Light Rail Transit and Economic Recovery: A Case of Resilience or Transformation?

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Abstract

In recent years, the ecological concept of "resilience" has been applied to social and economic systems in researchers' attempts to understand the extent to which those systems recover after calamity. Resilience strictly speaking can mean little more than carrying on as usual after a period of recovery. It can also mean learning from calamity so that while most functions resume, systems are prepared for the next, similar calamity. But transformation can also occur whereby systems are restructured, abandoning the most vulnerable pre-calamity elements while redirecting resources to new elements better able to withstand known and unknown future calamities. We apply the concepts of resilience and transformation to the seven light rail transit (LRT) systems operating in the U.S. before, during and after the Great Recession. Using shift-share analysis across groups of economic sectors, we trace the share and shift in the share of jobs in those sectors during each of the three time periods. We find some evidence that economic activity within 0.50-mile of light rail stations was more resilient to the economic downturn associated with the Great Recession than their metropolitan areas as a whole. But we found more: during recovery most of those metropolitan areas' economies appear to have been transformed such that jobs were shifting substantially more to LRT corridors in the post-recession period than before, though softened compared to the Great Recession period itself. We offer implications for the role of LRT systems and, by extension, all fixed guideway transit systems in facilitating economic resiliency if not outright transformation. Implications are offered.

Introduction

re·sil·ient *adjective* \ri-ˈzil-yənt\

a. capable of withstanding shock.

b. tending to recover from or adjust easily to misfortunate or change.

trans·for·ma·tion *noun* tran(t)sfərˈmāSH(ə)n/

a. thorough or dramatic change in form or appearance.

b. metamorphosis during the life cycle of an animal.

c. the induced or spontaneous change of one element into another by a nuclear process.

It seems an article of faith among transit proponents that transit systems, especially fixed-guideway ones, enable local economies to withstand economic shocks better than areas without these options. Alternatively, because transit systems induce economic development and investment in the region, they may transform it. Yet, there is scant literature making either of these connections theoretically and none testing it empirically. In this preliminary exploration, we start what should be a new literature connecting transit with economic resilience and transformation.

We begin with a review of resiliency and transformability as concepts, review recent literature applying the concepts to transit and, using economic resiliency and transformability literature, we craft a theory of transit and economic resilience. We continue with an application of our theory to the seven light rail transit (LRT) systems operating in the United States from 2004 into the post-recession period, to 2014. We offer implications for the role of these forms of fixed-guideway transit on economic resiliency.

Resiliency

Pendall et al. (2010) and Martin-Breen and Anderies (2011) offer sweeping views of resiliency as a concept from such disciplines as ecology, psychology, geography, political science and economics. Here, we focus on some of the key elements in the evolution of the concept as applied to urban policy.

The earliest applications of the concept emanate from the field of "ecological resilience" (Holling, 1973). It was used to describe the biological capacity of an ecosystem to adapt and thrive under adverse environmental conditions. Specifically, resilience was described as "the persistence of relationships within a system; a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist" (Holling, 1973). Since then, this definition of resilience has been expanded to similar fields that emphasize the link between social and environmental systems (Berkes et al., 2003; Folke, 2006; Walker and Salt, 2006), including urban planning (Bristow, 2010)

As appealing as the idea of resilience might be for urban planners and regional researchers, there is the distinct danger of "fuzziness" (Pendell et al., 2010). One reason for the popularity of the term resilience, and the subsequent fuzziness, is the term's malleability; it can mean different things to different people (Christopherson et al., 2010). For instance, to engineers, resiliency is "the ability to store strain energy and deflect elastically under a load without breaking or being deformed" (Gordon, 1978). Psychologists adopted the term resilience to describe patients who were able to overcome adverse conditions (Masten et al., 1990). In economics, resilience has been defined in terms of return to a fixed and narrowly defined equilibrium following a shock (as measured by employment, for example). In the social sciences

the term regional resilience is associated and almost synonymous with regional adaptation (Christopherson et al., 2010).

As a result, the new term *social-ecological resilience* emerged and is defined as the amount of disturbance a system can absorb and still remain within the same state; the degree to which the system is capable of self-organization; and the degree to which the system can cope with change (Wilkinson et al., 2010). This definition can be applied in an urban and regional planning context where the city, neighborhood or metropolitan area is the system, and the disturbance may be any number of internal or external shocks.

The resilience approach to urban planning assumes that the future will include a major element of surprise, and that urban systems must be designed and operated in ways that accommodate sudden and unexpected changes (Sheltair Group, 2003). This approach is understandably appealing to urban planners because they must make long-term plans in the face of an uncertain future.

