 21.7 | 2.41 | -0.39 | 38.7 | 18.8 | 2.06 | -0.01 | 2009 |
| 2010 | 807 | 788 | 1.02 | 50.0 | 16.9 | 2.95 | 0.54 | 37.8 | 15.0 | 2.52 | 0.46 | 2010 |
| 2011 | 819 | 799 | 1.02 | 89.7 | 16.4 | 5.46 | 2.51 | 34 | 15.5 | 2.19 | -0.33 | 2011 |
| Trend | | | | | | | | | | | | Trend |

Table 6: Jobs-housing balance for all income categories

The overall jobs-housing ratio for both the comparable and transit corridors is relatively job-rich. The transit corridor has about twice as many jobs per worker than the metropolitan area. While the jobs-housing ratio improves slightly for the first three years, it moves further from parity for the jobs-housing ratio for the metro after 2007. The initial improvement occurs as a result of a rise of the number of workers with homes in the corridor, which peaks in 2006, and declines until 2010. The number of workers peaks a year later, before declining sharply for the following years. The general trend for the jobs-housing ratio in the transit corridor is away from parity, and toward being a job-rich area. In contrast, the jobs-housing ratio for the comparable corridor is flat for the same time period (barring a 2011 spike).

## Income Balance

Jobs-housing balance by earnings category improves on the overall jobs-housing balance, as the overall jobs-housing ratio provides only a rough metric of the degree to which residents are matched to places of work within a corridor. Matching low income residents to high income workplaces will not increase job accessibility. Comparing the jobs-housing ratio by income category makes it possible to gauge not just the overall improvement in jobs-housing balance, but which earnings categories benefit the most from proximity to transit. To determine the degree to which an earnings-specific match is accomplished, **Table 7** compares the jobs-housing balance to the earnings category.

| Low Income | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Metro | | | Comparable | | | | Transit | | | | Year |
| | Work, 000's | Home, 000's | Jobs-Housing Ratio | Work, 000's | Home, 000's | Jobs-Housing Ratio | Year on Year Change | Work, 000's | Home, 000's | Jobs-Housing Ratio | Year on Year Change | |
| 2002 | 191 | 186.10 | 1.03 | 14.9 | 6.9 | 2.15 | 0.00 | 7.3 | 6.8 | 1.07 | 0.00 | 2002 |
| 2003 | 191 | 185.93 | 1.03 | 14.4 | 6.5 | 2.20 | 0.05 | 7.3 | 6.4 | 1.14 | 0.07 | 2003 |
| 2004 | 203 | 199.03 | 1.02 | 14.6 | 6.6 | 2.21 | 0.02 | 7.5 | 6.8 | 1.11 | -0.03 | 2004 |
| 2005 | 218 | 213.20 | 1.02 | 15.3 | 6.9 | 2.21 | 0.00 | 9.5 | 7.6 | 1.25 | 0.14 | 2005 |
| 2006 | 221 | 215.34 | 1.03 | 14.7 | 7.4 | 1.98 | -0.23 | 9.0 | 7.9 | 1.14 | -0.11 | 2006 |
| 2007 | 214 | 209.45 | 1.02 | 14.9 | 6.2 | 2.39 | 0.41 | 7.9 | 6.5 | 1.22 | 0.08 | 2007 |
| 2008 | 206 | 199.88 | 1.03 | 13.6 | 5.7 | 2.40 | 0.01 | 7.7 | 5.4 | 1.41 | 0.19 | 2008 |
| 2009 | 181 | 176.15 | 1.03 | 11.8 | 5.4 | 2.17 | -0.22 | 6.8 | 5.1 | 1.34 | -0.07 | 2009 |
| 2010 | 174 | 169.18 | 1.03 | 11.4 | 4.2 | 2.70 | 0.53 | 6.6 | 4.0 | 1.64 | 0.30 | 2010 |
| 2011 | 175 | 169.96 | 1.03 | 15.2 | 4.2 | 3.65 | 0.95 | 5.9 | 4.3 | 1.39 | -0.25 | 2011 |
| Trend | | | | | | | | | | | | Trend |

