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The Influences of the Hiawatha LRT on Changes in Travel Behavior: A Retrospective Study on Movers

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Following scant evidence for the effects of proximity to rail transit on auto use, we pinpoint the impacts of rail transit and neighborhood characteristics on both transit and car use in the Minneapolis-St. Paul metropolitan area. In this vein, we apply the structural equations modeling approach on 597 residents who moved into the Hiawatha light rail transit (LRT) corridor after it opened. Using a quasi-longitudinal design to compare the behavior of movers into the Hiawatha and control corridors, we found that the Hiawatha LRT acts as both a catalyst and a magnet. Movers into the Hiawatha corridor experience transit improvement, which increases transit use and reduces car use. The LRT also enables transit-liking people who were unable to realize their preference previously to relocate near the LRT. However, the LRT has no significant effects on changes in auto ownership. This suggests that besides transit infrastructure, planners should promote transit-friendly neighborhood characteristics.

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The Influences of the Hiawatha LRT on Changes in Travel Behavior: A Retrospective Study on Movers

Final Report

Prepared by:

Jason Cao
Alireza Ermagun
Humphrey School of Public Affairs
University of Minnesota

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University of Minnesota
200 Transportation and Safety Building
511 Washington Avenue S.E.
Minneapolis, MN 55455

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Executive Summary

Following scant evidence for the effects of proximity to rail transit on auto use, we pinpoint the impacts of rail transit and neighborhood characteristics on both transit and car use in the Minneapolis-St. Paul metropolitan area. In this vein, we apply the structural equations modeling approach on 597 residents who moved into the Hiawatha light rail transit (LRT) corridor after it opened. Using a quasi-longitudinal design to compare the behavior of movers into the Hiawatha and control corridors, we found that the Hiawatha LRT acts as both a catalyst and a magnet. Movers into the Hiawatha corridor experience transit improvement, which increases transit use and reduces car use. The LRT also enables transit-liking people who were unable to realize their preference previously to relocate near the LRT. However, the LRT has no significant effects on changes in auto ownership. This suggests that besides transit infrastructure, planners should promote transit-friendly neighborhood characteristics.

Chapter 1: Introduction

Developed countries have witnessed a considerable increase in private vehicle use. Total vehicle miles traveled (VMT) increased by 35 percent in the U.S. between 1990 and 2012 (EPA 2014), although its growth is stagnant after the peak in 2007. This trend arouses the concern of policymakers over traffic jams at peak hours, energy consumption, and adverse environmental impacts such as climate change and noise pollution. For example, 28 percent of total U.S. greenhouse gas emissions belong to the transportation sector in which passenger cars account for 43 percent of vehicles (EPA 2014). Policymakers and researchers have struggled to find effective solutions for persuading private car users to switch to public transit.

From the perspective of land use planning, manipulating urban form, particularly siting residences in proximity to valued destinations, lowers travel distances and thereby reduces auto travel (Ewing and Cervero 2010). From the travel behavior viewpoint, rail transit has been advocated as a way to promote transit ridership because high accessibility to and by transit increases the share of public transportation (Moniruzzaman and Páez 2012). Hence, rail transit programs and transit-oriented development (TOD) have bloomed throughout the past decades. It has imposed, however, a substantial financial burden on the government to improve the infrastructure and to implement the strategies. The capital cost of Hiawatha light rail transit (LRT) in Minneapolis, for instance, was more than $710 million for a 19.2 Km trunk rail. The 24-Km LRT of North South Line in Salt Lake City cost around $400 million (Cain et al. 2007). Hence, evaluating the costs and benefits of rail transit has become a hot issue in recent studies (Litman 2005), and has been the impetus behind the transit network development.

The underlying assumption of TOD programs is that clusters of buildings near transit promote transit ridership and hence reduce auto travel. It is rooted deeply in two main hypotheses. First, households near transit stations use private cars less frequently than those farther from transit. Second, households in new housing units around transit stations drive less than those in older housing units. Many studies have sought to uncover the nexus between proximity to transit stations and transit ridership (Cervero 2007, Dill 2008). Subsequently, it has long been a mantra among transportation and urban planners that living near transit stations increases transit ridership. It remains, however, unclear whether the households near transit stations also own and use private vehicles less. A few studies have attempted to scrutinize the impacts of living around transit stations on auto ownership and use (Chatman 2013, Dueker and Bianco 1999, Loo, Chen, and Chan 2010). However, they produced mixed outcomes.

This study strives to understand the impacts of rail transit and neighborhood characteristics on both transit use and car use. Using a self-administered survey in the Minneapolis-St. Paul metropolitan area (Twin Cities) in May 2011, it employs quasi-longitudinal analyses to explore the effects of the Hiawatha LRT on travel behavior of current residents who moved into the Hiawatha corridor after its opening. In this vein, the structure equations modeling approach is applied to disentangle the complex interaction among the Hiawatha LRT, transit attributes, neighborhood characteristics, and travel behavior. The core questions are: (1) does the Hiawatha LRT lead to an increase in transit use and a reduction in auto ownership and use? (2) are neighborhood characteristics around rail stations associated with changes in travel behavior?

The remainder of the study is organized in the following order. First, the impacts of transit and neighborhood characteristics on both transit ridership and auto travel are synthesized in the following section. The conceptual framework of the study, then, is presented followed by a description of data and variables. The penultimate section discusses modeling results. The last section summarizes the findings and makes some suggestions for further studies.