The discourse of resilience is also taking hold in discussions around desirable local and regional development activities and strategies (Hassink, 2010). The global financial crises and the accompanying increase in livelihood insecurity has revealed the advantages of those local and regional economies that have greater resilience by virtue of being less dependent upon global activities. A resilience approach would draw parallels between healthy ecosystems and healthy economies: Healthy ecosystems possess a high degree of functional diversity, and successful economic regions possess greater economic diversity and/or have a determination to adapt and make significant structural changes (Ashby et al., 2009; Larkin and Cooper, 2009).

Similarly, resilience emerged in relation to emergency and disaster planning in cities. Wardekker et al. (2009) gathered urban planners from across Holland to operationalize resilience

strategies to plan and prepare for the uncertain effects of climate change. Their "regional resilience" approach to disaster planning is rooted in the principles of resiliency; change will occur, unexpected shocks cannot be predicted, therefore cities must strengthen their capacity to withstand and rebound from shocks.

The challenge is for planners to prepare and implement plans that will reduce the severity and negative aspects of an inevitable shock. We suggest that the location improvements induced by transit investments and transit allows cities to withstand shocks, as well as hasten the recovery from a shock. Across the U.S., transit development has enhanced urban travel corridors by triggering reinvestment and development in the area (Bartholomew and Ewing, 2011). We see transit development as a metropolitan-scale strategy to promote resilience, and we test this hypothesis here.

Transformability

Transformability and resilience are complementary concepts, yet there exist differences between resilience and transformability. Resilience describes the capacity of a particular system to respond to a shock, while transformability refers to fundamentally altering the nature of the system (Walker et al., 2004). We emphasize that resilience stresses that a system remains in "the same state," or retains the "same function." *Transformability* is the capacity to create a fundamentally new system when "ecological, economic, or social structures make the existing system untenable" (Walker et al., 2004). While resilience is the capacity to maintain a current state, transformation is the capacity to change to a new state. However, the two concepts remain complementary, where resilient systems can and should transform. Resilience thinking suggests that a shock may open up opportunities for learning, novelty and innovation, possibly resulting in

transformational change (Folke et al., 2010). A resilient system may not "recover" back to an original state, but rather resilience could facilitate transformation to a new state.

Transformability can also be characterized by the introduction of new characteristics, or the strengthening of latent characteristics (Folke et al., 2010). If a system's pre-shock characteristics were fundamentally inefficient (and perhaps contributed to the shock), then a shock to the system would stop further inefficient outcomes and reward more efficient ones. Transformations in resilient systems "make use of crises as windows of opportunity" to break down the resilience of the old, and build the resilience of the new (Folke et al., 2010, pg. 7).

Transit and Resiliency

According to Marshall (2012), the studies into transportation resilience have focused mostly on the ability of transportation systems to sustain target levels of service during a shock and/or the delay in returning to that service (see also Heaslip and Louisell, 2009; 2010). There is a substantial and growing literature on transportation infrastructure resiliency with respect to climate change (see Cybulski, 2013, for a review of the literature). Yet, there is no literature directly relating transit with economic resilience. When it comes to economic resiliency, Marshall's review of literature concludes that it has focused on spikes in gasoline prices (see also Briguglio et al., 2005, 2008; Zheng et al., 2010). Marshall is presently engaged in U.S. DOT-sponsored research that explores "the varying impact of transit infrastructure and TODs on the ability of different households to be resilient to uncontrollable outside forces, such as rising gas prices." (Marshall, 2012: 2)

A Theory of Transit and Economic Resilience

That there *should* be an association between transit and economic development has been established reasonably well in the literature. That there *is* may not yet be conclusive, though emerging evidence seems supportive. A key measure of economic effects is using the real estate market to estimate the premium the market is willing to pay for proximity to transit. Three recent papers have compiled literature providing a preponderance of evidence showing this for both residential and office development (Bartholomew and Ewing, 2011; Petheram et al., 2013; and Ko and Cao, 2013).

Another key measure is how jobs are affected by transit investments. In their recent study of employment within 0.50 mile of transit stations serving 34 transit systems over the period 2002 through 2008, Belzer, Srivastava and Austin (2011) found that while jobs increase in the arts, entertainment and recreation sector, as well as the food and accommodation, and health care and social assistance sectors, they fell in the manufacturing sector. They also found that the public administration sector had the greatest share of jobs found near transit stations. Several other sectors also concentrated around transit stations such as professional, scientific and technical services, and retail. On the other hand, as a whole the station areas experienced declining shares of jobs relative to their regions, with the exceptions of jobs in the utilities, information and arts, entertainment and recreation sectors. Indeed, data for 2008, the first full year of the Great Recession, indicated that most sectors within 0.50 mile of transit stations lost job share relative to their regions as a whole. They surmised that much of the metropolitan job growth continues to favor auto-oriented locations.

