The Exposition Light Rail Line Study
A Before-and-After Study of the Impact of New Light Rail Transit Service

Prepared for:
The Haynes Foundation

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Executive Summary

Background
Los Angeles, the world's prototypical automobile city, is transforming into a multi-modal metropolis. The six rail transit lines projected to open between 2012 and 2020 will make the Los Angeles Metro Rail system longer than the present day Metro in Washington D.C. At the same time, ambitious state regulations require that metropolitan planning organizations demonstrate how their transportation plans meet greenhouse gas emission (GHG) reduction targets. There is a pressing need to evaluate the impact of new transportation investments comprehensively. Yet, transportation, as a field, has rarely systematically evaluated the impact of major projects using an experimental – control group design. To help close that gap, we conducted the first-ever experimental – control group, before – after study of the impact of a major transportation investment in California.

As transportation becomes more varied – with localities experimenting with programs that include real-time parking pricing, toll lanes, neighborhood vehicles, and bicycle plans – it will be increasingly important to evaluate the impact of these projects in a consistent and credible way. Social scientists have applied the methods of experimental research designs for decades, but such techniques have only recently made inroads in transportation.

Study Design
We conducted a detailed study of travel behavior changes around new Expo Line light rail stations, using experimental methods. The Exposition (Expo) Line is a light rail line in the Los Angeles metropolitan area that extends south and west from downtown Los Angeles. Phase I of the line, which opened in two stages in April and June 2012, runs 8.7 miles from downtown Los Angeles westward to Culver City, near the junction of the 405 and 10 Freeways. The six western-most stations along the Expo Line (Phase I) comprise the experimental neighborhoods, and similar control group neighborhoods were chosen nearby. This research project enrolled experimental households, within ½ mile of a new Expo Line station, and control households, living beyond ½ mile from the station. In fall of 2011, those households were asked to track their travel for seven days, recording daily odometer readings for all household vehicles and logging trips by travel mode and day for each household member 12 years or older. In approximately half of the households, an adult also carried a geographic positioning device (GPS) and an accelerometer, to measure travel (via the GPS device's location tracking function) and physical activity. The same households were invited to complete the seven day travel study again in fall, 2012, after the Expo Line opened. In total, 204 households (103 in the experimental neighborhoods, 101 in control neighborhoods) completed the travel tracking before and after the Expo Line opened.

We used those data to conduct before-after evaluations of the impact of the Expo Line on travel behavior. The research design is a classic "differences-in-differences" approach. The impact of the Expo Line can be inferred by examining experimental minus control group differences and how those differences change after the Expo Line opens relative to baseline, "before opening" experimental minus control group differences. The travel behavior variables studied are household daily averages for: vehicle miles traveled (VMT), car driver trips, train transit trips, bus transit trips, walking trips, bicycle trips, walking minutes, and bicycling minutes. Additionally, we studied changes in physical activity for the adults who carried an accelerometer, and CO_2 emissions for household vehicles.

Results

The analysis gives the following results.

- In "before opening" travel data collection, experimental and control households had the same travel patterns. There were no statistically significant differences across experimental and control households, before the Expo Line opened, in household daily average VMT, car driver trips, train transit trips, bus transit trips, walking trips, bicycle trips, walking minutes, or bicycling minutes.
- After opening, the differences-in-differences approach shows that the experimental group reduced their daily household VMT by 10 to 12 miles relative to the control group. That result persists after outlier observations are removed and when alternative statistical methods are used. We interpret this as evidence that the Expo Line reduces VMT among households living within ½ mile of the Expo Line stations.
- We used the GPS data to examine whether the large VMT changes could be an artifact of households systematically misreporting vehicle odometer logs. While the GPS provides at best a crude check on odometer logs (because the person carrying the GPS could have ridden in several vehicles), we find no evidence of any systematic reporting biases that would reduce our faith in the result that experimental households reduced their VMT by 10 to 12 miles, relative to control group households, after the Expo Line opened.
- In some statistical tests, there is evidence that the Expo Line increased rail transit ridership among experimental households. Control group households also increased their rail ridership, but not by as much as experimental households. On net, the differences-in-differences evidence suggests that the Expo Line resulted in about 0.1 more daily train trips per household in the experimental group, but we caution that this result is not nearly as robust as the finding for VMT reduction among experimental group households.
- The experimental and control group households had no statistically significant differences in vehicle CO_2 emissions before the Expo Line opened, but after opening experimental group households had approximately 30% less vehicle CO_2 emissions than control group households. That "after opening" difference is statistically significant.
- The accelerometer data allow us to measure physical activity in minutes of moderate or vigorous activity per day. After the Expo Line opened, those individuals living in the experimental neighborhoods who were the least physically active had the largest increases in physical activity relative to control group subjects. The Expo Line opening was associated with increases in physical activity among approximately the 40 percent of experimental subjects who had the lowest physical activity levels before the line opened. The impact was as high as 8 to 10 minutes of increased daily moderate or vigorous physical activity among those experimental group subjects who were the least active before the Expo Line opened. Note though that for more than half of the experimental group subjects (those more physically active before the Expo Line opened) our statistical test suggests that the Expo Line is associated with decreases in physical activity.
- The impact of the Expo Line on VMT and rail ridership was larger near stations with more bus lines and near stations with streets with fewer traffic lanes, suggesting that bus service increases the impact of

rail transit and that wide streets (which can be barriers to pedestrian access) reduce the impact of rail transit, at least in the Expo Line corridor.

Summary and Policy Implications

Los Angeles has made a substantial commitment to rail transit, but several policy questions continue to be debated. Among those questions, possibly the most basic is whether new transportation options will change travel modes, and whether Angelenos will modify their travel as new options become available. Against that backdrop, the results from this research are in some ways striking. We find evidence that the Expo Line is associated with large reductions in VMT, some increase in rail transit ridership, changes in physical activity, and large reductions in GHG emissions among households living within ½ mile of a station. The research design, using a control group to account for factors other than the rail investment, allows us to make causal inferences more strongly than is often the case in social scientific research. In short, the Expo Line is associated with travel behavior change, and we can infer that the association reflects a causal effect of the Expo Line on household travel. The large impacts for VMT and GHG reduction occur within a small area – ½ mile around six new stations. Viewed from the perspective of the greater Los Angeles region, these impacts will be small, but they are large in the neighborhoods surrounding the Expo Line.

Several policy implications follow. First, this is some optimistic evidence for the rail transit investment program in Los Angeles. We did not conduct a formal benefit-cost assessment, but clearly the rail line is associated with changes in travel behavior that are consistent with the anticipated effects. Second, the evidence indicates that the travel impacts of light rail are enhanced by local land use characteristics. Bus lines and streets with narrower width are likely to be more conducive to increasing the effects of rail transit, at least based on the results from this study. Third, economic theory predicts that the travel impacts documented here will likely lead to downstream effects including changes in the resident population near Expo Line stations, changes in land prices (and hence rents and house prices), and changes in land uses. It is too early to draw conclusions about those downstream effects, and whether they will advantage existing residents or new residents or a combination of both. Yet, the fact that the Expo Line has changed travel behavior suggests that the rail service is valued by nearby residents. That value will likely be reflected in land prices and land uses in later years, which will lead to broader social and economic impact around the rail transit lines.

I. Introduction

1. Background and research objectives

Los Angeles is pursuing possibly the most ambitious rail transit investment program in the nation. Eighty percent of Los Angeles County's transportation sales tax revenues (from Propositions A and C, passed in 1980 and 1992, and Measure R, passed in 2008) are dedicated to transit, either by bus or rail. During the next ten years, the Los Angeles Metropolitan Transportation Authority will commit funds to six new rail transit lines, an expansion that will create a network longer than the current Washington Metro.[1] Transit-oriented development (TOD), and transit more generally, will be central to the Los Angeles region's plans for air quality attainment, greenhouse gas (GHG) emission reduction, and co-benefits such as community quality of life and the promotion of increased physical activity. Against that backdrop, we have limited information about how rail transit investments reduce driving, increase transit use and non-motorized travel, and link to environmental sustainability and community quality of life goals. The nation's first truly automobile city is rapidly transforming its transportation system – a transition from an almost complete reliance on the automobile and busses to a broader range of travel modes. This paradigm shift in transportation policy and investment creates new requirements for understanding and policy research.

In order to better understand the impact of this change, the University of California, Irvine and University of Southern California have undertaken a multi-year, multiple objective study of the impact of light rail investment in Los Angeles. That research is a collaboration between those universities, begun in 2011 and continuing to the present. This document reports on the results from the Haynes Foundation funding to the University of Southern California, which supported collection of travel data from study subjects in the Expo Line corridor during Fall, 2012 and the analysis of those data.

The research objectives for the Haynes funding were:

- To complete a second round of travel data collection for a set of households who were originally surveyed in Fall of 2011, before the Expo Line opened, allowing a comparison of travel change before and after the Expo Line opened;
- To analyze the travel data and measure travel change among the panel of households, from Fall 2011 to Fall 2012, comparing travel for households within ½ mile of the Expo Line (an experimental group) with travel for households farther from the Expo Line (a control group);

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[1] Information on the current length of the Los Angeles MTA rail system is from "Facts at a Glance," http://www.metro.net/news/pages/facts-glance/#P37_586, accessed August 11, 2011. Information on planned rail lines is from the Los Angeles Metropolitan Transportation Authority (2009, pp. 66-68). Information on the Washington Metro, which currently covers 106 miles, is from "Metro Facts," http://www.wmata.com/about_metro/docs/metrofacts.pdf, accessed August 11, 2011.

- To examine the land use and built environment characteristics of the Expo Line corridor to assess factors that may be associated with any observed travel changes.

2. The policy context

The context for regional transportation and land use planning in California has changed dramatically in the past few years. State Senate Bill (SB) 375 brings new, and still evolving, requirements for metropolitan planning organizations to align transportation and land use in ways that meet GHG emission reduction targets from the transport sector. The targets have been set by the California Air Resources Board (ARB), and the greater Los Angeles region's first plan to comply with those targets has been published as the Southern California Association of Government's (SCAG's) Regional Transportation Plan / Sustainable Communities Strategy (RTP/SCS). By 2020, the ARB target requires that the SCAG region reduce GHG from the ground transport sector by 8%, and the target requires a 13% reduction by 2035. Both targets are from a 2005 per capita baseline. The SCAG RTP/SCS anticipates meeting and even exceeding the targets. Yet compliance with targets is based almost entirely on transportation forecasting models, potentially limiting the evolution and flexibility of the SB 375 policy framework in ways discussed below.

This policy context brings new challenges for transportation data collection and project evaluation. SB 375 requires metropolitan planning organizations (MPOs) to credibly quantify the impact of transportation investments on GHG emissions. The research summarized here gives results of a before-after, experimental-control group method to evaluate the impacts of transportation investments. This is a promising technique, but one that has only rarely been applied in transportation planning. By applying this method, we can illuminate how a broad range of transportation projects and policies could be similarly evaluated.