| Medium Income | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Metro | | | Comparable | | | | Transit | | | | Year |
| | Work, 000's | Home, 000's | Jobs-Housing Ratio | Work, 000's | Home, 000's | Jobs-Housing Ratio | Year on Year Change | Work, 000's | Home, 000's | Jobs-Housing Ratio | Year on Year Change | |
| 2002 | 346 | 337 | 1.03 | 2.6 | 12.0 | 0.21 | 0.00 | 17.6 | 12.1 | 1.45 | 0.00 | 2002 |
| 2003 | 354 | 345 | 1.03 | 2.5 | 11.6 | 0.22 | 0.00 | 16.3 | 12.0 | 1.36 | -0.09 | 2003 |
| 2004 | 371 | 362 | 1.02 | 2.7 | 11.6 | 0.23 | 0.02 | 14.5 | 11.8 | 1.23 | -0.13 | 2004 |
| 2005 | 384 | 374 | 1.03 | 2.6 | 12.2 | 0.22 | -0.02 | 16.6 | 12.9 | 1.28 | 0.05 | 2005 |
| 2006 | 401 | 391 | 1.03 | 2.8 | 13.0 | 0.21 | -0.01 | 16.4 | 13.9 | 1.18 | -0.10 | 2006 |
| 2007 | 406 | 395 | 1.03 | 2.7 | 11.7 | 0.23 | 0.02 | 16.6 | 12.3 | 1.35 | 0.17 | 2007 |
| 2008 | 388 | 376 | 1.03 | 2.4 | 10.3 | 0.24 | 0.01 | 16.5 | 11.2 | 1.47 | 0.12 | 2008 |
| 2009 | 361 | 350 | 1.03 | 2.2 | 11.2 | 0.20 | -0.04 | 14.5 | 10.8 | 1.34 | -0.13 | 2009 |
| 2010 | 355 | 344 | 1.03 | 2.1 | 8.7 | 0.23 | 0.04 | 13.5 | 8.8 | 1.54 | 0.20 | 2010 |
| 2011 | 358 | 346 | 1.03 | 3.14 | 8.44 | 0.37 | 0.14 | 12.9 | 8.8 | 1.46 | -0.08 | 2011 |
| Trend | | | | | | | | | | | | Trend |

| High Income | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Metro | | | Comparable | | | | Transit | | | | Year |
| | Work, 000's | Home, 000's | Jobs-Housing Ratio | Work, 000's | Home, 000's | Jobs-Housing Ratio | Year on Year Change | Work, 000's | Home, 000's | Jobs-Housing Ratio | Year on Year Change | |
| 2002 | 176 | 176 | 1.00 | 14.2 | 3.5 | 4.02 | 0.00 | 11.6 | 1.8 | 6.32 | 0.00 | 2002 |
| 2003 | 194 | 194 | 1.00 | 15.9 | 3.7 | 4.27 | 0.24 | 12.8 | 2.0 | 6.30 | -0.02 | 2003 |
| 2004 | 212 | 212 | 1.00 | 17.4 | 3.8 | 4.56 | 0.29 | 13.2 | 2.2 | 5.90 | -0.40 | 2004 |
| 2005 | 249 | 247 | 1.01 | 18.7 | 4.6 | 4.05 | -0.51 | 15.4 | 2.9 | 5.25 | -0.65 | 2005 |
| 2006 | 274 | 272 | 1.01 | 19.2 | 5.2 | 3.70 | -0.35 | 15.4 | 3.5 | 4.45 | -0.80 | 2006 |
| 2007 | 297 | 294 | 1.01 | 16.9 | 4.9 | 3.47 | -0.23 | 16.9 | 3.5 | 4.77 | 0.31 | 2007 |
| 2008 | 307 | 304 | 1.01 | 20.5 | 4.8 | 4.23 | 0.76 | 17.4 | 3.4 | 5.15 | 0.38 | 2008 |
| 2009 | 281 | 278 | 1.01 | 18.5 | 5.1 | 3.65 | -0.59 | 17.4 | 2.9 | 6.00 | 0.85 | 2009 |
| 2010 | 278 | 275 | 1.01 | 18.0 | 4.0 | 4.54 | 0.89 | 17.7 | 2.2 | 7.91 | 1.91 | 2010 |
| 2011 | 286 | 283 | 1.01 | 43.2 | 3.8 | 11.25 | 6.71 | 15.0 | 2.4 | 6.28 | -1.64 | 2011 |
| Trend | | | | | | | | | | | | Trend |

**Table 7: Jobs-housing balance by income category**

The transit corridor is job-rich for all three income categories, but particularly for high income, where it has 4 to 8 times as many workers as working residents. The jobs-housing ratio is lower for medium-income workers, and lower still for low-income workers. Over time, the jobs-housing ratio for low income shows an erratic but steady pattern of increase, becoming more job-rich than the metropolitan region as a whole. The pattern is noticeably different than the comparable corridor, which shows a much strong pattern of increase in the jobs-housing ratio.