In short, while the relationship between transit and economic development measured in terms of value premiums is strong, the relationship with respect to jobs is not as clear. This paper will take a closer look at this nuance.

In measuring economic resilience, Pendall et al. (2010) suggest two related approaches: "equilibrium analysis," which measures resilience as the time it takes to return to the level before a shock, and "complex adaptation" adaptive systems, which measure the ability of a system to adapt to stresses caused by the shock. Hill et al. (2012) refines measuring the first approach in terms of the time it takes to return to the rate of growth of output, employment or population after a shock. For reasons noted below, we will focus on jobs as a key measure for resilience. On the other hand, while a quality location for warehousing may see employment recover to pre-recessionary levels, an increase in location quality might also result in that location transitioning to a higher-rent urban use.

While much of the literature on economic resilience focuses on measuring time-to-recovery, Briguglio et al. (2005; 2008) are more nuanced. To them, economic resilience refers to the ability to recover quickly from a shock and withstand the effect of a shock as it occurs (Briguglio et al., 2008: 4-5). In our view, their concepts can be reversed to measure the ability of an economy to withstand the shock as it occurs, and then the amount of time it takes to recover from the shock.

Briguglio et al. also saw a role for public policy in facilitating resilience by ameliorating adverse effects of economic shocks. In our view, transit may be one such policy. In terms of transit and economic resilience, we thus theorize that transit will dampen adverse outcomes associated with an economic shock and facilitate a speedier recovery. One way in which to

further measure these outcomes is to compare transit corridors with control corridors before, during and after an economic shock. This is illustrated in Figure 1.

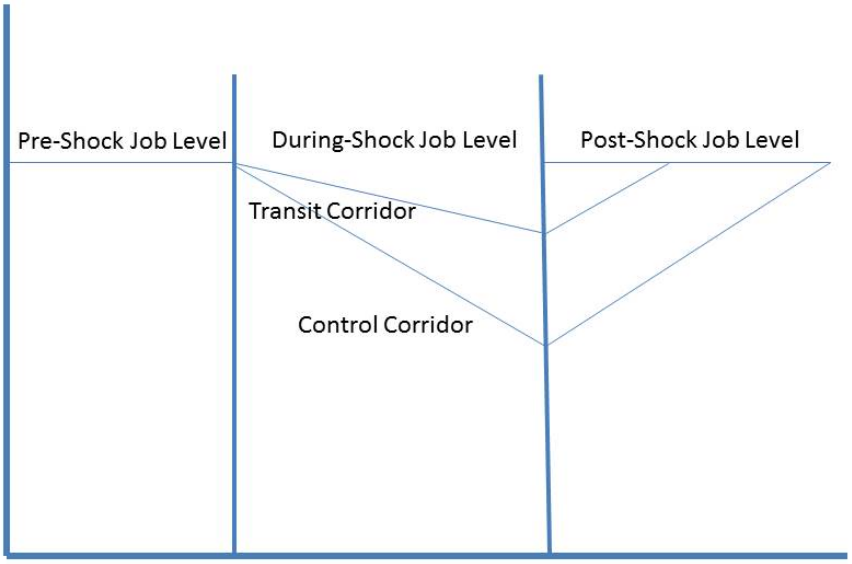

Figure 1

Pre-, During-, and Post-Shock Job Levels for Transit and Control Corridors

A Theory of Transit and Economic Transformability

An alternative theory on how transit may affect a metropolitan area's resilience can be viewed through the lens of transformability. Rather than transit investments bolstering regional resilience by allowing a metropolitan area's economy to return to pre-shock conditions, transit may affect a *transformation* to new economic conditions. For example, if pre-shock land use patterns were fundamentally inefficient (and perhaps contributed to the shock), then the shock would stop further inefficient outcomes and reward more efficient ones. In our context, the real estate market may favor transit accessibility over other locations both during a recession and especially afterward. Transit may not facilitate resilience in the sense of a "recovery" back to pre-recession sprawl, but rather resilience facilitates transformation of investment to locations that the private sector views as a hedge against future economic downturns. A shock would accelerate this transition.

We apply our theory to an empirical analysis as described next.

Research Question and Design

Based on our theory, transit oriented development (TOD) areas serving such fixed guideway transit systems as light rail transit (LRT) should retain if not capture a higher share of jobs than their regions during an economic downturn and afterward. Our research question is simple:

Do LRT TOD areas capture proportionately more jobs than their regions during an economic shock and the post-shock period? We mean the term "capture" as the share of total jobs and jobs within two-digit NAICS sectors that are within census blocks whose centroids are with 0.50 mile of LRT stations as described in our data below.