Beyond questions of impact measurement, Los Angeles' rail transit investment has the potential to transform neighborhoods – positively or negatively. The Expo Line Phase I corridor (the subject of our study) passes through lower income, predominantly minority communities, and is seen by residents along the corridor as both a possible catalyst for economic development and a potential threat. Will the Expo Line trigger new business activity that will provide jobs and retail opportunities in the corridor? Or will the Expo Line cause property price appreciation that may price out renters and displace some current corridor residents? Or possibly (even likely) might there be a combination of both effects, with complicated net effects? Those questions are beyond the scope of this travel behavior study, but a large body of theory argues convincingly that changes in land use, economic development, and quality of life are longer-term downstream effects that flow from (and are caused by) more short-term changes in patterns of accessibility and travel behavior (e.g. Handy, 2005). This study's focus on travel behavior change is an important first step in broader efforts to understand the longer-term impacts of the Expo Line.

3. Travel behavior variables

The travel data were collected in Fall of 2011 (with funding from the University of California and the Lincoln Institute of Land Policy) and in Fall of 2012 (with Haynes Foundation funding). These data allowed us to examine a broad set of travel behavior variables. In Fall of 2011, 284 households recorded their travel for a 7-day study period. The survey instruments included a 7-day trip log for all persons in the household aged 12 years and older, and vehicle odometer logs for all household vehicles. Of those 284 households, 204 completed the same survey and 7-day travel log protocol in Fall, 2012, after the Expo Line opened. From those data, we can study changes in the following travel variables, all expressed as household daily averages:

- Vehicle Miles Traveled
- Car Driver Trips
- Train Transit Trips
- Bus Transit Trips
- Walking Trips
- Bicycle Trips
- Walking Minutes
- Bicycling Minutes

Additionally, we used an emission model to calculate household GHG emissions from vehicle travel, allowing a comparison of vehicle GHG emissions before and after the Expo Line opened, using the panel of 204 households who completed both study waves. We also measured physical activity among a subset of 93 study subjects who carried an accelerometer for the 7-day tracking period, allowing a before-after comparison of physical activity changes in a subset of subjects in the experimental and control areas.

4. Structure of this report

The rest of this report proceeds in the following sections. In Section II, we describe the study design and data collection. Section III reports changes (before versus after the Expo Line opening) for the travel outcome variables, GHG emissions, and physical activity. Section IV analyzes those changes, examining whether pre-existing land use characteristics or the neighborhood built environment are associated with observed travel changes. In Section V, we interpret the results.

II. Methods and data collection[2]

1. Expo line background

The Exposition (Expo) Line is a light rail line in the Los Angeles metropolitan area that extends south and west from downtown Los Angeles. Phase I of the line, which opened April 28, 2012, runs 8.7 miles from downtown Los Angeles westward to Culver City, near the junction of the 405 and 10 Freeways. Construction of Phase II, which will extend the line into downtown Santa Monica, began during the summer of 2012 and is scheduled to be completed in 2015. Figure 1 shows a diagram of the Phase I portion of the line and its location within the LA metro area.

Figure 1: Expo line Phase 1 location and stations (Source: LACMTA)

Phase 1 of the Expo line stops at a total of 12 stations, 10 of which were newly constructed. It shares track with the Metro Blue light rail line over 1.2 miles near downtown Los Angeles, and also runs on the same route as the Metro Silver rapid bus and other Metro bus lines over 2.7 miles between the 7th Street/Metro Center station in downtown LA and the Expo Park/USC station. The Expo Line operates from 5 AM to 12:30 AM, with approximate headways of 12 minutes during the day and 20 minutes at other times. The system could run at headways as low as 6 minutes depending on demand and system capacity.

[2] This section draws heavily on the study area and data collection description in "The Exposition Light Rail Line Study: 'Before-After' Opening Travel Impacts and New Resident Sample Preliminary Analysis," Marlon G. Boarnet, Doug Houston, and Steven Spears, prepared for the Lincoln Institute of Land Policy, June, 2013.

In addition to downtown LA and Culver City, the Expo line serves the area south and west of the University of Southern California campus as well as the neighborhoods of Exposition Park, Leimert Park, Crenshaw, Jefferson Park, Baldwin Hills and West Adams. The neighborhoods served by the Expo line are predominantly minority and lower income, with more moderate income in the Culver City area.

2. Study area selection

In order to study the effect of the Expo Line on travel behavior and physical activity, we selected experimental neighborhoods in the immediate vicinity of the new stations, and comparison neighborhoods with similar built environment and socio-demographic characteristics at varying distances from the line. The approximate location of the study households are shown in Figure 2.[3]

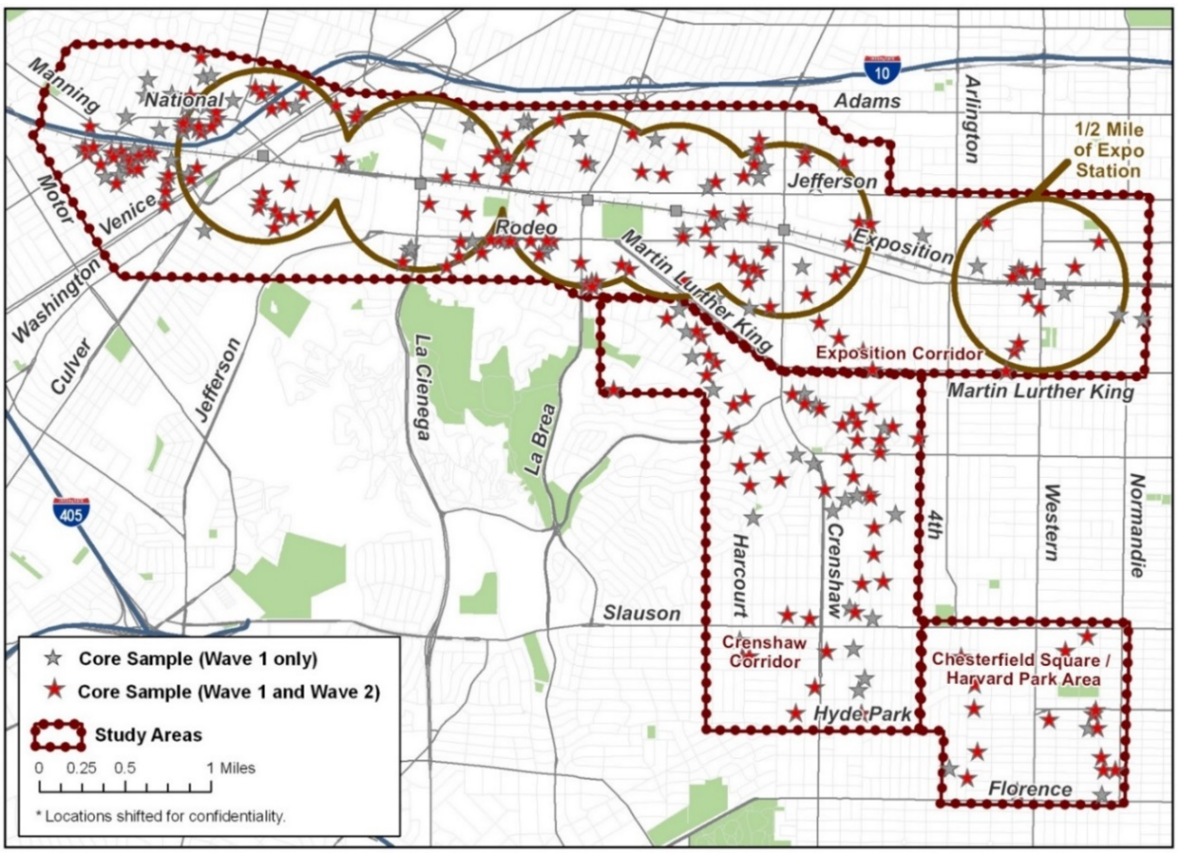


Figure 2: Survey household approximate locations

[3] To protect study subject anonymity, Figure 2 shows the pattern of household locations, sufficiently accurate to display the pattern of experimental and control households but without allowing any household location to be inferred. For research purposes, the study team used GIS methods that includes each households geocoded street address.

The experimental neighborhoods were chosen around the six westernmost Expo Line Phase I stations. The six easternmost stations were not chosen because they were also served by either the Blue Line light rail or the Silver Line rapid bus, which provide similar service in conjunction with the new Expo Line service. In addition, the Jefferson/USC, Expo Park/USC, and Expo/Vermont stations were excluded because of their proximity to the University of Southern California campus, which has a very different socio-demographic profile than the neighborhoods to the west. Because this area has a high proportion of university students, any travel behavior change, though interesting in its own right, may not be as generalizable as that of residents in other neighborhoods.

Comparison neighborhoods were selected at varying distance from the new stations, ranging from ½ to more than 2 miles in distance. They were chosen from areas with similar characteristics to the experimental areas, but they were also located along corridors that have been identified for future light rail lines by the Los Angeles Metropolitan Transit Authority (LAMTA). By doing this, we hoped to lay the groundwork for future longitudinal studies of travel behavior in these corridors as well. The first set of comparison neighborhoods used in the study extended south from the Expo/Crenshaw station along the proposed Crenshaw light rail line. The second set was chosen within a ½ mile radius of the Expo Line National/Palms station, which is the easternmost station of Expo Line Phase 2, and the first stop beyond the Expo Line Phase I Culver City station.

We chose the study corridor and control neighborhoods to be demographically similar, to approximate a treatment – control group design where the treatment group, within ½ mile of new stations, gets an improvement in access to light rail, and the control group, being more distant, does not benefit as much from the new Expo Line. The control households were drawn from locations over a half-mile from an Expo Line Phase I station, and 38 of our households (13 percent) live two miles or farther from one of the Phase I stations.

Characteristics of the treatment and control group neighborhoods are shown in Table 1. The treatment and control areas are similar in terms of population density, age and income distribution. The most apparent difference between the two is that the control neighborhoods have a higher proportion of African-American residents, and a larger proportion of Hispanics live in the experimental neighborhoods.

Table 1: Census data for Expo line experimental and control areas

	Experimental	Control	Source
Geography/population:			
Land Area (Acres)	3590	5011	2010 Census SF1 Data
Population Density	21.1	18.1	2010 Census SF1 Data
Housing Unit Density	7.8	7.2	2010 Census SF1 Data
Race and Ethnicity:			
Hispanic	51.8%	32.7%	2010 Census SF1 Data
African American	27.7%	46.4%	2010 Census SF1 Data
White	11.5%	12.5%	2010 Census SF1 Data
Asian	5.8%	5.3%	2010 Census SF1 Data
Other	1.0%	0.8%	2010 Census SF1 Data
Multiple Races	2.1%	2.3%	2010 Census SF1 Data
Age:			
Under 20 Years Old	27.5%	25.4%	2010 Census SF1 Data
65 Years Old and Older	9.2%	12.0%	2010 Census SF1 Data
Household Income and Benefits (2010 Inflation-adjusted Dollars):			
Less than $25,000	29.8%	31.9%	ACS 2010 5-year Estimate
$25,000 to $50,000	26.4%	27.8%	ACS 2010 5-year Estimate
$50,000 to $74,999	18.5%	17.5%	ACS 2010 5-year Estimate
$75,000 to $99,999	11.9%	8.1%	ACS 2010 5-year Estimate
$100,000 or more	13.5%	14.6%	ACS 2010 5-year Estimate

3. Participant recruitment and data collection

3.1. Before-opening data collection (9/2011-2/2012)

Households for the before-opening core sample were recruited in two phases. During the first phase, from September to November of 2011, we obtained addresses for a total of 27,275 households in the vicinity of six Expo stations (Western, Crenshaw, Farmdale, La Brea, La Cienega, Culver City) and control neighborhoods mostly to the south, including Crenshaw, Leimert Park, Harvard Park and Chesterfield Square, and to the west of the Culver City station area. Each household was mailed a letter inviting them to take part in the study.