Chapter 2: Literature Review

During the past decades, TODs have been in hot debates in planning practice and academic circles. TOD is centered on transit and combines five Ds, namely density, diversity, design, destination accessibility, and demand management which aim to encourage people to use transit services (Ewing and Cervero 2010). Accordingly, it is hypothesized that TOD programs increase transit ridership, and thereby reduce VMT. Both researchers and practitioners have attempted to scrutinize the effects of TODs on travel behavior and auto ownership (Renee 2005, Chatman 2013). A comprehensive literature review focuses on the nexus between the built environment and travel behavior (Ewing and Cervero 2010, 2001). There is a modest literature, however, examining travel behavior of station area residents. This section, therefore, is limited to synthesize the impact of proximity to rail transits on travel behavior, which is in line with the context of the current study.

Table 1 summarizes some studies with diverse geographic contexts, time spans, and analysis methods. Exploring the effects of neighborhood characteristics on automobile use is traced back to 1994 when Holtzclaw (1994) investigated the influence of four neighborhood characteristics, namely transit accessibility, pedestrian accessibility, residential density, and neighborhood shopping on car use in California. Ever since, a number of studies have shed some light on travel behavior of station area residents. Previous studies unanimously concluded a positive correlation between living near rail stations and transit ridership (Cervero 2007, Dill 2008, Dueker and Bianco 1999). A study in 2006, for instance, showed that residents in TOD housing units in California are up to five times more likely to take transit than non-TOD residents (Lund, Cervero, and Willson 2006). Likewise, Renne (2005) found that TOD residents use transit to commute about 3.5 times as often as non-TOD residents, on average, by analyzing 103 TODs across twelve U.S. regions. Yet little evidence has been proffered to indicate whether station area residents own and use personal vehicles less.

Contradictory findings are reported on the impacts of rail transit on auto ownership and use. In a disaggregate study, Chatman (2008) showed that proximity to heavy rail has a positive correlation with VMT, after controlling for built environment variables including activity density, network load density, and pedestrian connectivity. In other words, people dwelling near rail transit travel longer distance. Through an aggregate analysis, Loo et al. (2010) also concluded a positive correlation between auto ownership and rail transit ridership, presumably because of park-and-ride and kiss-and-ride activities. In contrast, several studies found a negative correlation. Dueker and Bianco (1999) studied the effects of LRT in Portland, Oregon, by employing a pre-post analysis. Using a parallel bus corridor as a control group, they found a slight negative effect on vehicle ownership. Further, the results show that households in the outer part of the rail corridor are more likely to use transit and be less auto-oriented compared with the control group. Dill (2008) conducted a survey near four LRT stations in Portland, Oregon, to explore whether residents of TODs drive less and use transit more. The results indicate that the net transit ridership increased by 16 percent in TOD corridors, of which 20 percent of the commuters switched from non-transit to transit modes. A recent study within a two-mile radius of 10 rail stations in New Jersey (Chatman 2013), further, exhibited that auto ownership and commuting are remarkably lower among households living in new housing near rail stations than those in new housing farther away. However, Chatman emphasized that access to rail transit plays an inconspicuous role in this behavior because parking and neighborhood characteristics are key drivers. Cervero and Arrington (2008) studied vehicle trips of 17 TOD multi-family housing projects near rail transit stations in four U.S. metropolitan areas. Employing pneumatic-tube recorders, they revealed that the vehicle trips per dwelling unit are 44 percent lower than manual estimates.

Although the literature has grown in recent years, it leaves several gaps. First, albeit previous studies have concluded a positive association between rail transit and transit use, they have yet to answer the following question: Does rail transit catalyze transit use of station area residents? Or does rail transit attract frequent transit users? Most previous studies were built on cross-sectional data that are less able to tease out the connections between travel behavior and residential self-selection among station area residents. Since overlooking residential self-selection may misestimate the results, longitudinal analysis is in need. Second, together with rail transit, station area built environment not only induces people living already in transit corridors to change their behavior, but also attracts other people, movers, to choose living near transit stations. In light of the residential self-selection notion, movers and non-movers to rail station areas tend to behave heterogeneously (Cao and Schoner 2014). However, to the best of our knowledge, few studies have attempted to understand the behavior of movers. Third, previous studies have suffered from weak controlled corridors. Ipso facto, many studies measured travel mode share in corridors where people dwell within quarter- or half-mile distance rings of rail stations. The share, then, is compared with that of either the whole region or the outer parts of TOD corridors (Lund, Cervero, and Willson 2006, Chatman 2013, Renee 2005). The consequence is that it overstates the impacts of transit, since people living in rail transit corridors tend to have higher transit share than those in the region before the introduction of rail transit (Cao and Schoner 2014). Last but not the least, although rail transit aims to diminish the car-oriented lifestyle by promoting transit use, few studies have examined the nexus among rail transit, transit use, and auto ownership and use in a simultaneous framework.

This study attempts to fill the gaps. Given that a longitudinal design is impossible, it applies a quasi-longitudinal analysis, seldom employed in the literature. It chooses comparable corridors to contrast travel behavior of residents moving into the Hiawatha LRT corridor after its opening. It provides an in-depth insight into the mechanism that the LRT influences transit use, auto ownership and use.