We consider LRT systems because of all the modes we address in this study, LRT has the largest sample size and seems the most emblematic of modern fixed-guideway transportation.

We use a pre-post design with an interrupted time period to address the research question. Next, we review our data, study period, the light rail systems selected for analysis, and analytic approach. This is followed by results and implications.

Data

Because we evaluate the shift in share of jobs by economic sector over time, we use employment data. The source of data is the Longitudinal Employer-Household Dynamics (LEHD) program which is part of the Center for Economic Studies at the U.S. Census Bureau.[1] For all LRT systems studied, two-digit NAICS data are available annually from 2002 through 2014 at the census block level. We include every block whose closest point is within 0.50 mile of the nearest LRT station point.

Study Periods

We evaluate shift in shares of jobs over three discrete time periods extending from before the Great Recession of the late 2000s, through the Great Recession itself, and during recovery:

- 2002-2007 covers the period of relatively constant growth from the early 2000s to the end of 2007. This is the pre-sheck period that we call "pre-recession".
- 2008-2010 covers the period of the Great Recession. This is the "shock" period. According to our theory, LRT TODs should retain if not capture a higher share of the shift of regional jobs than their regions as a whole. This is the interrupted period.

[1] For details, see http://lehd.ces.census.gov/.

- 2011-2014 covers the period after the Great Recession, the "post-shock" period that we call "post-recession". This is the post-test period. Based on our theory, LRT TODs should capture a higher share of the shift of regional jobs than their metropolitan areas as a whole. Whether this share in the shift would be higher than predicted during the Great Recession we cannot say, but we can predict it should be higher than the pre-recession period.

Light Rail Transit Systems Studied

We evaluate all seven U.S. LRT systems that were operating in 2004 in metropolitan areas with more than seven million people. Newer systems were excluded because they were launched on the heels of, or even during, the Great Recession: Houston (2006), Charlotte (2007), Phoenix (2008) and Seattle (2009). We also excluded systems serving large metropolitan areas with multiple networks of fixed guideway transit systems such as Los Angeles and the San Francisco Bay Area. The systems we evaluate and the year in which each commenced operations is reported in Table 1. Similar to Belzer et al. (2011), we use the 0.50 mile corridor (1.0 mile total width) as our "treatment" unit of analysis compared to the regions as a whole.

Table 1

Light Rail Systems used in Analysis

LRT System	Year
Dallas	1996
Denver	1994
Portland	1986
Sacramento	1987
Salt Lake City	1999
San Diego	1981
Twin Cities	2004

Analytic Approach

Given that change in employment share over time is our principal interest, we choose shift-share analysis as our analytic approach. This is similar to the approach we used to evaluate shifts in shares of jobs around bus rapid transit stations in the Eugene-Springfield (Oregon) metropolitan area. We adapt that analytic discussion to the present analysis (Nelson et al. 2013).

Shift-share analysis assigns the change or shift in the share or concentration of jobs with respect to the region, other economic sectors, and the local area. The "region" can be any level of geography and is often the nation or the state. In our case, where we want to see whether there are intrametropolitan shifts in the share of jobs by sector, our region is the "Transit Region" meaning those counties within which LRT systems operated during the entire study period. The "local" area is often a city or county or even state, but it can be any geographic unit that is smaller than the region. Our local areas are the LRT station areas within 0.50 mile of the nearest LRT station. We call these "LRT Stations". As shifts in the share of jobs may vary by sector over time because of changes in economic sector mixes, there is also an "industry mix" adjustment

that we call “sector mix”. Using notations by the Carnegie Mellon Center for Economic Development (no date), the shift-share formula is:

$$SS_i = TR_i + SM_i + LRT_i$$

Where

SS_i = Shift-Share

TR_i = Transit Region share

SM_i = Sector Mix

LRT_i = LRT Station Area shift

The Transit Region (TR) share measures by how much total employment in a LRT station area changed because of change in the TR economy during the period of analysis. If TR employment grew by 10 percent during the analysis period, then employment in the LRT station area would have also grown by 10 percent. The Sector Mix (SM) identifies fast growing or slow growing economic sectors in a LRT station area based on the TR growth rates for the individual economic sectors. For instance, an LRT station area with an above-average share of the TR’s high-growth sectors would have grown faster than an LRT station area with a high share of low-growth sectors. The LRT station area shift, also called the “competitive effect”, is the most relevant component. It identifies a LRT station area’s leading and lagging sectors. In particular, the competitive effect compares a LRT station area’s growth rate in a given economic sector with the growth rate for that same sector at the TR level. A leading sector is one where that sector’s LRT station area growth rate is greater than its TR growth rate. A lagging sector is one where the sector’s LRT station area growth rate is less than its TR growth rate.[2]

2 We have adapted the Carnegie Mellon Center for Economic Development’s description of how shift-share works for our application.