The study recruitment letter, which was provided in English and Spanish, directed potential participants to visit the project website and/or call a telephone number to contact us. In either case, the respondent was asked to complete an introductory questionnaire consisting of basic questions about household composition and travel behavior. These included the number of household members in three different age groups (over 18, 12 to 17, and under 12), number of vehicles, and whether anyone in the household had used transit in the past month. We also asked whether the participant would be willing to carry a GPS logger and physical activity monitor, and whether they would be willing to use a smart phone-based survey application. Participants were not informed of the study's objectives regarding effects of the

Expo Line. They were informed in study materials that "the purpose of this study is to examine the effects of local employment, shopping, transportation and neighborhood design on the distance people travel and the types of transportation they use".

Based on responses to the introductory questionnaire, potential participants were classified into three groups: web-based (participants who completed survey components online), paper-based (participants who completed survey components using hard copy materials), and mobile tracking (participants who completed survey components using hard copy materials and also participated in GPS and activity monitoring). All participants except those interested in carrying the GPS and activity monitor were mailed a packet that contained all of the materials necessary to complete the study. Those who agreed to carry the GPS and activity monitor (the mobile tracking group) met with a trained researcher and were provided the materials in person during training on how to use and charge tracking devices. The survey instruments included instructions, a 7-day travel log for each household member 12 years old or older, and a vehicle mileage log for each household vehicle. Each participating household completed the survey for all household members 12 years of age or older.

For participants who indicated preference for web survey (the web-based group), a password and username were provided. Participants were instructed to log in on the website using the username and password to complete the baseline survey and 7-day travel logs. Responses were captured using a survey form developed with the SurveyGizmo web application. Responses were stored on the SurveyGizmo servers and subsequently downloaded to project computers. Those who either did not have the internet access or preferred to mail the materials to us received a paper version of the surveys along with the instructions and 7-day travel log (the paper-based group). A self-addressed postage-paid envelope was provided to facilitate return of the survey instruments and logs. The survey materials included in the paper group packet were identical in content to those available on the web-based survey.

Households in the mobile tracking group were contacted to schedule a convenient time to meet with a trained researcher. At this meeting, the respondent was given instructions, survey materials, travel logs, and vehicle logs. These materials were identical to those received by the paper and the web survey groups. Participants were also given the two monitoring devices and personalized instruction on how to properly use them. At the end of the 7-day survey period, participants again met with one of our researchers, who collected all of the survey materials along with the GPS and activity monitors. The responses to the survey were checked by the researcher to ensure they were complete at the time of pick up. A total of 304 responses were received during the Before Opening study. Of these 284 were complete and usable: 146 (51.4%) in control neighborhoods and 138 (48.6%) in experimental neighborhoods.

3.2. After-opening data collection (9/2012-11/2012)

In September, 2012, approximately five months after the opening of the Expo Line, we began re-contacting households that completed the Before Opening study. Participants were mailed a letter asking them to reply by phone or email if they were willing to participate in the after opening study. Households that moved out of the study area were excluded from the After Opening data collection. As before, in order to not affect participant behavior, no mention was made of the Expo Line in the recruitment materials. To encourage study participation, we substantially increased study compensation. In the Before Opening study, each household that completed the survey materials received a supermarket gift card with a value of $15 (households that were not in the mobile tracking group) or $30 (households in the mobile tracking group.) For the After Opening study, paper and web respondents were offered $50 gift cards, while mobile tracking group households received $75 cards. Households that did not respond to the initial letter were also contacted by telephone or email using information obtained during the before opening study. Overall, return rate for the after opening study was quite good. A total of 204 households out of 284 (71.8%) returned a usable set of study materials.

Households completed the After Opening study between September and November of 2012. The survey protocol was the same as the Before Opening study, and the study was administered in the same way as before, with respondents completing the study by one of three methods (web, paper, or mobile tracking). Mobile tracking households from the before study were once again enrolled in the mobile tracking group of the after study to allow analysis of physical activity and travel pattern changes.

4. Data processing and preparation

Participants in the paper group and mobile tracking groups completed their survey materials on the paper forms that were provided to them and returned them to us via mail (paper-based group) or directly to research staff (mobile tracking group). All paper surveys were entered by research staff into the same web-based forms that were used by the web group. All completed survey responses were then downloaded for further processing and quality control checks. Quality control checks were performed on all Travel Log and Vehicle Mileage Log data to ensure that responses were complete and reasonable. Records with missing data or that were outside of reasonable ranges were flagged so they could be identified and appropriately handled in our analysis. In a few cases where responses appeared to be unreasonable due to input error (for example, odometer readings with transposed digits), research staff attempted to correct the values and flagged them as corrected.

III. Travel impact of Expo line

We examined changes in travel behavior for the 204 households who completed the before-opening and after-opening data collection protocol. This provides two advantages over most previous studies that have relied on aggregate data. First, we examined travel changes for the same households. Observed changes are changes in travel for the same households, and not differences caused by different households being drawn into different samples or by households moving in or out of the study area. Second, we have a control group of households more than ½ mile from the Expo Line stations. This allows us to compare travel changes in the experimental versus the control group. This experimental setup allows us to isolate travel impacts that are associated with the Expo Line while controlling for broader regional or national trends such as economic fluctuations or changes in gas prices that might also affect travel behavior. The following section provides the description of sample characteristics and detailed analyses of travel behavior outcomes, including changes in vehicle miles of travel, transit and active travel trips and time, physical activity behavior, and CO_2 emissions.

1. Sample comparisons – Descriptive statistics

1.1. Socio-demographics

Table 2 contains descriptive statistics for the households in each of the before- and after-opening samples, including the number of households in the experimental and control groups, household income, homeownership status, and age structure. The sample is comprised of a nearly even split between experimental (within ½ mile of an Expo station) and control areas.

Table 2: Expo line sample socio-demographic descriptive statistics[4]

	Before Opening		After Opening	
Study Area	**N**	**percent**	**N**	**percent**
Control	146	51.4	101	49.5
Experimental	138	48.6	103	50.5
Total	284	100.0	204	100.0
Household Income				
less than $15k	46	17.0	32	15.9
$15k to $35k	60	22.2	43	21.4
$35k to $55k	50	18.5	44	21.9
$55k to $75k	43	15.9	29	14.4
$75k to $100k	38	14.1	27	13.4
more than $100k	33	12.2	26	12.9
Total	270	100.0	201	100.0
Home Ownership				
Rent	147	53.3	109	54.2
Own	124	44.9	89	44.3
Other	5	1.8	3	1.5
Total	276	100.0	201	100.0
Age				
Under 12	70	12.6	48	12.3
12 to 17	35	6.3	18	4.6
18 to 29	70	12.6	53	13.6
30 to 44	121	21.8	81	20.8
45 to 64	185	33.3	144	36.9
65 and Older	75	13.5	46	11.8
Total	556	100.0	390	100.0

	Before Opening		After Opening	
	mean	**S.D.**	**mean**	**S.D.**
Household Size	2.160	1.340	1.890	1.178
Number of Vehicles	1.360	0.874	1.300	0.796
Number of Drivers Licenses	1.630	0.809	1.520	0.694

1.2. Travel outcomes

For all samples, we obtained a comprehensive set of travel outcomes from travel logs and vehicle odometer logs. Logs were completed for seven consecutive days, though the participants' start and end day of the week varied. Table 3 summarizes the mean number of trips taken by mode for each sample group. Summary data from the Federal Highway Administration's 2009 National Household Travel Survey (NHTS) are listed for comparison.

[4] The descriptive data in this sub-section is adapted from material that appeared in "The Exposition Ligh Rail Line Study: "Before-After" Opening Travel Impacts and New Resident Sample Preliminary Analysis," Marlon G. Boarnet, Doug Houston, and Steven Spears, prepared for the Lincoln Institute of Land Policy, June, 2013.

The NHTS data include all of Los Angeles County, California, which contains not only the dense urban core of the city of Los Angeles, but also smaller cities, suburban neighborhoods, and a considerable amount of rural area. Therefore, it is not surprising that the samples from the Expo study area, which is moderately dense and urban, show higher transit usage, lower daily personal vehicle trips, and slightly higher active travel (walk and bicycle) usage. However, it is notable that despite lower vehicle trip counts, overall vehicle miles traveled (VMT) are almost identical between the Expo and NHTS sample.

Table 3: Mean daily trip counts and VMT for Expo samples and NHTS

	LA County 2009 NHTS (n = 8,219)		Expo Before-opening, 2011 (n = 276)		Expo After-opening, 2012 (n = 204)	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Walk	1.36	3.24	1.49	1.97	1.59	1.93
Bike	0.11	0.72	0.16	0.56	0.27	0.93
Personal Vehicle	6.39	6.61	4.53	3.96	4.29	3.84
Bus	0.33	1.43	0.60	1.31	0.56	1.10
Rail transit	0.07	0.59	0.07	0.29	0.19	0.54
Other	0.11	0.63	0.34	3.32	0.07	0.71
Total trips	8.37	7.88	7.20	6.38	7.18	6.10
VMT	26.68	36.93	27.19	26.56	26.76	29.41

Table 4 shows transportation mode choice split in each of the samples. Personal vehicle use was lower for all Expo samples compared to the NTHS sample, with the after-opening approximately 7 percentage points lower than the before-opening group. Bus use was nearly twice the Los Angeles County rate for all Expo samples. Although the before-opening rail use rate of 1.0% was nearly equal to Los Angeles County as a whole (0.8%), the after-opening rate for the core and new residents were 3 to 4 times higher. Bus use remained essentially unchanged after the Expo Line opening.

Table 4: Mode split comparison for Expo samples and NHTS

	LA County NHTS		Expo Before-opening		Expo After-opening	
	N	**(%)**	**N**	**(%)**	**N**	**(%)**
Walk	11,137	16.2	2,820	21.5	2,294	22.3
Bike	898	1.3	325	2.5	380	3.7
Personal Vehicle	52,526	76.4	8,721	66.4	6,132	59.5
Bus	2,714	4.0	1,110	8.4	860	8.3
Rail transit	580	0.8	128	1.0	275	2.7
Other	900	1.3	38	0.3	91	0.9
Total	68,755	100.0	13,142	100.0	10,032	100.0

Note that the differences in Table 4 are not differences in experimental versus control groups, but instead are for the combined experimental and control group households, before and after the Expo Line opened.