Table 1: Summary of previous studies

Author	Location	Sample size	Mode: *Transit*	Mode: *Auto*	Mode: *Active*	Data Collection Method	Method of Analysis	Control Group	Finding
Cervero and Gorham (1995)	California	7 transit neighbo rhood	×	×	×	1990 US Census	Descriptive and Regression	7 Auto neighborhoo d	•Lower automobile use
Dueker and Bianco (1999)	Portland	-	×			Census years 1980 and 1990	Before-after	A parallel bus corridor	•Lower automobile use and ownership in rail corridor
Gossen (2005)	San Francisco	35,000	×	×		2000 Bay Area Travel Survey	Descriptive	-	•Lower automobile use •50% more VMT in suburban in compare with quarter-mile of rail transit
Lund et al. (2006)	California	624	×	×	×	Questionnaire Survey	Descriptive	Movers	•Five times more likely to commute by transit
Cervero (2007)	San Francisco	10,968		×		2000 Bay Area Travel Survey	Nested Logit Model	Not TOD	•Low automobile ownership, but self-selection does more to explain this fact
Renne (2007)	Australia	848	×	×	×	Questionnaire Survey	Descriptive	Average of the city	•No influence on automobile use
Chatman (2008)	California	1,113	×	×	×	Telephone survey	Tobit regression	Similar demographic and built environment	•Higher automobile use
Dill (2008)	Portland	300	×	×	×	Questionnaire Survey	Before-after	Movers	•16% switched from non-transit to transit modes •Lower automobile use
Cervero and Arrington (2008)	Four regions in the US	17 TOD projects		×		Vehicle count	Trip generation	ITE average rate	•Lower automobile use
Stiffler (Stiffler 2011)	California	55	×	×	×	Questionnaire Survey	Descriptive	Similar demographic and built environment	•Fewer trips
Chatman (2013)	New Jersey	5,000	×			Mail survey	OLS and logit regressions	Similar demographic and built environment	•Lower automobile use and ownership, but rail access does little to explain this fact

Chapter 3: Methodology

3.1 Conceptual model

This study attempts to explore the impacts of the Hiawatha LRT on travel behavior of station area residents. Since the Hiawatha LRT commenced in 2004, a before-after test is impossible. Instead, we opted to compare residents who moved into the LRT corridor after its opening with those who moved into other corridors without LRT. We expect that residents who relocated into the Hiawatha corridor would experience transit improvement (Figure 1). Based on the literature and our informed knowledge, we further hypothesize that the improvement is positively correlated to a reduction in auto ownership, which is in turn associated with an increase in transit use and a decrease in car use. Transit improvement is expected to have a negative association with change in car use and a positive association with change in transit use. We assume that the Hiawatha corridor has also associations with auto ownership and travel behavior and the associations may result from both observed and unobserved factors.

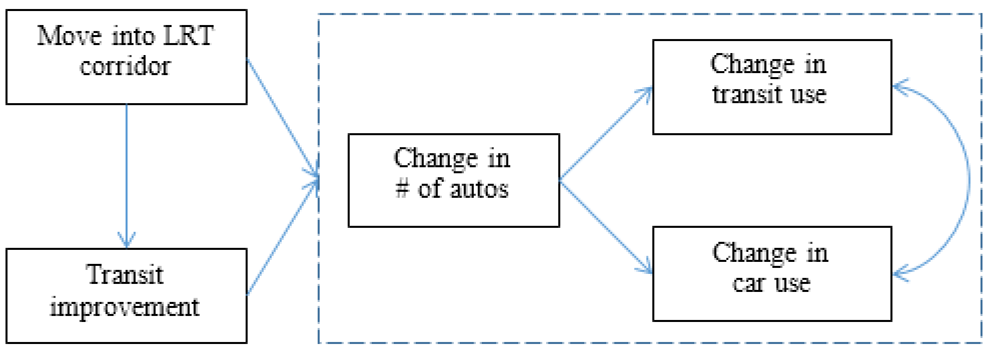


Figure 1: Conceptual Model

Overall, the conceptual model illustrated in Figure 1 presents complex relationships among the Hiawatha LRT, transit improvement, and travel behavior. We need to employ the structure equations modeling approach (Mueller 1996) to uncover the connections. In Figure 1, moving into the Hiawatha corridor is an exogenous variable and other variables are endogenous. Simply put, an exogenous variable impacts other variables but will not be affected by other variables whereas an endogenous variable can serve as a mediating variable or the dependent variable in an equation.

3.2 Data and variables

To test the conceptual model in Figure 1, we mailed a self-administered survey to households in five corridors in the Twin Cities in May 2011. The description of data and variables is heavily borrowed from Cao and Cao (2014), which explores LRT effect on auto ownership. The Hiawatha LRT line totals 12 miles, has 19 stations, and runs between downtown Minneapolis and the Mall of America in Bloomington through the Minneapolis-Saint Paul International Airport. Five stations are located around downtown Minneapolis and six stations mainly serve the airport and the Mall of America (http://metrotransit.org/light-rail). These station areas mostly accommodate commercial or institutional land uses whereas the middle section of the LRT line is mainly for industrial and residential uses. In this study, the Hiawatha corridor means the middle section: the corridor within a ½ mile of the Hiawatha LRT from Lake Street to 50^{th} Street in South Minneapolis.

We employed a case-control observational design and chose two sets of control corridors. As shown in Figure 2, the corridors along Nicollet Avenue and Bloomington Avenue in South Minneapolis were chosen as urban control corridors to resemble the Hiawatha corridor in terms of location context, built environment elements, and demographics. The urban corridors have similar transit services but are not served by LRT. Suburban control corridors are chosen from Coon Rapids and Burnsville. The two corridors are located directly north (14 miles) and south (17 miles) of downtown Minneapolis. Their key demographic characteristics (such as household income and size) are relatively similar to those of the Hiawatha corridor. The suburban corridors were mainly developed in the 1970s. Compared to the Hiawatha corridor, they have different street networks and poor transit service (Figure 3).