The equations for each component of the shift-share analysis are:

$$TR = ({}_iLRT\ Station\ Area^{t-1} \times TR^{t}/TR^{t-1})$$

$$SM = [({}_iLRT\ Station\ Area^{t-1} \times {}_iTR^{t}/{}_iTR^{t-1}) - TR]$$

$$LRT = [{}_iLRT\ Station\ Area^{t-1} \times ({}_iLRT\ Station\ Area^{t}/{}_iLRT\ Station\ Area^{t-1} - {}_iTR^{t}/{}_iTR^{t-1})]$$

Where:

${}_iLRT\ Station\ Area^{t-1}$ = number of jobs in the LRT Station Area sector (i) at the beginning of the analysis period (t-1)

${}_iLRT\ Station\ Area^{t}$ = number of jobs in the LRT Station Area in sector (i) at the end of the analysis period (t)

TR^{t-1} = total number of jobs in the Transit Region at the beginning of the analysis period (t-1)

TR^{t} = total number of jobs in the Transit Region at the end of the analysis period (t)

${}_iTR^{t-1}$ = number of jobs in the Transit Region in sector (i) at the beginning of the analysis period (t-1)

${}_iTR^{t}$ = number of jobs in the Transit Region in sector (i) at the end of the analysis period (t)

We analyze those jobs which normally occupy space in urban settings. This excludes the North American Industrial Classification System (NAICS) sectors of agriculture, forestry, mining, and construction. We also exclude the industrial sectors (utilities, manufacturing, transportation and warehousing, and wholesale trade) because of their land-extensive nature, making them usually unsuitable per se for locating near transit stations.[3] We further assemble

[3] Urban microbreweries and small-scale crafts shops are the kinds of exceptions that support our general rule.

other sectors into roughly comparable space-consuming land uses based on Nelson (2004) which are reported in Table 2. This allows us to detect differences in the nature of shifts in shares over time by comparable land use categories. As noted earlier, we evaluate employment performance within 0.50 mile of LRT stations.

Table 2
Conversion of NAICS Economic Sectors into Land Use Classifications for Analysis

Land-Use Classification	NAICS Sector	NAICS Label
Retail & Lodging	44-45	Retail Trade
	72	Accommodation and Food Services
Office	52	Finance and Insurance
	53	Real Estate and Rental and Leasing
	55	Management of Companies and Enterprises
	56	Administrative and Support and Waste Management
	81	Other Services (except Public Administration)
	92	Public Administration
Knowledge	51	Information
	54	Professional, Scientific, and Technical Services
Education	61	Educational Services
Health	62	Health Care and Social Assistance
Entertainment	71	Arts, Entertainment, and Recreation

Source: NAICS information from Census.

Results and Discussion

For brevity, Table 3 reports only the share of change attributable to LRT station areas meaning the TR and SM results are not reported here. The table reports LRT station area results for each of the seven transit regions we studied and the composite for all seven,[4] over each of the three time periods. Table 4 summarizes outcomes for transit regions, showing for each transit region which economic group gained or lost share in the shift of jobs between time periods. Table 5 summarizes outcomes for combined economic sectors. We discuss outcomes for economic groups followed by results for each of the seven transit regions.

Results and Discussion for Economic Groups

During the pre-recession period 2004 through 2007, LRT TOD station areas lost share of jobs in nearly all economic sectors and overall. As this was a period of extraordinary outward expansion of metropolitan areas (see Nelson, 2013), we are expected this outcome. Overall, the only economic groups that gained jobs were education (many LRT stations serve major educational institutions) and entertainment. During this period, the overall shift was nearly 43,000 jobs away from LRT TODs.

As we expected from our theory, the Great Recession stressed the economies of all seven transit regions making locations near LRT TODs more attractive to firms. The period of economic shock, 2008-2010, saw gains in most economic groups with an overall shift in more than 41,000 jobs toward LRT TODs. Nonetheless, the retail and lodging, knowledge, and entertainment economic groups lost share in the shift of jobs, with the latter changing directions. We suspect that the entertainment group, which is comprised of arts, entertainment and

[4] This analysis groups data for all seven TRs into a common pool for shift-share analysis.

recreation activities may be outbid for locations near LRT TODs and are pushed into other locations.