Table 5 shows travel behavior variables for the experimental and control groups. All variables are household daily averages. Average household VMT, car trips, and bus trips dropped after the opening of Expo line. However, rail trips, walk trips, and bicycle trips increased after the opening of the light rail. Note that the standard deviations for most travel variables are as large as their corresponding mean values, suggesting that there is a lot of variability in the data. Also, most travel variables follow a somewhat skewed normal distribution, which is typical for travel variables.

Table 5: Descriptive statistics of the travel variables in Expo samples

Variables		N	Mean	S.D.	Min	Max	Percentiles				
							0.10	0.25	0.50	0.75	0.90
VMT	Before opening	198	28.58	28.10	0.00	158.57	0.00	10.14	22.43	39.79	61.00
	After opening	199	26.76	29.41	0.00	218.00	0.00	8.83	19.29	32.57	57.67
Car trips	Before opening	205	3.50	3.04	0.00	13.29	0.00	1.14	2.86	5.00	7.83
	After opening	203	3.29	2.85	0.00	13.14	0.00	1.00	2.86	4.81	7.29
Bus trips	Before opening	205	0.65	1.40	0.00	12.50	0.00	0.00	0.00	0.67	2.00
	After opening	203	0.56	1.10	0.00	6.57	0.00	0.00	0.00	0.71	2.14
Rail trips	Before opening	205	0.07	0.28	0.00	2.00	0.00	0.00	0.00	0.00	0.00
	After opening	203	0.19	0.54	0.00	3.57	0.00	0.00	0.00	0.00	0.57
Walk trips	Before opening	205	1.52	2.10	0.00	14.52	0.00	0.29	1.00	2.00	3.29
	After opening	202	1.59	1.93	0.00	9.57	0.00	0.00	0.86	2.29	4.29
Walk minutes	Before opening	205	27.26	37.67	0.00	226.00	0.00	2.14	17.86	34.29	62.29
	After opening	203	34.69	58.73	0.00	437.14	0.00	0.00	14.29	41.25	85.71
Bike trips	Before opening	205	0.18	0.61	0.00	4.00	0.00	0.00	0.00	0.00	0.57
	After opening	203	0.27	0.93	0.00	7.71	0.00	0.00	0.00	0.00	0.86
Bike minutes	Before opening	205	3.59	12.85	0.00	87.64	0.00	0.00	0.00	0.00	7.14
	After opening	202	4.52	15.30	0.00	150.71	0.00	0.00	0.00	0.00	13.71

2. Impacts on VMT and other travel variables

2.1. Before-opening differences, experimental versus control groups

Table 6 shows the differences between travel in the experimental and control households before the opening of the Expo Line. The t-statistic in the right-most column of Table 6 is the t-statistic for the differences in mean values for the experimental and control groups. There are no statistically significant differences in travel across the experimental and control groups before the Expo Line opened.

Table 6: Travel behavior variables, before-opening, experimental and control group

Variables		N	Mean	Mean Diff.	t	Sig.
VMT	control	98	27.41	2.30	0.57	
	experimental	100	29.71			
Car Driver Trips	control	99	3.55	-0.11	-0.26	
	experimental	106	3.44			
Bus Trips	control	99	0.58	0.15	0.75	
	experimental	106	0.72			
Train Trips	control	99	0.05	0.04	1.14	
	experimental	106	0.09			
Walk Trips	control	99	1.29	0.44	1.50	
	experimental	106	1.73			
Walk Minutes	control	99	26.21	2.04	0.39	
	experimental	106	28.24			
Bicycle Trips	control	99	0.17	0.01	0.13	
	experimental	106	0.18			
Bicycle Minutes	control	99	3.41	0.34	0.19	
	experimental	106	3.75			
Total Trips	control	99	6.82	0.66	0.82	
	experimental	106	7.48			

Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

2.2. After-opening differences, experimental versus control group

After-opening data are shown in Table 7. Experimental households had 10.15 fewer vehicle miles of travel per day, compared to the control households, and experimental households had more than twice as many rail transit trips (0.27 versus 0.12 per day) and approximately 40 percent more daily walking trips (1.86 versus 1.31) compared to control households. All of those differences are significant at the five percent level or better.

Table 7: After-opening differences, experimental versus control group

Variables		N	Mean	Mean Diff.	t	Sig.
VMT	control	98	31.91	-10.15	-2.46	*
	experimental	101	21.76			
Car Driver Trips	control	100	3.42	-0.24	-0.61	
	experimental	103	3.17			
Bus Trips	control	100	0.56	-0.01	-0.03	
	experimental	103	0.56			
Train Trips	control	100	0.12	0.15	2.05	*
	experimental	103	0.27			
Walk Trips	control	100	1.31	0.55	2.03	*
	experimental	102	1.86			
Walk Minutes	control	100	27.81	13.57	1.65	°
	experimental	103	41.38			
Bicycle Trips	control	100	0.23	0.08	0.64	
	experimental	103	0.31			
Bicycle Minutes	control	99	3.13	2.73	1.27	
	experimental	103	5.85			
Total Trips	control	100	6.6	1.13	1.32	
	experimental	102	7.74			

Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

2.3. Changes after opening compared to before opening

To compare before and after opening travel behavior, we separately examined pre-post changes in travel behavior for the experimental group and the control group. Table 8 shows the travel behavior comparison, before versus after opening, for the experimental households. VMT dropped by 7.79 miles, and this change is statistically significant. Train trips increased by 0.18 daily average trips, significant at the 1% level. Walk minutes increased by 13.13 minutes and bicycle trips by 0.12, and these changes are significant at the 10% level.

Table 8: Experimental households, before opening and after opening travel behavior

Variables		N	Mean	Mean Diff.	t	Sig.
VMT	before opening	96	29.71	-7.79	-2.57	*
	after opening	96	21.93			
Car Driver Trips	before opening	103	3.4	-0.22	-1.06	
	after opening	103	3.17			
Bus Trips	before opening	103	0.7	-0.14	-1.43	
	after opening	103	0.56			
Train Trips	before opening	103	0.09	0.18	2.88	**
	after opening	103	0.27			
Walk Trips	before opening	102	1.74	0.12	0.45	
	after opening	102	1.86			
Walk Minutes	before opening	106	28.24	13.13	1.86	°
	after opening	103	41.38			
Bicycle Trips	before opening	103	0.19	0.12	1.89	°
	after opening	103	0.31			
Bicycle Minutes	before opening	106	3.75	2.10	0.92	
	after opening	103	5.85			
Total Trips	before opening	102	7.38	0.35	0.58	
	after opening	102	7.74			

Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

For the control group (Table 9), none of the before-after travel behavior changes are statistically significant. It should be noted that VMT increased after the Expo Line opening, but this within control group change is not statistically significant. Train trips also increased, but again, this change is not significant.

Table 9: Control households, before opening and after opening travel behavior

Variables		N	Mean	Mean Diff.	t	Sig.
VMT	before opening	94	26.24	5.16	1.5	
	after opening	94	31.4			
Car Driver Trips	before opening	98	3.56	-0.12	-0.58	
	after opening	98	3.44			
Bus Trips	before opening	98	0.56	-0.01	-0.16	
	after opening	98	0.55			
Train Trips	before opening	98	0.05	0.07	1.43	
	after opening	98	0.12			
Walk Trips	before opening	98	1.28	0.03	0.19	
	after opening	98	1.32			
Walk Minutes	before opening	99	26.21	1.60	0.24	
	after opening	100	27.81			
Bicycle Trips	before opening	98	0.17	0.06	0.57	
	after opening	98	0.23			
Bicycle Minutes	before opening	99	3.41	-0.29	-0.18	
	after opening	99	3.13			
Total Trips	before opening	98	6.83	-0.19	-0.69	
	after opening	98	6.63			

Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

To evaluate statistical significance of the travel behavior change associated with the Expo Line, we performed two tests. In the first test, we computed the change in travel behavior for each household that completed both the before and after study. We then compared the means of the change in travel behavior for the control and experimental groups. This difference in means reflects the differential effect of the Expo Line opening on those households within ½ mile of the stations compared to those further away.

As shown in in Table 10, daily household VMT increased by 5.8 miles in the control group and decreased by 7.8 miles in the experimental group. The difference in the means of 13.57 miles is significant at the 1% level, indicating that the opening of the Expo Line reduced VMT among experimental households by 13.57 miles per day compared to control households. Interestingly, train, walk, and bicycle trips all increased for both experimental and control households. However, none of the group differences, except for VMT, are statistically significant.

Table 10: After minus before group differences, experimental minus control group

Variables		N	Group Difference (after – before)	Mean Diff.	t	Sig.
VMT	control	96	5.79	-13.57	-2.92	**
	experimental	96	-7.79			
Car Driver Trips	control	100	-0.19	-0.03	-0.11	
	experimental	103	-0.22			
Bus Trips	control	100	-0.04	-0.10	-0.75	
	experimental	103	-0.14			
Train Trips	control	100	0.07	0.11	1.42	
	experimental	103	0.18			
Walk Trips	control	100	0.03	0.08	0.27	
	experimental	102	0.12			
Walk Minutes	control	100	3.40	9.55	1.18	
	experimental	103	12.94			
Bicycle Trips	control	100	0.05	0.07	0.59	
	experimental	103	0.12			
Bicycle Minutes	control	99	-0.29	2.30	1.42	
	experimental	103	2.01			

significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

The second test of the Expo Line's travel impact involves a differences-in-differences (DID) analysis. DID is an econometric technique commonly used with quasi-experimental panel data to evaluate the effect of a treatment over time. DID analysis assumes that the differences that arise in the control and experimental groups are due only to the treatment – in this case, the opening of the new light rail line. Defining μ_{it} as the mean of the outcome for group i at time t, the DID estimator is $(\mu_{11} - \mu_{01}) - (\mu_{01} - \mu_{00})$, where "i" = 1 for experimental households and "i" = 0 for control households. This estimator can be evaluated using the following regression model:

$$y_{it} = \beta_0 + \beta_1 X_i + \beta_2 T_t + \beta_3\, X_i{*}\, T_t + \varepsilon_{it}$$

where y_{it} is the outcome for household i at time t, X_i is a dummy variable where 0 represents the control group and 1 the experimental group, and T_t is a dummy variable that takes the value 0 in the before opening period and 1 for the after opening period. The coefficient β_3 on the interaction between X_i and T_t represents the DID estimator. Note that β_3 takes a value of 1 only for experimental households in the after opening time period. The coefficient on β_3 is the effect of the treatment (the Expo Line in this case) on the outcome variable. See, e.g., Card and Krueger (1994) for a discussion. We use the regression above to obtain DID estimates of the effect of the Expo Line on each of the travel behavior variables.