After the advent of transit, the jobs-housing ratio seesaws erratically for medium income workers in the transit corridor, but shows a general upward trend after 2004. The pattern is noticeably different than the comparable corridor. For medium income workers, the comparable corridor is job-poor, and never makes any significant gains toward parity with the metropolitan area.

The jobs-housing ratio for high income workers sees dramatic changes for both corridors, including large year on year changes. These dramatic changes are caused by changes in both the number of high income workers in the corridor and the number of high income workers living in the corridor. The transit corridor is always very job-rich in high income workers.  The jobs-housing ratio has its nadir, where it is nearest to parity with the metropolitan region, in 2006, but then becomes steadily more job-rich until 2011.

## Industry Balance

Industry balance provides a more refined understanding of the match between place of residence and place of work. Comparing the jobs-housing ratio by industry category makes it possible to determine which industries benefit the most from proximity to transit. The industry balance for the transit corridor is presented in **Table 8**. The jobs-housing ratio has been broken into two data series by the year of the advent of transit.

If any population is making extensive use of transit, they would be expected to be both working and living in the transit corridor. If so, the number of people in any given industry both working and living in the corridor should increase over time, bringing the jobs-housing ratio for the corridor closer to the ratio for the metropolitan area.

| Industry | Comparable 2002 | Comparable 2002 to 2004 | Comparable 2004 | Comparable 2004 to 2011 | Comparable 2011 | Transit 2002 | Transit 2002 to 2004 | Transit 2004 | Transit 2004 to 2011 | Transit 2011 |
|---|---|---|---|---|---|---|---|---|---|---|
| Utilities | 7.76 | | 8.97 | | 19.22 | 0.70 | | 0.72 | | 0.68 |
| Construction | 1.87 | | 2.20 | | 2.14 | 0.47 | | 0.46 | | 0.55 |
| Manufacturing | 1.55 | | 1.51 | | 1.13 | 0.70 | | 0.99 | | 1.12 |
| Wholesale | 2.11 | | 2.34 | | 1.94 | 1.55 | | 0.54 | | 0.89 |
| Retail | 2.39 | | 2.48 | | 3.36 | 1.11 | | 1.28 | | 1.05 |
| Transportation | 2.70 | | 3.04 | | 4.20 | 0.62 | | 0.92 | | 0.37 |
| Information | 1.72 | | 1.68 | | 2.26 | 1.68 | | 2.64 | | 2.29 |
| Finance | 3.92 | | 3.99 | | 4.74 | 1.07 | | 1.15 | | 1.57 |
| Real Estate | 2.10 | | 2.94 | | 2.40 | 1.08 | | 0.94 | | 1.44 |
| Professional | 4.54 | | 4.86 | | 5.67 | 1.88 | | 1.81 | | 2.68 |
| Management | 6.08 | | 6.77 | | 3.62 | 0.66 | | 0.78 | | 1.11 |
| Administrative | 1.88 | | 1.77 | | 2.29 | 0.43 | | 0.61 | | 0.45 |
| Education | 0.24 | | 0.28 | | 0.40 | 0.09 | | 0.19 | | 4.12 |
| Health Care | 2.45 | | 2.78 | | 2.88 | 1.97 | | 1.83 | | 1.68 |
| Arts, Ent. Rec. | 2.26 | | 2.36 | | 2.38 | 2.11 | | 2.50 | | 4.14 |
| Lodging & Food | 1.72 | | 1.93 | | 1.82 | 2.12 | | 1.77 | | 1.89 |
| Other Services | 2.75 | | 2.33 | | 3.67 | 2.08 | | 1.94 | | 1.51 |
| Public Admin | 13.30 | | 15.20 | | 20.24 | 15.22 | | 19.96 | | 31.24 |

**Table 8: Job accessibility trends over time by industry sector and corridor**

In 2004, when transit operations began, the transit corridor was job-rich in about half of the industries, including a very heavy concentration of Public Administration. Following the advent of transit, numerous industries moved toward parity with the metropolitan jobs-housing ratio of 1.02.

The following industries had a falling jobs-worker ratio, but tended toward parity: Retail, Information, Health Care, and Other Services. The only job-poor industry, Wholesale, moved toward parity with the metro region. Many industries, already job-rich in the corridor, became more so. These industries include Finance, Professional, Arts/Entertainment/Recreation, Lodging/Food, and Public Administration.