We ordered a database of "movers" and a database of "nonmovers" for each corridor from a commercial data provider, AccuData Integrated Marketing (http://www.accudata.com). In this study, we use the movers, who included all residents who had relocated to the corridors after 2004 when the Hiawatha LRT commenced. We asked the provider to randomly draw a sample of about 1,000 residents in the Hiawatha corridor and about 500 residents in each of Nicollet, Bloomington, Coon Rapids, and Burnsville corridors.

We invited students and staff members of our School and neighbors and friends of the principal investigator to pre-test the survey. We revised the survey based on pre-testers' feedback. Two reminder postcards were mailed one and two weeks, respectively, after we posted the survey. As an incentive for participation, ten $50 gift cards were provided through a lottery. The original database of movers consisted of 3,040 addresses but only 2,951 were valid. The number of responses totaled 597, equivalent to a 20.2% response rate based on the valid addresses only. This is a good response rate for a long (10-page) survey because the typical rate for the general population survey ranges from 10 to 40% (Sommer and Sommer 1997). Table 2 compares the characteristics of movers for different corridors. There are no significant differences in demographics between Hiawatha movers and urban movers. However, movers in suburban corridors tend to be older and less educated than movers in the Hiawatha and urban corridors. Employment rate is also lower in suburban corridors.

The variables used in this study include four categories: travel behavior, demographics, neighborhood characteristics, and residential preferences. In the survey we asked respondents to indicate how many personal vehicles (cars, SUVs, vans, small trucks, and motorcycles) their households have currently and just before they move. The difference in the two numbers is the change in the number of autos after residential relocation. Respondents were also asked to report "How much do you ***drive*** now, compared to when you lived at your previous residence?" on a five-point ordinal scale from "a lot less now" (1) to "a lot more now" (5). A similar question asked their use of transit including bus and LRT. The two variables represent change in car use and change in travel use after residential relocation. In addition to common demographic characteristics, the survey measured changeable demographics such as household income and household size, which help explain movers' changes in travel behavior.