During the post-recession period, all but two TOD areas gained share in the shift of jobs; as during the Great Recession, the entertainment economic groups lost share. However, offices also lost share in shift of jobs. We speculate that one reason is that with such a sizeable gain in share during the Great Recession (nearly 48,000 jobs), the small negative shift (about 1,500) is negligible. Overall, the post-recession shift toward LRT TODs sustains trends seen during the recession; indeed, the latter period saw more economic groups with positive shifts. In Table 4, we summarize outcomes for economic groups between the pre-event and event periods, the event and post-event periods, and between the pre-event and post-event periods. Notably, whereas nearly all economic groups lost share of job shift in all transit regions combined during the pre-recession period (the exceptions being education and health), nearly all gained share during the post-recession period (the exception being entertainment).

Figure 2 illustrates the overall shift in the share of jobs in these seven transit regions before, during and after the Great Recession. While before-and-after trends are mirror images, the post-recession trend shows LRT TODs continuing to gain share of transit region jobs, though with a decidedly smaller share than the Great Recession period. We explore the implications of these trends later.

We now present results and discussion about individual transit regions.

Table 3
Light Rail Transit TOD-Area Share of Change by Time Period

Metro Area	Dallas	Denver	Portland	Sacramento	Salt Lake City	San Diego	Twin Cities	Composite
Sector			***Transit Station Shift-Share Results 2002-2007 Pre-Recession***					
Retail & Lodging	(5,488)	(490)	140	(483)	(2,210)	2,174	122	(4,273)
Office	(10,228)	1,210	(798)	(18,152)	(113)	(2,231)	(2,023)	(36,101)
Knowledge	(1,230)	4,563	252	(811)	(786)	(2,230)	(3,261)	(3,184)
Education	242	2,183	135	(1,382)	(1,235)	(1,198)	769	463
Health	(3,930)	(665)	(1,053)	1,150	977	29	2,193	(233)
Entertainment	(899)	474	223	264	(215)	451	287	508
Total	(21,534)	7,274	(1,100)	(19,413)	(3,582)	(3,005)	(1,914)	(42,820)
Sector			***Transit Station Shift-Share Results 2008-2010 Great Recession***					
Retail & Lodging	(2,347)	89	(442)	214	(1,987)	(224)	(932)	(6,519)
Office	6,596	7,920	(2,355)	35,016	(1,498)	3,593	(2,977)	47,819
Knowledge	(575)	(2,845)	514	1,227	198	336	1,238	(1,084)
Education	1,144	(3,030)	(195)	(359)	1,130	1,376	863	498
Health	3,076	(1,930)	(2,833)	(1,892)	1,787	431	3,995	2,984
Entertainment	1,188	(942)	(242)	(810)	193	(386)	(1,476)	(2,219)
Total	9,082	(737)	(5,552)	33,397	(178)	5,126	711	41,479
Sector			***Transit Station Shift-Share Results 2011-2014 Post Great Recession***					
Retail & Lodging	5,816	1,400	(779)	(311)	1,534	451	551	8,906
Office	6,026	(2,823)	3,113	1,575	(493)	(12,437)	11,377	(1,562)
Knowledge	3,061	(3,409)	490	933	(63)	(1,084)	1,929	2,885
Education	(6,791)	16,072	(14,785)	174	1,094	5,293	(359)	1,004
Health	1,155	3,353	(2,119)	(3,324)	3,974	(573)	98	1,128
Entertainment	(542)	44	229	(228)	(60)	(2,365)	1,904	(671)
Total	8,726	14,638	(13,851)	(1,182)	5,987	(10,714)	15,501	11,690

Table 4

Pre-Recession, Great Recession and Recovery Shift-Share TOD-Area Outcomes by Combined Economic Sector

Sector	Pre-Recession LRT Shift (2004-2007)	Great Recession LRT Shift (2008-2010)	Outcome Pre-Recession through Recession	Post-Recession LRT Shift (2011-2014)	Outcome Recession to Post-Recession	Outcome Pre-Recession to Post-Recession
Retail & Lodging	(4,273)	(6,519)	Lost	8,906	Gained	Gained
Office	(36,101)	47,819	Gained	(1,562)	Lost	Gained
Knowledge	(3,184)	(1,084)	Gained	2,885	Gained	Gained
Education	463	498	Gained	1,004	Gained	Gained
Health	(233)	2,984	Gained	1,128	Lost	Gained
Entertainment	508	(2,219)	Lost	(671)	Gained	Lost
Total	(42,820)	41,479	Gained	11,690	Lost	Gained