Table 11 shows the result of the DID analysis. The second column indicates the difference-in-difference estimator (β_3) for the travel behavior variables. For VMT, the DID estimator is -12.4, and it is significant at the 5% level. The significantly negative DID estimator indicates that the opening of the Expo Line reduced household VMT within the experimental group by approximately 12 miles per day. Similar to the previous results, we found general trends of less car trips and more train, walk, and bicycle trips after the opening of the Expo line. However DID estimators for other travel variables do not show any significant treatment effect. The difference in other travel outcomes before and after the Expo Line opening may be too small to yield any statistically significant results.

Table 11: Differences-in-Differences estimation results with an unbalanced panel data

Dependent Variables	Difference in difference	Std. Error	p-value	N	Sig.
VMT	-12.4442	5.7416	0.031	397	*
Car Driver Trips	-0.1329	0.5850	0.820	408	
Bus Trips	-0.1520	0.2503	0.544	408	
Train Trips	0.1103	0.0841	0.191	408	
Walk Trips	0.1075	0.3985	0.787	407	
Walk Minutes	11.5371	9.7400	0.237	408	
Bicycle Trips	0.0721	0.1555	0.643	408	
Bicycle Minutes	2.3850	2.8010	0.395	408	

Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

Because missing values were disproportionately distributed across two waves, we next restrict our analysis to only households with full data in both waves. Table 12 shows the results of the DID regression with this balanced panel data set. The result is essentially the same as the unbalanced data set. The DID estimator for VMT is slightly larger for the balanced set, but it is statistically significant at the 5% level in both cases. Similar to the unbalanced set, the DID estimators for other travel variables in Table 12 are not statistically significant.

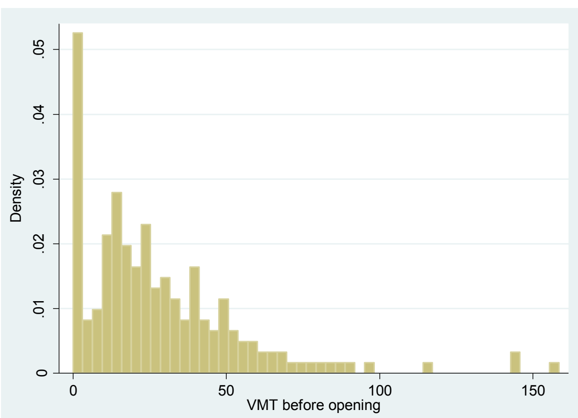
Table 12: Differences-in-Differences estimation results with a balanced panel data

Dependent Variables	Difference in difference	Std. Error	p-value	N	Sig.
VMT	-14.302	5.756	0.013	384	*
Car Driver Trips	-0.115	0.588	0.845	406	
Bus Trips	-0.170	0.251	0.499	406	
Train Trips	0.110	0.085	0.194	406	
Walk Trips	0.111	0.401	0.783	404	
Walk Minutes	10.139	9.672	0.295	406	
Bicycle Trips	0.075	0.156	0.632	406	
Bicycle Minutes	2.440	2.822	0.388	404	

Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

2.4. Robustness check of the VMT analysis

The results of the preceding analyses show that the change in VMT between the experimental and control groups, from before to after the opening of the Expo Line, is statistically significant. With this result, we conducted robustness check to ensure the reliability of our regression models. As shown in Figure 3, the data are skewed to the right. Also, there are many zero values (29 zeros) in VMTs in both panel samples, requiring regression specifications that can handle data that are censored at zero.



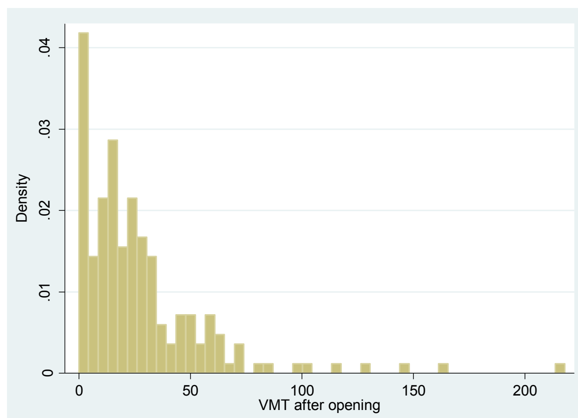


Figure 3: Distribution of before and after opening VMT data

Given the characteristics of the data, we applied various exclusion and estimation strategies in order to assess any potential bias in the regression results. The exclusion strategies include four parts: 1) removal of observations with zero VMT; 2) removal of households with daily average VMT > 100 miles; 3) removal of households with daily average VMT > 150 miles; and 4) removal of households with daily average VMT > 200 miles (Table 13). We also developed a Tobit model to account for the many zero values.

Table 13: Exclusion criteria for VMT

Exclusion criteria	Frequency	Percentage
All observations	192	100%
VMT = 0	29	15%
VMT > 100	10	5%
VMT > 150	3	2%
VMT > 200	1	1%

Table 14 shows the DID results after applying the different exclusion criteria. The DID estimators remain quite significant until the 14 households with VMT less than 100 miles per day are excluded. Note that the DID estimator is not significant after removing households with average VMT greater than 100 miles per day. Note that excluding households with VMT > 100 miles per day removes 7 percent of the observations – considerably more than typical outlier exclusions. Similarly, 2001 travel data for the five-county SCAG region show that the 90^{th} percentile of household daily VMT is 104 miles per day (Boarnet et al., 2011.) We conclude that removing households with VMT in the range from 100 to 150 miles per day is, in effect, removing valid data rather than removing outliers. Because large VMT households have more ability to reduce their VMT, the exclusion criterion of removing households with daily average VMT > 100 miles likely inappropriately biases results against finding an Expo Line treatment effect even if such an effect exists.

Table 14: DID (Ordinary Least Square) regression of VMT with different exclusion criteria

Exclusion criteria	Difference in difference	Std. Error	p-value	N	Sig.
VMT = 0	-15.811	6.201	0.011	326	*
VMT > 200	-12.339	5.443	0.024	382	*
VMT > 150	-10.118	5.108	0.048	378	*
VMT > 100	-5.269	4.311	0.222	364	

Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

As an additional robustness check, we conducted a separate Tobit regression of VMT left-censored at zero with the different exclusion criteria (Table 15). Tobit regression allows for estimating both left- and right-censored data, and censoring at zero effectively accommodates the special structure of the data, consisting of non-negative values with many zeros. The Tobit regression indicates that the DID estimator remains significant up to VMT greater than 150. Although the estimator is marginally significant with VMT>150, the effective size becomes larger than that of the Ordinary Least Square (OLS) regression results. The robustness checks confirmed that our regression models are robust and reliable even with different exclusion and estimation strategies.

Table 15: DID (Tobit) regression of VMT (left-censored at 0) with different exclusion criteria

Exclusion criteria	Difference in difference	Std. Error	p-value	N	Sig.
VMT > 200	-13.201	6.202	0.034	382	*
VMT > 150	-10.876	5.834	0.063	378	·
VMT > 100	-5.627	4.948	0.256	364	

Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

2.5. Comparison of GPS and travel diary

The reduction in VMT associated with the Expo Line, when measured as experimental versus control group differences, is large – approximately 10 to 12 miles per day in a sample with a baseline VMT of 27 miles per day (according to Table 3). This implies that the Expo Line is associated with approximately a 40 percent reduction in VMT among experimental households. Statistically, this result remains when we remove outliers and use alternative (tobit) estimation techniques. Given the size of the impact, additional examination is important.

One possible risk, which we examine in this section, is a "Hawthorne effect," so named after a classic experiment which found that study subjects altered their behavior in ways they thought would correspond to the study objectives (Adair, 1984). Could it be that the experimental households reported artificially lower VMT during the "after opening" data collection, in the hopes of, in their view, meeting the research team's expectations? We believe that is unlikely. Study subjects were never told that the research focused on the Expo Line, and survey materials did not mention the Expo Line. The VMT data are from self-reports of vehicle odometer readings, recorded each day for seven days, providing opportunities for the research team to check the consistency of the reported data. Because the vehicle odometers are objective, we believe that information even from self-reported odometer readings is of high quality.

Additionally, we have GPS data that allow some examination of any reporting bias across experimental and control households. In 104 of the households, an adult carried a GPS before and after the Expo Line opened. If that adult rode in the same household vehicle each day and if no other persons drove that vehicle, those GPS and odometer readings should match. Of course, there are many ways that the GPS carried by an adult and household vehicle odometers would not match. Simply riding in multiple household vehicles would create offsets between the GPS data and any vehicle's odometer readings. Still, a comparison between GPS and vehicle odometer data can be useful, and we undertake such a comparison here.

We estimated vehicle travel from the GPS, using travel speeds and several algorithms designed to separate vehicle travel from bus or car travel in the GPS traces. We then compared vehicle VMT for the car in the household that most closely matched the adult GPS VMT estimate. Table 16 shows that 61 percent of the households for which this comparison is possible (n=140) have GPS-odometer agreement within 60 percent.[5] Note that we refer to the "before opening" data as Wave 1 and the "after opening" data as Wave 2. There are no clear differences in accuracy, by this measure, across the waves (Table 16).

Table 16: Comparison of GPS and odometer for both waves

	All (N=140)	%	Wave 1	%	Wave 2	%	Experimental	%	Control	%
90% similarity	33	24%	19	14%	14	10%	20	14%	13	9%
80% similarity	58	41%	33	24%	25	18%	29	21%	29	21%
70% similarity	72	51%	40	29%	32	23%	36	26%	36	26%
60% similarity	85	61%	47	34%	38	27%	43	31%	42	30%

Table 17 shows the GPS-odometer comparison for the experimental and control groups in the two waves. Here, there is evidence that the experimental households were less accurate, if accuracy is determined by GPS-odometer agreement, which is a rather questionable measure of self-report accuracy for the reasons noted above.

Table 17: Comparison of GPS and odometer for each wave

	Wave 1 (N=70)				Wave 2 (N=70)			
	Experimental	%	Control	%	Experimental	%	Control	%
90% similarity	13	19%	6	9%	7	10%	7	10%
80% similarity	18	26%	15	21%	11	16%	14	20%
70% similarity	21	30%	19	27%	15	21%	17	24%
60% similarity	25	36%	22	31%	18	26%	20	29%

Table 18 shows the magnitude of the difference, GPS versus odometer, for the two waves. If there is an increase in agreement based on mean levels, it is not due as much to changes in the experimental households as to changes in the control households where GPS-odometer agreement is better in Wave 2.

Table 18: Average difference between odometer and GPS VMT for all observations

	Wave 1 (N=70)		Wave 2 (N=70)	
	Experimental	Control	Experimental	Control
Average difference (Odometer– GPS)	-5.68	-16.85	-4.23	-2.97
SD of the difference	24.34	61.02	17.01	17.79

[5] To calculate different matching threshold, we used a percentage similarity score between the GPS VMT and the odometer VMT using the following formula: $1 - \frac{|GPS\ VMT - odometer\ VMT|}{GPS\ VMT}$

Lastly, Table 19 shows mean values for both GPS and odometer VMT for experimental and control groups, before and after opening. The odometer readings (right-hand side of Table 19) show decreases in VMT among experimental households and increases in VMT among control households. The GPS VMT, from a smaller subset of the full sample, shows little change in experimental VMT and a large increase in control VMT.