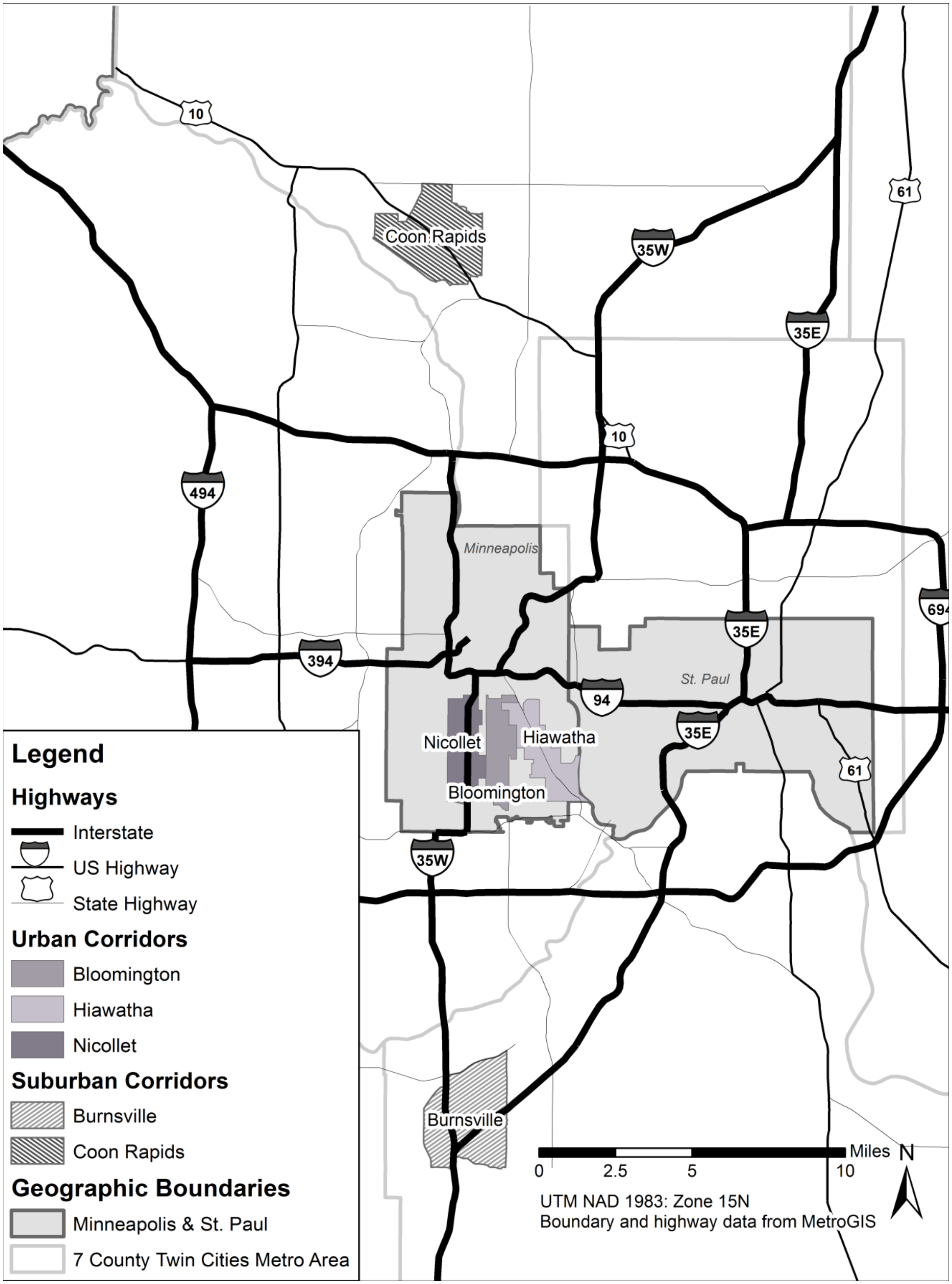


Figure 2: Locations of Corridors

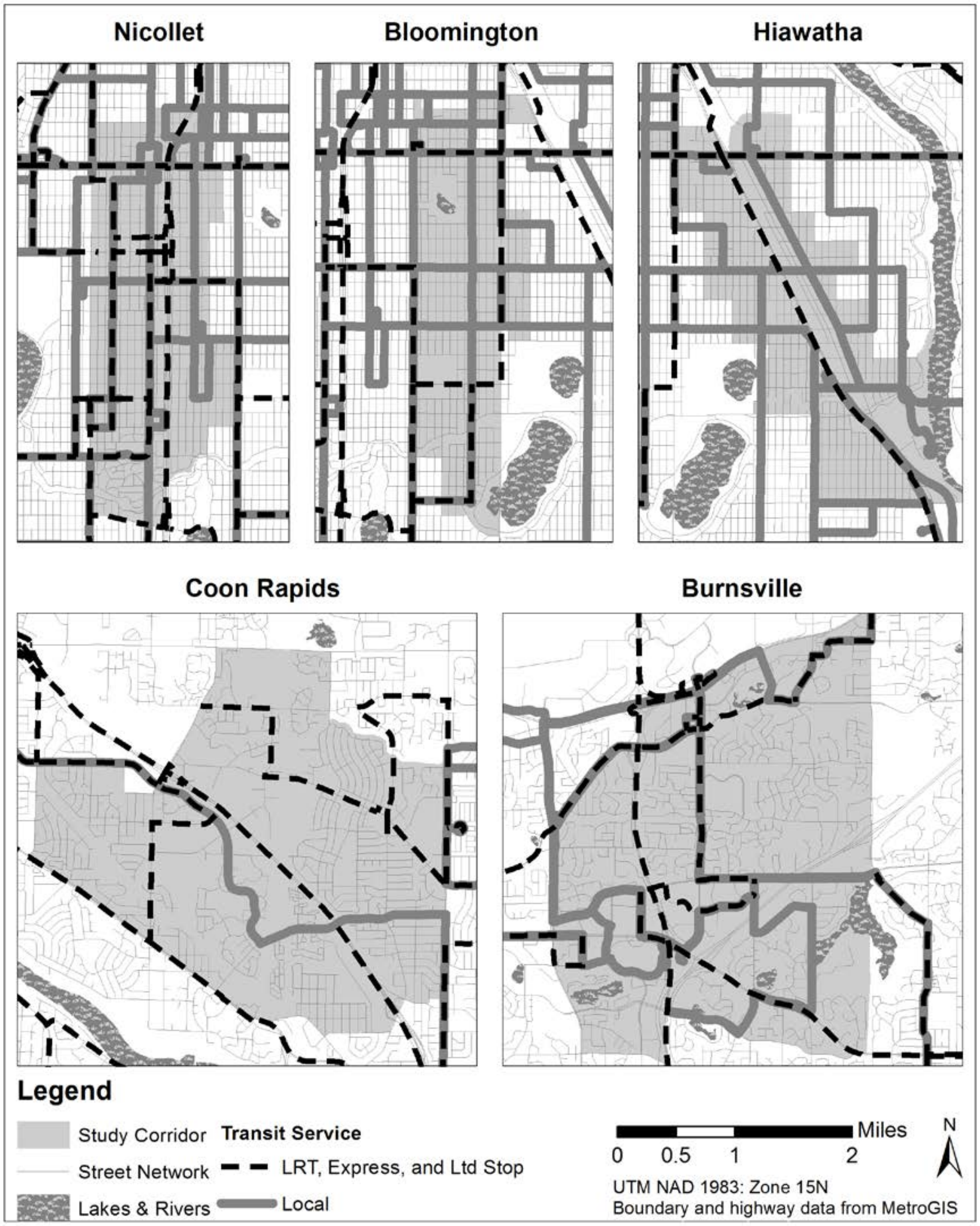


Figure 3: Map of Corridors

We measured perceived neighborhood characteristics in the survey. In particular, we asked respondents to indicate how true 30 characteristics are for their current and previous neighborhoods on a four-point scale from “not at all true” (1) to “entirely true” (4). They are associated with living units, land use and transportation systems, social environment, safety, and so on. In terms of residential preferences, we measured the importance of the 30 characteristics to respondents when they were looking for a new place to live on a four-point scale from “not at all important” (1) to “extremely important” (4). Because some of the characteristics are highly correlated, we conducted a joint factor analysis to reduce them (after dropping some) to eight dimensions: transit, attractiveness, spaciousness, safety, quietness, safety, socializing, and physical activity infrastructure (Table 3). Each of current neighborhood characteristics, previous neighborhood characteristics, and residential preferences included the same eight factors. Changes in neighborhood characteristics were computed as the difference in the factors between movers’ current and previous neighborhoods.