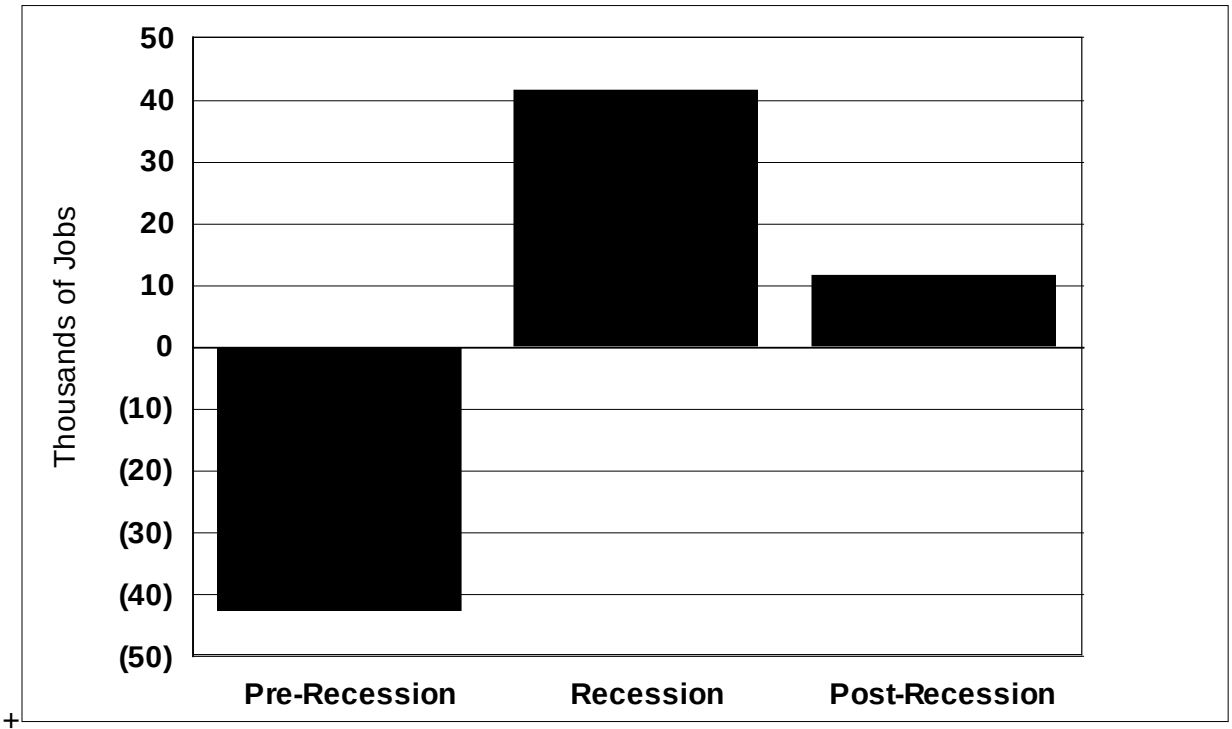

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Figure 2

Light Rail Corridor Composite Shift-Share Results for Pre-recession, Great Recession, and Post-Recession Time Periods

Results and Discussion for Transit Regions

Overall results for individual transit regions are summarized in Table 5. During the pre-recession period, only the Denver transit region saw overall gains in the share of jobs shifting to LRT TODs. All others lost share. The Great Recession saw reversals in shifts among most transit regions. Where Dallas, Sacramento, Salt Lake City, San Diego and the Twin Cities lost share during the pre-recession period, they gained share during the Great Recession, but Denver's direction changed as it lost jobs. Notably, Portland's shift of jobs away from LRT TODs accelerated during the Great Recession.

While the Great Recession seemed to change the attractiveness of jobs attracted to or retained in LRT TODs for nearly all transit regions, this trend was not sustained in most of them during the post-recession period (Dallas, Portland, Sacramento and San Diego), even though overall transit regions still gained overall share after the Great Recession. We comment on this below.

When looking at the overall change in the share of jobs shifting in transit regions before and after the Great Recession, we see that only Portland and San Diego lost share while all others gained, and all LRT TODs gained overall. We comment on this as well next.

San Diego (1981), Portland (1986) and Sacramento (1987) are pioneers in having the nation's oldest light rail transit systems. Indeed, the second-generation LRT systems were launched more than a decade (or two) after the first one, so planners learned lessons from the pioneers. What are they (see Nelson et al. 2015)?

- To economize on costs, early LRT lines were placed in or along rail freight corridors or along major highways, especially interstates.

- While early LRT systems connected major nodes to each other they did not create opportunities for smaller nodes to grow, often because line locations prohibited this.
- Some of the early LRT stations were essentially park-and-ride lots that actually discouraged the market from making investments near those stations.