## Discussion & Implications

Theoretically, proximity to the transit line should be valuable for employers, with the MAX BRT providing access that is either faster, cheaper, or more reliable than alternative modes. Ideally, this would induce employees working in the corridor to also reside in the corridor. Realistically, this is unlikely. The average duration of employment is lower than historic levels, so matching home and work would require repeated relocations. Even if it were possible, matching residence to work requires an acceptable location.

New transit lines are situated to maximize ridership. Maximizing ridership means focusing on density. The more origins and destinations near a transit station, the more likely it is to generate ridership. Employment tends to be concentrated, so that employment densities are almost always greater than residential densities. Thus, transit systems tend to be built in job-rich locations.  Secondly, if a transit system is effective at providing accessibility, it is likely that commercial uses would outcome residential uses for those locations on the basis of higher rents per square foot.

It is difficult to draw any conclusion about the effects of transit on the jobs-housing balance for Las Vegas, because both the number of employees and number of employees resident in the transit corridor only show signs of recovery in 2011. Overall, there is support for the idea that proximity to transit worsens the jobs-housing balance, but there is not strong consistent trend. The jobs-housing ratio by incomes does not suggest that transit improves jobs-housing balance, and indeed may aggravate it. Year on year changes are erratic, with no clear trend standing out.

Metropolitan regions grow outward from historic cores, with residential development taking place along the periphery, and employment and commercial development congregating in central locations and along highly accessible corridors. Over time, as the metropolitan region expands outward, so does the roadway network. As employment continues to concentrate along network corridors, the jobs-worker balance tends to improve, bringing areas into better jobs-worker parity with the metropolitan region. Thus, the jobs-worker balance is more likely affected by relative location within a metropolis than by the presence of transit.

The jobs-housing ratio improves to become more balanced for only a small number of industries, and is very far from parity for most industries. While improving the job-worker ratio along the corridor towards parity would be a positive result, the failure to do so may not capture the whole story. For many metropolitan areas with a single high capacity transit line, all accessible destinations from transit must be in proximity to that line. The MAX BRT is not just a transit line, but it is part of a transfer network of transit routes.  Effectively gauging the effect on jobs-housing balance would require evaluating the jobs-worker balance over the whole transit network.

# 7-SUMMARY OF FINDINGS

Summaries of the results of the analysis for the five policy questions bellow.

**Are TODs attractive to certain NAICS sectors?**
**Do TODs generate more jobs in certain NAICS sectors?**
**Are firms in TODs more resilient to economic downturns?**
**Do TODs create more affordable housing measured as H+T?**
**Do TODs improve job accessibility for those living in or near them?**

## Q1: Attractiveness to NAICS sectors (Location quotient)

Transit corridor

- Substantial Increases: Education & Arts/Entertainment/Recreation
- Notable Increases: Wholesale, Real Estate, & Professional
- Substantial Reductions: Public Administration &Other Services

Transit advantage over comparable corridor

- Public Administration falls more in comparable corridor
- Minor increases significant in comparison: Real Estate & Professional
- Arts/Entertainment/Recreation does substantially better

## Q2: Do TODs generate more jobs in certain NAICS sectors? (Shift-share analysis)

Numeric Change in Transit corridor

- Employment in transit corridor shrank more than metropolitan area
- Substantial numeric increases: Education
- Substantial percent increases: Arts/Entertainment/Recreation
- Substantial reductions:  Construction, Manufacturing & Lodging/Food

Effect of corridor, as per shift-share

- Overall Corridor Effect is negative
- Education benefits the most
- Minor Benefit: Arts/Entertainment/Recreation
- Strong negative for: Public Administration, Health Care, & Lodging/Food

Transit advantage over comparable corridor

- High Corridor Benefit for Wholesale, Education, Arts/Entertainment/Recreation
- Corridor Effect much more positive for transit corridor for most industries

## Q3: Are firms in TODs more resilient to economic downturns? (Interrupted Time Series)

In this example, resilience is defined as the capacity to maintain a positive trend despite the economic shock of the 'Great Recession'. The $R^2$ values measure the amount of variation in trends before and after the recession. More resilient industries will have more comparable $R^2$ values.

Transit corridor after 2008

- Positive trends: Arts/Entertainment/Recreation & Management
- Strong positive trends: Management

Transit Corridor Differences before and after Great Recession

- Better trend after: Transportation, Finance, & Arts/Entertainment/Recreation
- Strengthened trend: Management

Advantage over comparable corridor:

- Better trends: Arts/Entertainment/Recreation & Transportation
- More Resilient: None

## Q4: Do TODs create more affordable housing measured as H+T? (Housing affordability)

Unlike other analyses in this report, this analysis measures changes in more than just the 0.50mile buffers. The magnitude of the effect of transit should be proportional to proximity to transit.