Table 19: Comparison of descriptive statistics for GPS and odometer VMT

	GPS VMT				Odometer VMT			
	Wave 1 (N=70)		Wave 2 (N=70)		Wave 1 (N=192)		Wave 2 (N=192)	
	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control
N	36	34	36	34	98	94	96	96
Mean	22.70	30.39	22.35	24.87	30.04	26.24	21.93	32.44
S.D.	25.09	58.21	20.88	25.72	31.58	21.06	21.18	35.77
Min	0	0	0	0	0	0	0	0
Max	143.06	308.21	77.43	98.15	158.57	83.14	130.29	218

On net, the patterns in Table 18 and Table 19 raise the possibility that the increase in self-reported control household VMT, which contributes to the "after opening" gap between experimental and control group VMT, is due to increases in control household reporting accuracy or over-estimates of odometer VMT in the control households before the Expo Line opened. We believe such patterns would be a highly implausible Hawthorne effect. Similarly, if there is any inaccuracy in reporting among control households, Table 19 suggests that may be manifested in higher self-reported VMT (compared to the GPS value) before the Expo Line opened. Again, such an "anticipatory" Hawthorne effect that purposefully overestimates the baseline data would be implausible. We believe the most reasonable conclusion is that the lack of correspondence between the GPS and the self-reported odometer data occurs because the GPS and the odometer measure different things – one person's travel (GPS) versus a vehicle's travel (odometer.)[6] We see no sign of self-report bias in the odometer data from this comparison with the GPS data.

3. Impacts on physical activity

3.1. Data and research hypotheses

During both the before and after opening data collection, a subsample of our households carried physical activity monitors (accelerometers.) To evaluate the physical activity impact of the Expo Line, we formed the following three hypotheses.

[6] Note that we had to estimate private vehicle travel from the travel data in the GPS information, introducing a potential source of error into the GPS VMT estimates.

H_1: Environmental exposure hypothesis:

We first hypothesize that people living near light rail stations become more physically active than those living far away. This hypothesis is based on a large body of research examining the relationship between land use and travel behavior (see TRB 2005 for a comprehensive review of this topic). In general, people are willing to walk to transit stops if they live within a half-mile boundary. Thus, this hypothesis tests whether exposure to transit-friendly environment leads to more physical activity.

H_2: Mode switching hypothesis:

The second hypothesis tests whether people who switch travel modes (e.g. car to transit) become more physically active than non-switching group.

H_3: Past behavior and personal influence hypothesis:

The third hypothesis focuses on the influence of past behavior on physical activity participation. We hypothesize that people's past physical activity patterns affect current physical activity behavior.

3.2. Descriptive statistics of the physical activity data

Table 20 shows the physical activity outcomes. The experimental group decreased physical activity across all levels. The control group actually increased hard activity. It is hard to tell if this difference is meaningful because none of the measures are statistically significant. The fact that the experimental group decreased physical activity in wave 2 is counter intuitive. At least at the aggregate level, the result does not appear to support the environmental exposure hypothesis, implying that there is little treatment effect of the Expo Line on physical activity. Even if there is any treatment effect, it is likely to be moderated by other factors, either observed or unobserved.

Table 20: Physical activity outcomes before and after the new light rail

Variables[a]		Control (*N*=44)			Experimental (*N*=38)		
		Wave 1	Wave 2	Sig.	Wave 1	Wave 2	Sig.
Raw counts	Mean	205,475.55	201,532.22	0.846	228,170.33	215,642.65	0.427
	SD	100,913.29	89,055.97		74,849.93	61,048.21	
Daily sedentary minutes	Mean	512.98	510.41	0.924	484.99	505.91	0.346
	SD	123.85	129.43		90.99	100.87	
Daily light minutes	Mean	260.83	264.57	0.835	271.01	268.29	0.861
	SD	84.85	83.47		66.21	69.16	
Daily moderate minutes	Mean	19.88	18.42	0.698	22.78	21.62	0.739
	SD	17.76	17.63		16.11	14.15	
Daily hard minutes	Mean	0.19	0.31	0.570	0.76	0.42	0.503
	SD	0.62	1.27		2.83	1.40	
MVPA[b]	Mean	20.07	18.73	0.725	23.55	22.04	0.674
	SD	17.79	17.94		16.36	14.68	
	Min	0	0.71		1.43	1.14	
	Max	96.00	79.60		74.86	47.80	

[a]: t-test used for significance; . <0.10, * < 0.05, ** < 0.01, *** < 0.001
[b] MVPA (moderate and vigorous physical activity) is a common measure of physical activity which combines minutes in moderate and hard physical activity. Note that only one subject in control group has 0 MVPA in wave 1.

3.3. Results of the physical activity analysis

Differences-in-Differences (DID) model results

The hypotheses we developed were tested with two different approaches: differences-in-differences (DID) and lagged dependent variable (LDV) models. For the DID approach, we examined the effect of living near transit stations (hypothesis 1) and the effect of switching transport mode (hypothesis 2). DID 1 in Table 21 shows the treatment effect of living near transit stations. As expected from the descriptive analysis, neither time nor the treatment effect was statistically significant. Further, the differences-in-differences estimator (time x experimental) has a negative coefficient, but it is not statistically significant. Experimental subjects who took more bus trips did increase their physical activity (DID2 and DID4 in Table 21). For every additional daily average bus trip, the study subjects had about a 14 minute increase in moderate and vigorous physical activity (MVPA.)

Table 21: DID models of average daily MVPA minutes

Variables	DID 1		DID 2		DID 3		DID 4	
	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value
Intercept	20.07	7.91 ***	21.23	10.49 ***	20.30	10.18 ***	20.39	9.92 ***
Time[a]	-1.35	-0.38	-3.95	-1.38	-2.44	-0.86	-4.07	-1.40
Experimental[b]	3.48	0.93						
Time x Experimental	-0.16	-0.03						
Increased bus trips[c]			2.43	0.50			-0.71	-0.14
Increased train trips[c]					9.03	1.75 ·	9.31	1.71 ·
Time x More bus			14.38	2.10 *			13.92	1.93 ·
Time x More train					6.68	0.92	1.36	0.18
N	160		156		156		154	
R^2	0.012		0.075		0.075		0.114	
Adjusted R^2	-0.006		0.057		0.057		0.085	

Dependent variable: Average daily MVPA minutes
[a] 0 = wave 1, 1 = wave 2; [b] 1 = within ½ mi, 0 = otherwise; [c] 1 = increase, 0 = otherwise
· <0.10, * < 0.05, ** < 0.01, *** < 0.001

In attempting to investigate the treatment effect more closely, we plotted MVPA minutes by distance from transit stops. Figure 4 compares the treatment effect between the experimental and control groups. The y-axis is the average MVPA minutes, and the x-axis represents distance from home to the nearest Expo Line station. In Wave 1 (before opening), there is no gradient effect. In Wave 2 which represents "after opening", the gradient effect seems to follow a non-linear function. The gradient effect on physical activity is more pronounced between 3/8th of a mile and 5/8th of a mile, which we call the "effective range". The half-mile boundary falls within this range, but the effect is not linear as we previously expected. Further research will be needed to investigate this non-linear effect of distance to transit on physical activity, possibly using other regression techniques, such as regression discontinuity or poisson regression.

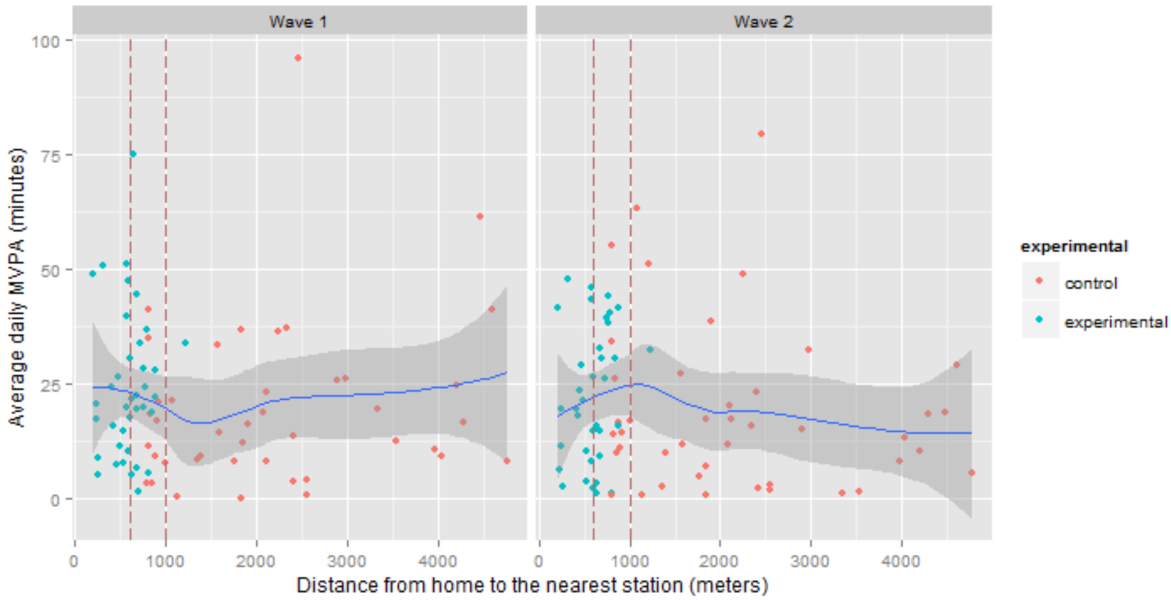


Figure 4: Distance to the nearest station by MVPA minutes in wave 1 and wave 2

* The dotted lines indicate the effective range (between 3/8th of a mile and 5/8th of a mile)

Lagged Dependent Variable (LDV) model results

Even though the first hypothesis did not hold, the LDV models strongly support the second and third hypotheses. Table 22 shows the LDV models where MVPA minutes in wave 2 were regressed on MVPA minutes in wave 1 and other covariates. LDV 1 is the basic model with core demographics: age, sex, and body mass index (BMI.) The coefficient on MVPA1 is marginal, but positive and significant at the 1% level. This implies that physical activity in Wave 1 affected physical activity in Wave 2. The coefficient on Age is negative and marginally significant at the 10% level. Physical activity goes down with increasing age. Males have higher levels of MVPA minutes.