From the data and our personal knowledge of these pioneering systems, it appears that development prospects were limited to mostly major nodes. They also built out within a few years of station openings. By the time our study period began, there was little room for many of the LRT TODs to grow, at least within the 0.50 mile study areas.

In contrast, the newer systems were all designed to maximize development opportunities within and near LRT TODs, especially Dallas, Denver and the Twin Cities. We surmise that one consequence of the Great Recession is that the market will be attracted to LRT TODs much more so than in the past, but there also needs to be sufficient buildable land in and near those TODs to meet market demand.

Table 5
Pre-Recession, Great Recession and Recovery Shift-Share TOD-Area Outcomes by Metropolitan Area

Metro Area	Pre-Recession LRT Shift	Great Recession LRT Shift	Outcome Pre-Recession through Recession	Post-Recession LRT Shift	Outcome Recession into Post-Recession	Outcome Pre-Recession into Post-Recession
Dallas	(21,534)	9,082	Gained	8,726	Lost	Gained
Denver	7,274	(737)	Lost	14,638	Gained	Gained
Portland	(1,100)	(5,552)	Lost	(13,851)	Lost	Lost
Sacramento	(19,413)	33,397	Gained	(1,182)	Lost	Gained
Salt Lake City	(3,582)	(178)	Gained	5,987	Gained	Gained
San Diego	(3,005)	5,126	Gained	(10,714)	Lost	Lost
Twin Cities	(1,914)	711	Gained	15,501	Gained	Gained
Composite	(42,820)	41,479	Gained	11,690	Gained	Gained

Implications

Our theory that fixed-guideway transit systems, such as light rail systems, may improve metropolitan-scale resilience and even advance transformability as a consequence of economic shocks appears substantially supported. Before the Great Recession, the LRT TODs saw their overall share of jobs erode relative to transit regions as a whole. In other words, jobs were moving away from TODs. This is consistent with trends of the 2000s to the Great Recession in 2008 during which the nation sprawled more than during any other period. Trends changed dramatically during the Great Recession and were sustained into the post-recession period.

Before we speculate on reasons why we think that LRT TODs are resilient to economic shock, and why they may be transforming transit regions, we must note several limitations of our work. Our research design is unable to establish causality simply because it is not a purely experimental research design. Further, we are unable to control for every confounding variable that can influence economic growth such as factor inputs, government regulation/intervention and so forth. However, the research design we employed offers greater insight over cross-sectional research designs because we have multiple years of data and we utilize a control group—the transit region defined as counties within which LRT systems operated during our entire study period. Thus, while we cannot definitively declare that LRT *will* improve regional economic resilience, the analysis supports an association between LRT TODs and regional resilience to economic downturns, and transformation afterward. Accordingly, we offer the following reasons on why LRT TODs—and by extension TODs served by other fixed guideway systems—can improve regional resiliency during economic shocks and transformation of regional economies afterward. We now offer implications of our work.

First of all, times have changed. In the era before the Great Recession, urban sprawl in the United States was—and still is—the dominant urban form. It was fueled by vast amounts of inexpensive land in suburbs accessed by perhaps the world's most extensive intrametropolitan highway systems. Downtowns lost their dominance in metropolitan economies as smaller suburban centers rose (Lang, LeFurgy and Nelson 2006). Jobs followed people as people sought new housing away from urban centers (Nelson 2006).

It can be argued that the Great Recession has changed the dynamics driving America's urban form. Research has shown that America's suburban form, comprised largely of single family detached homes, was financially and economically unsustainable (Nelson et al. 2017). The economy paid the price as millions of jobs were lost, the US federal government spent several trillion dollars rescuing financial institutions, and home owners lost trillions of dollars in equity—almost entirely in suburban areas. Arguably, the Great Recession showed how inefficient, sprawling development is (Nelson 2013a). The market, including commercial real estate lenders and investors, turned inward favoring closer-in locations and especially those accessed by fixed guideway transit systems (Pivo and Fisher 2010).

But the market may face a new challenge as there may not be enough supply to meet demand for LRT TOD investment. TODs are attractive to both commercial and residential markets. Numerous surveys indicate that perhaps a quarter or more of American households want the opportunity to choose to live near fixed-guideway transit stations. Even if all new housing units were built within 0.50 mile of those stations between now and mid-century, however, the demand may not be met (Nelson, 2013b). The combination of job and residential demand for locating near TODs may already exceed supply, as suggested in the cases of Portland and San Diego noted above. The transformation of America's metropolitan economy may be

stifled unless more fixed guideway transit systems are provided and their TOD areas better equipped to meet demand.

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