Table 2: Sample Characteristics of Movers

	Hiawatha Movers	**Urban Movers**	**Suburban Movers**
Household size	2.22	2.28	2.52
Income	5.65	5.73	5.16
Education*	**4.25**	**4.40**	**3.77**
Age*	**40.6**	**41.1**	**45.8**
Share of workers*	**0.84**	**0.89**	**0.71**
Share of renters	0.27	0.28	0.31
Share of female	0.56	0.52	0.56

* The variables are significantly different between suburban movers and urban (Hiawatha) movers at the 0.05 level (Bonferroni tests of analysis of variance).

Table 3: Pattern Matrix for Perceived and Preferred Neighborhood Characteristics

	Attractiveness	Spaciousness	Physical activity infrastructure	Transit	Accessibility	Quietness	Safety	Socializing
High quality living unit	0.605							
Good investment potential	0.391							
Attractive appearance of neighborhood	0.673							
High level of upkeep in neighborhood	0.609							
Large back yards		0.640						
Lots of off-street parking (garages or driveways)		0.481						
Sidewalks throughout the neighborhood			0.452					
Good bicycle routes beyond the neighborhood			0.839					
Parks and open spaces nearby			0.377					
Good public transit service (bus or rail)				0.964				
Easy access to transit stop/station				0.921				
Shopping areas within walking distance					0.393			
Easy access to a regional shopping mall					0.720			
Easy access to downtown					0.375			
Religious or civic buildings nearby					0.507			
Low level of car traffic on neighborhood streets						0.874		
Quiet neighborhood						0.735		
Low crime rate within neighborhood							0.426	
Safe neighborhood for walking							0.815	
Safe neighborhood for kids to play outdoors							0.540	
Lots of interaction among neighbors								0.784
Lots of people out and about within the neighborhood								0.752

Note: The method was Principal axis factoring with Oblimin with Kaiser Normalization. Loadings smaller than 0.300 were suppressed.

Table 4 illustrates that transit improvement and transit preference differ among the three corridors. Bonferroni tests further indicate that residents moving into the Hiawatha LRT corridor tend to experience a higher transit improvement than those moving into the urban and suburban control corridors and Hiawatha movers prefer transit more strongly than movers in the control corridors (results not shown). Thus, transit-preferring individuals did self-select into the Hiawatha corridor. Moreover, Hiawatha movers are more likely to increase transit use than their counterparts in the control corridors whereas there are no significant differences in change in auto ownership and use among the three corridors.

Table 4: Key Variables by Corridor

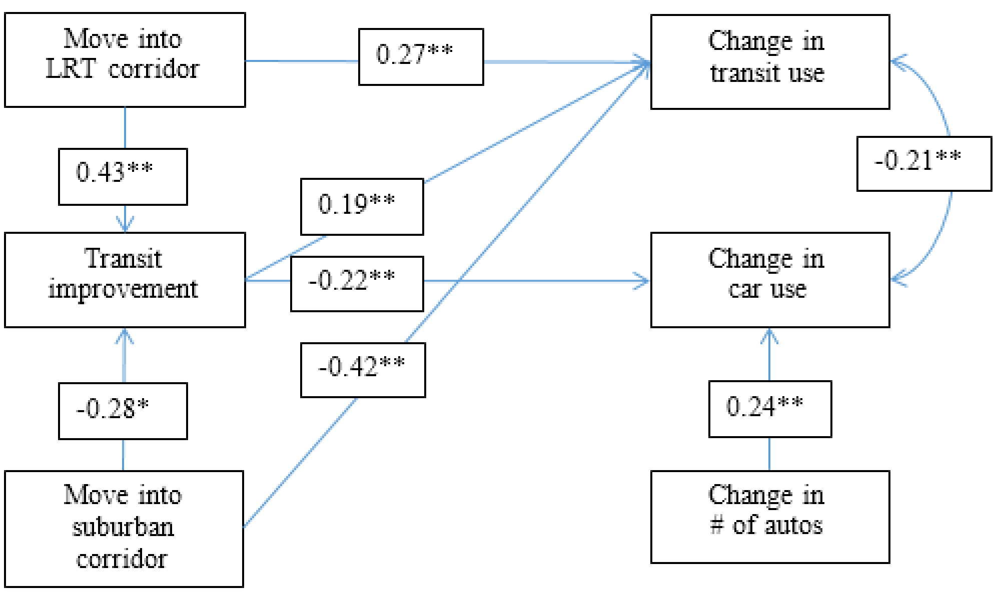
	Transit improvement	**Transit preference**	**Chang in # of autos**	**Change in transit use***	**Change in car use***
Hiawatha	0.944	0.170	0.153	3.445	2.747
Urban	0.516	-0.178	0.107	3.106	2.679
Suburban	0.220	-1.031	0.069	2.598	2.699
ANOVA p-values	0.000	0.000	0.588	0.000	0.860

* a value larger than 3 indicates an increase

Chapter 4: Modeling and Results

Since the data include respondents from three types of corridors, we create two corridor dummy variables (Hiawatha and suburban) with urban corridors as the reference category. In the conceptual model, change in the number of automobiles was treated as an endogenous variable. However, none of our key variables (including the corridor dummies and transit improvement) had direct effects on it. This is consistent with Cao and Cao (2014), which analyzes change in auto ownership using the same data. So it was relaxed as an exogenous variable. The structural equations models were developed using the maximum likelihood estimation in Stata 12.0. Because the modeling approach requires the data to follow multivariate normal distribution and our data may not meet the requirement, we adopted the bootstrap method to produce the variance-covariance matrix of the estimates. We adopted an incremental modeling approach and developed two SEMS, with and without accounting for the influences of other confounding factors. When estimating models, the exogenous variables that were insignificant at the 0.10 level were manually dropped to obtain parsimonious models.