Table 22: LDV models of average daily MVPA minutes

Variables	LDV 1		LDV 2		LDV 3		LDV 4	
	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value
Intercept	16.90	2.03 *	15.16	1.89 ·	16.96	2.44 *	3.16	0.41
$MVPA_1$	0.51	5.86 ***	0.69	6.50 ***	0.70	7.57 ***	0.74	8.47 ***
Experimental[a]	0.15	0.05	10.46	2.22 *	8.36	2.04 *	9.83	2.55 *
$MVPA_1$ x Experimental[a]			-0.47	-2.76 **	-0.53	-3.63 ***	-0.57	-4.16 ***
Age	-0.19	-1.79 ·	-0.22	-2.13 *	-0.29	-3.14 **	-0.24	-2.75 **
Sex[b]	8.27	2.65	9.72	3.20 **	7.74	2.90 **	7.61	3.05 **
BMI	-0.02	-0.12	-0.05	-0.32	-0.03	-0.23	-0.03	-0.22
Increased train trips[c]					4.65	1.20	1.42	0.38
Increased bus trips[c]					15.70	4.53 ***	13.62	4.13 ***
Knowledge about transit service[d]							2.17	3.34 **
N	74		73		70		69	
R^2	0.425		0.480		0.629		0.680	
Adjusted R^2	0.387		0.437		0.586		0.638	

Dependent variable: MVPA minutes in wave 2
[a] 1 = within ½ mi, 0 = outside ½ mi; [b] 1 = Male, 0 = Female; [c] 1 = increase, 0 = otherwise; [d] 1 = lowest, 7 = highest
· <0.10, * < 0.05, ** < 0.01, *** < 0.001

LDV 2 is slightly more complex than LDV 1, partly because it has the interaction effect of previous physical activity level and the treatment effect. The interaction term is highly significant but has a negative coefficient (-0.47). Persons living within ½ mile of the Expo Line stations had a 10.46 minute in MVPA minutes – a large impact given common public health recommendations that adults should have 30 minutes of MVPA per day. The negative coefficient on the interaction term ($MVPA_1$ x Experimental) means that the effect on physical activity from the Expo Line is larger for those persons in the experimental group (within ½ mile from stations) who were less physically active before the line opened.

LDV 3 and 4 test the effects of modal behavior and attitude (Hypotheses 3 and 4). In LDV 3, subjects who increased bus trips in Wave 2 were significantly more physically active than those who decreased or maintained the same bus trip frequency. The coefficient has a large effect size and is highly significant at the 0.1% level (15.70). This implies that increasing bus trips in Wave 2 raises average daily MVPA minutes by almost fifteen minutes. This is a substantial physical activity gain, which could lead to meaningful health benefits. Fifteen minutes is about half of the daily physical activity level recommended by physicians. This result is consistent with the previous studies that there is a close relationship between bus trips and physical activity (Lachapelle and Noland 2012; Besser and Dannenberg 2005). Interestingly, subjects who took more train trips also increased physical activity, but the coefficient is not statistically significant.

LDV 4 examines whether pro-transit attitudes increase physical activity participation. Of several attitudinal variables, knowledge about transit significantly increased physical activity. A 1-point rise in knowledge about transit service (a scale of 1 to 7) increases average daily MVPA minutes by 2.17. A positive attitude may be correlated with other factors associated with physical activity, but attitudes are well known mediators between transit use and physical activity. Psychological satisfaction and positive evaluation of service quality help maintain transit use, and subsequently leads to more physical activity (Brown, Werner, and Kim 2003; Hoehner et al. 2005).

3.4. Robustness check of the physical activity analysis

As a robustness check of our regression results, we applied three exclusion criteria to remove potential outliers from our sample. The first criterion is to use all observations without making any assumptions on the influential observations. The second criterion is to drop any observations when daily average MVPA minutes change more than 60 minutes a day. Only one individual changed the MVPA minutes over 60 minutes between the two waves. The third criterion is to drop all observations when the percentage change in daily average MVPA minutes between the two waves is higher than 15%.

Table 23 shows the DID results after removing influential observations using the proposed exclusion criteria. The results appear to be robust with or without removing influential observations. The coefficients and the standard error remain relatively the same regardless of different criteria being applied.

Table 23: Comparison of DID 4 results after removing influential observations

Variables	DID 4 (criterion 1)			DID 4' (criterion 2)			DID 4" (criterion 3)		
	Estimate	t-value		Estimate	t-value		Estimate	t-value	
Intercept	20.39	9.92	***	19.50	9.75	***	19.80	9.71	***
Time[a]	-4.07	-1.40		-2.94	-1.04		-3.22	-1.12	
Increased bus trips[b]	-0.71	-0.14		-0.07	-0.01		-0.29	-0.06	
Increased train trips[b]	9.31	1.71	·	9.87	1.88	·	9.68	1.84	·
Time x Increased bus	13.92	1.93	·	13.09	1.88	·	13.30	1.90	·
Time x Increased train	1.36	0.18		0.64	0.09		0.81	0.11	
N	154			152			148		
R^2	0.114			0.121			0.122		
Adjusted R^2	0.085			0.092			0.092		

Dependent variable: Average daily MVPA minutes
[a] 0 = wave 1, 1 = wave 2; [b] 1 = increase, 0 = otherwise
· <0.10, * < 0.05, ** < 0.01, *** < 0.001

Table 24 compares the LDV 4 results with and without influential observations. The experimental effect remains statistically significant in criterion 2, but the effect attenuates after applying criterion 3, and the experimental effect becomes statistically insignificant. Interestingly, the coefficients and the standard errors for the interaction term between $MVPA_1$ and the experimental group, age, and sex all attenuate after removing influential observations. All other coefficients and the standard errors remain relatively similar across different exclusion criteria.

In summary, the DID models are consistent regardless of different criteria applied, but the LDV models results change depending on which criterion is applied. The applied exclusion criteria are systematic but based on a subjective decision. If drastic change in the MVPA levels is the result of measurement error, then it would be reasonable to choose the criterion 3. However, there is no reason to believe that over 15 % change in the MVPA levels are due to erroneous measures. People may change physical activity over time, and such change could be drastic.

Table 24: Comparison of LDV results after removing influential observations

Variables	LDV 4 (criterion 1)			LDV 4' (criterion 2)			LDV 4" (criterion 3)		
	Estimate	t-value		Estimate	t-value		Estimate	t-value	
Intercept	3.16	0.41		4.08	0.55		1.34	0.19	
$MVPA_1$	0.74	8.47	***	0.73	8.75	***	0.74	9.25	***
Experimental[a]	9.83	2.55	*	6.64	1.68	·	3.87	1.00	
$MVPA_1$ x Experimental[a]	-0.57	-4.16	***	-0.38	-2.51	*	-0.30	-2.05	*
Age	-0.24	-2.75	**	-0.22	-2.58	*	-0.20	-2.43	*
Sex[b]	7.61	3.05	**	6.23	2.51	*	5.94	2.52	*
BMI	-0.03	-0.22		-0.04	-0.37		0.00	0.04	
Increased train trips[c]	1.42	0.38		0.49	0.13		0.51	0.15	
Increased bus trips[c]	13.62	4.13	***	13.12	4.12	***	13.03	4.29	***
Knowledge about transit service[d]	2.17	3.34	**	1.97	3.10	**	2.08	3.42	**
N	69			68			66		
R^2	0.680			0.701			0.732		
Adjusted R^2	0.638			0.661			0.696		

Dependent variable: MVPA minutes in wave 2
[a] 1 = within ½ mi, 0 = outside ½ mi; [b] 1 = Male, 0 = Female; [c] 1 = increase, 0 = otherwise; [d] 1 = lowest, 7 = highest
· <0.10, * < 0.05, ** < 0.01, *** < 0.001

In addition to the modified LDV model, we calculated a marginal effect of the interaction term (Experimental x $MVPA_1$) on $MVPA_2$.[7] We compared the marginal effects using the different exclusion criteria. The marginal effect becomes smaller after removing influential observations. Decrease in the magnitude of the marginal effect suggests that this negative effect becomes smaller after removing influential observations. Figure 5 shows the sensitivity of the different exclusion criteria on the magnitude of the marginal effect on the MVPA levels in wave 2. Further, the marginal effect of the interaction term is positive only up to a certain point but negative after that. This changing sign means that those subjects with relatively lower physical activity levels in wave 1 are more likely to increase their activity levels in wave 2. Conversely, those with relatively higher physical activity levels in wave 1 are likely to decrease their activity levels in wave 2.

As shown in Figure 5, the threshold point determining the lower and higher activity levels varies by different exclusion criterion but similar across the sample. The threshold point is 17.21 for the sample with the criterion 1 (≈ 46th percentile); 17.29 for the sample with the criterion 2 (≈ 46th percentile); and 12.73 for the sample with the criterion 3 (≈ 36th percentile). Substantively, this suggests that the Expo Line had more positive effect on those who maintained relatively low physical activity (the bottom 36 to 46th percentile range) in the experimental group than those with higher physical activity levels (the top 64 to 54th percentile range).

[7] The marginal effect is calculated using this formula:

$\frac{\partial MVPA_2}{\partial \text{Experimental}} = \beta_2 + \beta_3 MVPA_1$, where β_2 is the experimental effect and β_3 is the interaction term

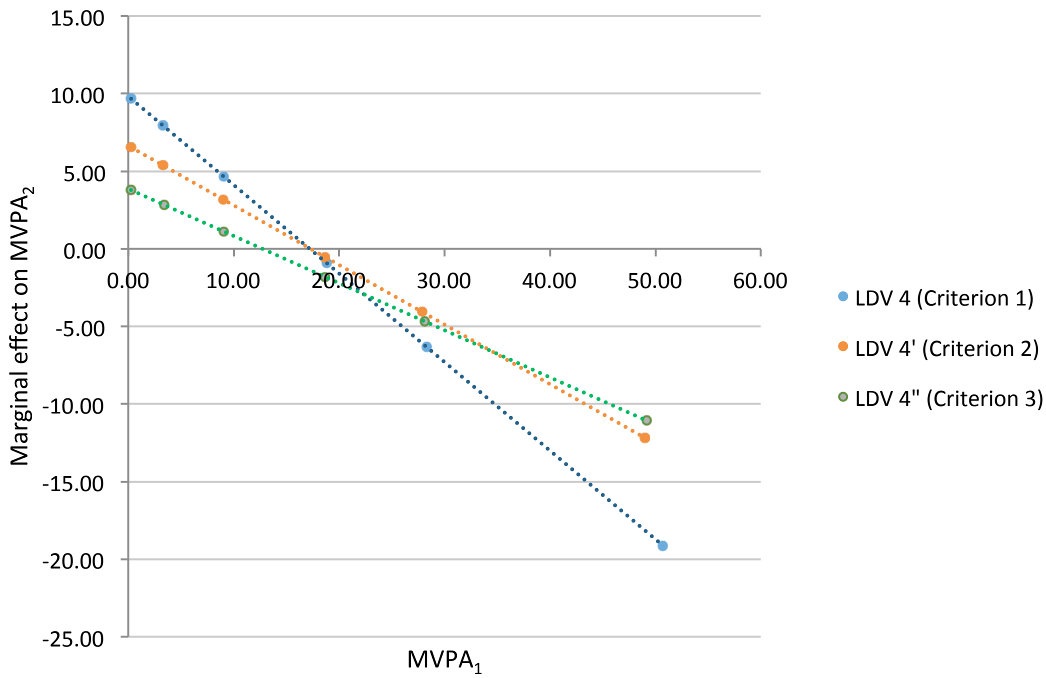


Figure 5: Sensitivity of the marginal effect of the interaction term (Experimental x $MVPA_1$) on $MVPA_2$

In summary, the DID models are robust but the LDV models are not robust to the different exclusion criteria. However, further robustness checks revealed that the inconsistent results of the LDV models may stem from different individual responses to the treatment. It is possible that the subjects with different baseline MVPA levels responded differently to the opening of the Expo line. The marginal effect plot confirms this speculation that Expo Line had a more positive impact on people with lower baseline physical activity than those with higher activity level in the before-opening sample. The experimental subjects with baseline MVPA levels in the bottom 36^{th} to 46^{th} percentiles increased their MVPA levels after the opening of the Expo line. The marginal effect plot indicates that this positive treatment effect remains strong even after applying stricter exclusion criteria. This finding indicates that the physical activity impact of the Expo Line varies by resident's past physical activity levels. Residents with previously lower physical activity levels appear to have a positive impact on their physical activity from the Expo Line intervention.