Transit corridor

- H+T costs for the transit corridor are less than the metropolitan average
- H+T costs fall with proximity, barring the area within 0.25 miles
- Housing costs are lower nearer to the transit corridor

Transit corridor transportation costs and housing costs by tenure

- Transportation costs nearly flat
- For renters, housing costs are lower nearer the transit corridor
- For owners, housing costs higher than metro average within 0.25 miles of transit

Advantage over comparable corridor

- H+T costs for transit corridor lower than metropolitan area for all distances.
- H+T costs for transit corridor lower than comparable corridor for all distances.

## Q5: Do TODs improve job accessibility for those living in or near them?

Jobs accessibility was operationalized as the balance between number of workers and number of workers residing in the corridor, using the jobs-housing ratio as a comparison. The jobs-housing ratio for the metro was used as the preferred ratio. The differences were compared for all workers in the corridor, for workers by earnings, and for workers by industry.

- Job rich at start of study period, with jobs-housing ratio greater than that of the metropolitan area
- Erratic trends, big year on year changes
- Changes in jobs-housing ratio caused by both declining number of workers, and declining number of workers resident in the corridor
- Jobs-housing ratio improved steadily for high income workers until 2011
- Wholesale industry, previously job-poor, moved toward parity
- Job-rich, moved toward parity: Retail, Information, Health Care, & Other Services

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# 9-APPENDIX A

## LEHD

*The Longitudinal Employer-Household Dynamics (LEHD) program is part of the Center for Economic Studies at the U.S. Census Bureau. The LEHD program produces new, cost effective, public-use information combining federal, state and Census Bureau data on employers and employees under the Local Employment Dynamics (LED) Partnership. State and local authorities increasingly need detailed local information about their economies to make informed decisions. The LED Partnership works to fill critical data gaps and provide indicators needed by state and local authorities.*

*Under the LED Partnership, states agree to share Unemployment Insurance earnings data and the Quarterly Census of Employment and Wages (QCEW) data with the Census Bureau. The LEHD program combines these administrative data, additional administrative data and data from censuses and surveys. From these data, the program creates statistics on employment, earnings, and job flows at detailed levels of geography and industry and for different demographic groups. In addition, the LEHD program uses these data to create partially synthetic data on workers' residential patterns.*

*All 50 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands have joined the LED Partnership, although the LEHD program is not yet producing public-use statistics for Massachusetts, Puerto Rico, or the U.S. Virgin Islands. The LEHD program staff includes geographers, programmers, and economists.*

Source: http://lehd.ces.census.gov/

## Shift-Share Calculations

| | Local Economy | | | | Reference Economy | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NAICS SECTOR | Initial Year | Final year | # Change | % Change | Initial Year | Final year | # Change | % Change | County Share (CS) | Industry Mix (IM) | Local Economy Effect (LEE) |
| Sector A | a | b | =(b-a) | =(b-a)/a | a2 | b2 | =(b2-a2) | =(b2-a2)/a2 | =[(b2+d2+f2-(a2+c2+e2)]/(a2+c2+e2) | =a*[(b2-a2)/a2] | =[(b-a)]-CS+IM for Sector A |
| Sector B | c | d | =(d-c) | =(d-c)/c | c2 | d2 | =(d2-c2) | =(d2-c2)/c2 | =[(b2+d2+f2-(a2+c2+e2)]/(a2+c2+e2) | =b*[(d2-c2)/c2] | =[(b-a)]-CS+IM for Sector B |
| Sector C | e | f | =(f-e) | =(f-e)/e | e2 | f2 | =(f2-e2) | =(f2-e2)/e2 | =[(b2+d2+f2-(a2+c2+e2)]/(a2+c2+e2) | =c*[(f2-e2)/e2] | =[(b-a)]-CS+IM for Sector C |
| Totals | a+c+e | b+d+f | =(b+d+f)-(a+c+e) | =[(b+d+f-(a+c+e)] / (a+c+e) | a2+c2+e2 | b2+d2+f2 | =(b2+d2+f2)-(a2+c2+e2) | =[(b2+d2+f2-(a2+c2+e2)] / (a2+c2+e2) | na | na | Sum of LEE for Sectors A, B & C |