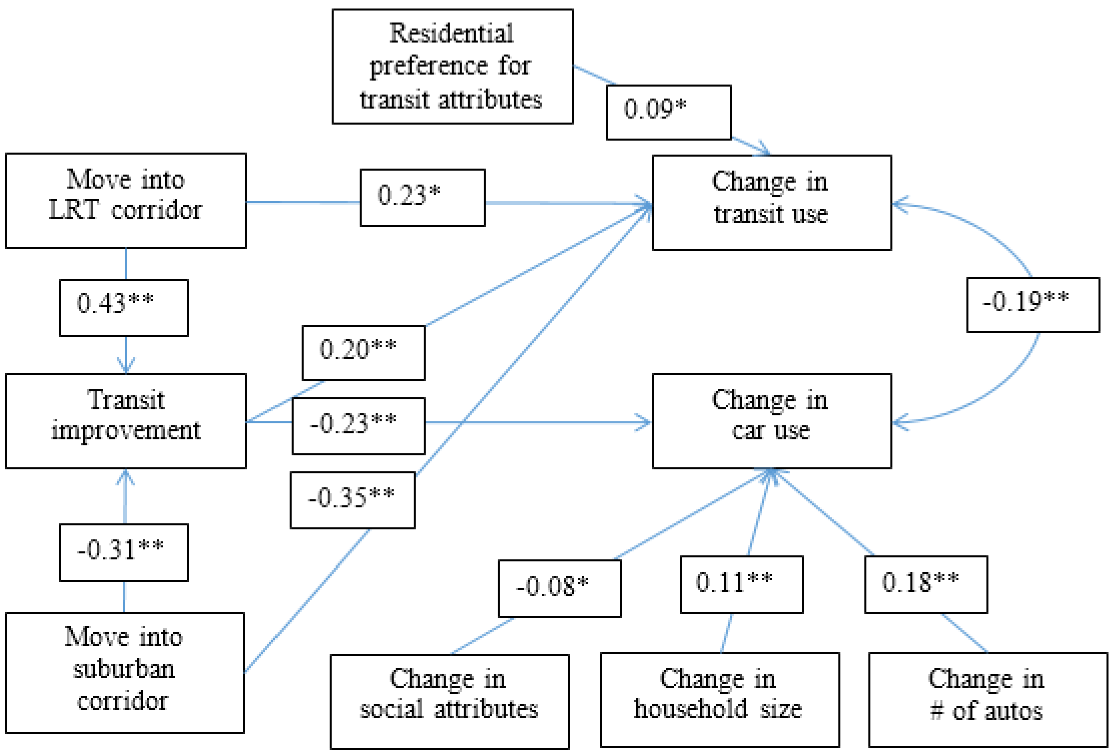
We use Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Standardized Root Mean Squared Residual (SRMR) to evaluate the goodness of fit for the SEMs. According to the Stata manual (http://www.stata.com/manuals13/semestatgof.pdf, accessed on May 17, 2015), RMSEA values less than 0.05 indicate a good fit; CFI values closer to 1 indicate a good fit; and SRMR values less than 0.08 indicate an acceptable fit. As shown in Figures 4 and 5, both models have adequate measures of goodness of fit.



* significant at the 0.10 level; ** significant at the 0.05 level.
Notes: maximum likelihood estimation with bootstrap (50). N = 559. RMSEA = 0.008; CFI = 0.999; SRMR = 0.018.

Figure 4: Structural Equations Model without Controlling for Confounding Factors

Figure 4 shows the SEM without controlling for confounding factors. The error terms of change in transit use and change in car use are significantly and negatively correlated. This indicates that unobserved factors influence the two variables in an opposite way. This is reasonable because transit and driving are two competing means of transport. Moving into the Hiawatha corridor is positively associated with transit improvement whereas the latter has a negative association with moving into suburban corridors. Transit improvement is positively correlated to change in transit use but has a negative connection with change in car use. That is, the Hiawatha LRT affects transit use and car use through its impact on transit improvement. Additionally, Hiawatha and suburban dummy variables are directly associated with change in transit use. However, their direct links with change in car use are insignificant. Furthermore, change in the number of automobiles is positively associated with change in car use but has no significant influence on change in transit use. Overall, all of the observed significant effects are consistent with our assumptions.



* significant at the 0.10 level; ** significant at the 0.05 level.
Notes: maximum likelihood estimation with bootstrap (50). N = 546. RMSEA = 0.039; CFI = 0.946; SRMR = 0.024.

Figure 5: Structural Equations Model while Controlling for Confounding Factors

Figure 5 considers the influences of potential confounding factors including changes in neighborhood characteristics, changes in demographics, and residential preference for transit. First and foremost, after controlling for the confounding factors, all of the variables significant in Figure 4 are also significant in Figure 5.

In terms of confounding factors, changes in other neighborhood characteristics may bring about changes in travel behavior. We found that change in social attributes (the socializing factor) is negatively associated with change in car use. Therefore, the presence of people and interactions with neighbors, or a sense of community, help reduce driving. This finding is consistent with Aditjandra et al. (2012). It is worth noting that change in spaciousness is also significant for change in driving. In other words, large backyard and abundant park spaces induce driving. This is consistent with Cao et al. (2007). However, its presence in the model substantially deteriorates the goodness of fit measures. Accordingly, we manually removed it from the model. Other neighborhood characteristics do not significantly affect changes in travel use and car use. Changes in demographics may also influence changes in travel behavior. We tested change in household income and household size and found that only change in household size has a positive association with change in car use. Furthermore, residential preference for transit has a positive association with change in transit use but is insignificant for change in car use.

Overall, transit improvement (in terms of service quality and access to stop) is positively correlated to environment-friendly travel behavior (either an increase in transit use or a decrease in driving). This study controls for confounding factors, particularly residential preference for transit, and presumably eliminates the rival hypothesis that individuals preferring transit intentionally choose to live near the LRT. Further, transit improvement occurred before changes in travel behavior. Accordingly, this study seems to establish the three prerequisites for a causal inference (Singleton and Straits 2005): association, non-spuriousness, and time precedence. Thus, it offers stronger evidence on the causal influence of transit service on travel behavior than do previous studies.

Moving into the Hiawatha corridor leads to an increase in transit use directly and indirectly through transit improvement. Its total effect is positive and significant. This result is contradictory to Cao and Schoner (2014), in which transit use of movers into the Hiawatha corridor and urban corridors is similar. We speculate that before their residential relocation, movers into urban corridors used transit more frequently than their counterparts in the Hiawatha corridor. Although they have similar transit use now, the former tended to have a smaller change in transit use than the latter. This implies the process of residential self-selection: movers relocated into urban corridors to match their preference for travel, leading to a similar level of transit use; movers relocated into the Hiawatha corridor for the LRT and substantially increased their transit use. Therefore, the LRT is a magnet that attracts potential transit users. Further, this study adopts a quasi-longitudinal design. Modeling changes in variables is able to cancel out the influences of time-invariant variables. So it is better than the cross-sectional design used in Cao and Schoner (2014). Although they adopted the propensity score matching approach to adjust observed confounding factors, the unobserved confounders may still bias the results.

The effect of the Hiawatha dummy may capture the influences of many factors in the Hiawatha corridor. Besides its influence through transit improvement, the Hiawatha dummy variable is directly and positively associated with change in transit use. Therefore, some unobserved elements of the LRT corridor affect transit use. Without separating transit service from other influential elements, we are unable to disentangle the impact of the LRT. Future studies should also attempt to identify other elements with a true longitudinal analysis.

Chapter 5: Conclusions

This study employs the structural equations modeling approach to examine the nexus among rail transit, transit use, auto ownership and use in a simultaneous framework. It chooses comparable corridors to contrast with the Hiawatha LRT corridor. It compares the residents who relocated into the Hiawatha corridor and control corridors after the LRT started revenue service. It adopts a quasi-longitudinal design by retrospectively asking respondents to report their changes in travel behavior and neighborhood characteristics.

This study has a few limitations. It used retrospective measures. Because of potential recall bias, we focused on recall accuracy instead of measurement precision. So changes in travel behavior were measured in an ordinal scale. Moreover, perceived neighborhood characteristics may be subject to reporting bias; for example, residents who use transit frequently may be more aware of transit attributes than those who do not use, thus it may inflate the impact of neighborhood characteristics on transit use. However, this will not affect the impact of the Hiawatha corridor (see Table 3) because changes in neighborhood characteristics are mediating variables. On the other hand, a true longitudinal study is essential to obtain precise estimates of the influence of neighborhood characteristics on travel behavior, as Giles-Corti et al. (2013) did. Scholars could also design a companion study: a longitudinal design compared to a quasi-longitudinal design. This will help quantify recall and reporting biases and their impacts on travel behavior. Nevertheless, this study offers insights on the influences of LRT on changes in auto ownership, transit use and car use simultaneously.

The Hiawatha LRT acts as both a catalyst and a magnet. Residents moving into the Hiawatha LRT corridor experience transit improvement, which increases transit use and reduces car use. Since this study adopts a quasi-longitudinal design and controls for transit preference, we are more confident to conclude that the Hiawatha LRT affects travel behavior by improving transit service. This illustrates the mechanism that the LRT influences travel behavior. The capacity of the Hiawatha LRT to reduce car use is particularly prominent because few studies have addressed the issue. On the other hand, residents who prefer transit move into the Hiawatha corridor and hence the LRT attracts transit-liking people. This self-selection does not mean that the LRT has no benefits. The LRT enables transit-liking people who were unable to realize their travel preference previously to relocate near the LRT. That is, they can self-select and increase transit use (Næss 2009, Levine 1999). Further, about 1,000 new housing units have been constructed near the Hiawatha LRT since it opened. The residents in these units would have had to live in other urban neighborhoods or suburban neighborhoods if the LRT were not built. Regardless of whether the LRT is a magnet or catalyst, the increase in transit use and reduction in car use associated with these housing units are non-trivial, particularly compared to those people living in suburban neighborhoods.

There is no difference in changes in auto ownership among the three corridors. This suggests that the accessibility benefits of a single LRT line are inadequate to enable many residents to shed cars. Choice riders tend to use transit for commute trips and may still rely on personal vehicles for non-work trips.

Moreover, a strong sense of community – people out and about and interacting with neighbors – tends to dampen car use. So does compact development (e.g., limited lot size and parking infrastructure). This suggests that besides transit infrastructure, planners should also pay attention to transit-friendly neighborhood characteristics. They may promote transit use or attract residents who prefer such a transit-friendly environment. Both are important for the sake of ridership growth.

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