4. Impacts on emissions

4.1. Assumptions and calculation

This section reports the impact of the Expo Line on the household-level daily average carbon dioxide (CO_2) emissions (in grams) from motor vehicles. The estimation of emission is based on the emission model EMFAC 2011 (http://www.arb.ca.gov/emfac/) developed by the California Air Resource Board (CA-ARB). The formula to estimate the daily average CO_2 emission of each vehicle is as follows:

Daily average CO_2 emission = Run Rate (per mile) x daily average VMT + Start Rate (per day)

The "run rate" is the mass of CO_2 emitted by the vehicle while running, the "start rate" is the mass of CO_2 emitted by the vehicle when the engine is being turned on. Both rates, corresponding to the specific vehicle type (light-duty automobile, tier-1 and tier-2 light duty trucks or motorcycle) and model year, are the average estimates in Los Angeles County for the corresponding year of the survey (2011 for Wave 1 and 2012 for Wave 2) available in the EMFAC 2011 emission database. Since we do not have the exact trip number for each vehicle, we use the average start rate per day (rather than per trip), assuming that the trip number for each vehicle is the average of the vehicles in the same type and model year in Los Angeles County.

Run rate emission data for hybrid and electrical vehicles comes from the EPA fuel economy online database (http://www.fueleconomy.gov/). The CO_2 emission rate of these vehicles includes both tailpipe and upstream (from power grids) emissions. Also, we assume a zero start rate of all hybrid and electrical vehicles. The categorization of light duty trucks (LDTs) depends on the weight of the vehicle[8]. The weight is calculated by curb weight plus 300 pounds. Because of the scarcity of a comprehensive vehicle weight database, additional information on curb weight comes from publicly available information[9]. The household-level daily average CO_2 emission equals to the sum of the daily average CO_2 emission for each vehicle in the household. We dropped the household as having incomplete data if a) the make, model or year of at least one vehicle is missing; b) the odometer log has error that cannot be corrected; or c) less than three days' odometer readings are available.

4.2. Descriptive statistics of the emissions data

Table 25 shows the basic descriptive statistics of the CO_2 emissions of all households with usable data. 209 of the 284 households in Wave 1 and 163 of the 204 households in Wave 2 have usable data in this analysis. Compared to Wave 1, the household-level daily average CO_2 emission is slightly lower in Wave 2. CO_2 emissions in Wave 2 also have higher standard deviations, indicating more variation after the Expo Line opening.

[8] The standard vehicle weights are available at http://www.arb.ca.gov/msei/vehicle-categories.xlsx.

[9] Additional information were obtained from the popular car-shopping website (http://www.edmunds.com).

Table 25: Descriptive statistics of CO_2 emissions of all households

	wave 1	wave 2
Total number of households in the study	284	204
Total number of vehicles in the study	354	249
Number of households with usable data	209	163
Number of vehicles with usable data	295	218
Average of daily household-level CO_2 emissions (grams)	12050	11502
S.D. of daily household-level CO_2 emissions (grams)	9535	11368
Max. of daily household-level CO_2 emissions (grams)	58763	92596
Min. of daily household-level CO_2 emissions (grams)	0.00	0.02

As shown in Table 26, 140 households have full CO_2 emission information in both waves. Of these households, 71 are in the control group and 69 are in the experimental group. Similar to the previous analysis of the larger sample of households in either Wave 1 or Wave 2, we also see a slight decrease in daily average household-level CO_2 emissions and an increase in the variance in Wave 2 compared to Wave 1.

Table 26: Descriptive statistics of CO_2 emissions of household in both wave 1 and wave 2

	wave 1			wave 2		
	sum	control	experimental	sum	control	experimental
Total number of households	140	71	69	140	71	69
Total number of vehicles	192	103	89	186	97	89
Average of daily household-level CO_2 emissions (grams)	12,329	12,112	12,553	11,449	13,495	9,344
S.D. of daily household-level CO_2 emissions (grams)	9,875	7,407	11,949	11,335	14,037	7,136
Max. of daily household-level CO_2 emissions (grams)	58,763	33,615	58,763	92,596	92,596	31,061
Min. of daily household-level CO_2 emissions (grams)	150	150	430	164	1,580	164

4.3. Results of the emissions analysis

The CO_2 emission levels in the experimental group are significantly lower compared to the control group in Wave 2.Yet, no significant differences exist between the two groups in Wave 1. According to Table 27, household-level CO_2 emissions in the experimental group is 3.6% higher than that in the control group in Wave 1, and the p-value of the two-sample t-test is 0.794, indicating no significant difference. In Wave 2, the household-level daily CO_2 emissions in the experimental group is 30.8% lower than that in the control group. This difference is statistically significant at the 5% level.

Table 27: CO_2 emission between two groups in wave 1 and in wave 2

	wave 1		wave 2	
	control	experimental	control	experimental
Number of households with usable data	71	69	71	69
Number of vehicles with usable data	103	89	97	89
Average of daily household-level CO_2 emissions (grams)	12111.91	12552.85	13495.21	9343.52
Difference: experimental-control)	440.94		-4151.68	
% Difference: (experimental-control)/control	3.6%		-30.8%	
p-value of two-sample t-test (double-sided)	0.794		0.029	

The daily average CO_2 emission of the households in the experimental group has a significant decrease from Wave 1 to Wave 2, while that of the households in the control group has an insignificant increase. According to Table 28, households in the experimental group show a 25.6% decrease in the average daily CO_2 emissions from Wave 1 to Wave 2. The p-value of 0.005 indicates that this is a significant reduction. However, households in the control group have an 11.4% decrease, but this decrease in not statistically significant. While the Expo Line opening had no significant impact on the CO_2 emission levels for the control group, the experimental group significantly reduced CO_2 emission levels after the opening.

Table 28: CO_2 emission between the two waves in experimental and control groups

	control		experimental	
	wave1	wave2	wave1	wave2
Number of households with usable data	71	71	69	69
Number of vehicles with usable data	103	97	89	89
Average of daily household-level CO_2 emissions (grams)	12111.91	13495.21	12552.85	9343.52
Difference: wave2-wave1	1383.29		-3209.33	
% % Difference: (wave2-wave1)/wave1	11.4%		-25.6%	
p-value of paired t-test (double-sided)	0.408		0.005	

Emission impacts on households with no vehicle changes

As expected over the course of a year, some households changed their vehicle holdings between Wave 1 and Wave 2. To understand the impact of the Expo Line more closely, we examined the emission changes for the households with and without vehicle changes separately. The households with no vehicle changes are defined as those for which the make, model and year of each vehicle remains the same across the two waves. Table 29 shows that 104 households did not have vehicle changes. Of those households, 50 households are in the control group and 54 households in the experimental group, indicating a balanced distribution between the two groups. Since there are no vehicle changes in these households, we conclude that the CO_2 emission changes come primarily from travel behavior changes, specifically the changes in VMT documented earlier.

Table 29: Descriptive statistics of CO_2 emissions of households with no vehicle changes across waves

	wave 1			wave 2		
	total	control	experimental	wave 2	control	experimental
Number of households with usable data	104	50	54	104	50	54
Number of vehicles with usable data	134	66	68	134	66	68
Average of daily household-level CO_2 emissions (grams)	11761.29	11299.55	12188.83	11351.26	13357.02	9494.08
S.D. of daily household-level CO_2 emissions (grams)	10184.16	6767.05	12603.14	9806.64	11645.92	7361.77
Max. of daily household-level CO_2 emissions (grams)	58763.26	29304.66	58763.26	59660.59	59660.59	31061.46
Min. of daily household-level CO_2 emissions (grams)	429.81	1425.71	429.81	163.81	1579.72	163.81

The CO_2 emission levels in the experimental group are significantly lower compared to the control group in Wave 2, while no significant differences exist between the two groups in Wave 1. Table 30 shows that in Wave 1 the CO_2 emission from the households in the experimental group is 7.87% higher than the emissions from the control group. However, this difference is not significant. In Wave 2, the CO_2 emissions from the experimental group are 28.92% lower than the control group, which is a statistically significant difference. This indicates that the households living near the Expo Line emitted significantly lower CO_2 than those living far from the stations after the opening, restricting attention to the households with no changes in vehicle holdings.

Table 30: CO_2 emission between two groups in wave 1 and in wave 2 for households with no vehicle changes

	wave 1		wave 2	
	control	experimental	control	experimental
Number of households with usable data	50	54	50	54
Number of vehicles with usable data	66	68	66	68
Average of daily household-level CO_2 emissions (grams)	11299.55	12188.83	13357.02	9494.08
Difference: experimental-control	889.28		-3862.93	
% Difference: (experimental-control) / control	7.87%		-28.92%	
p-value of two-sample t-test (double-sided)	0.652		0.048	

The daily average CO_2 emissions of the households in the experimental group has significantly decreased from Wave 1 to Wave 2. The control group has increased CO_2 emissions in Wave 2, but it is not statistically significant. According to Table 31, the households in the control group have 18.21% increases in CO_2 emissions from Wave 1 to Wave 2. However, this increase is not significant according to the paired t-test. In contrast, the households in the experimental group show a significant reduction of 22.11% from Wave 1 to Wave 2. This indicates that the households living near the Expo Line stations significantly decreased their CO_2 emissions after the opening of Expo Line, again restricting attention to households with no changes in vehicle holdings.

Table 31: CO_2 emission between the two waves in the two groups for households with no vehicle changes

	control		experimental	
	wave1	**wave2**	**wave1**	**wave2**
Number of households with usable data	50	50	54	54
Number of vehicles with usable data	66	66	68	68
Average of daily household-level CO_2 emissions (grams)	11299.55	13357.02	12188.83	9494.08
Difference: wave2-wave1	2057.46		-2694.75	
% Difference: (wave2-wave1)/wave1	18.21%		-22.11%	
p-value of paired t-test (double-sided)	0.153		0.03	

Emission impacts on households with vehicle changes

The households with a change in vehicle holdings were defined as those with changes in the number of vehicles or the make, model or year of any vehicle[10]. More than half of those households changed a vehicle but kept the same number of vehicles over time. Among the 15 households in the experimental group with a change in vehicle holdings, three households increased the number of vehicles, three households decreased the number of vehicles, and nine households kept the same number of vehicles. Among the 21 households in the control group, three households increased the number of vehicles, eight households decreased the number of vehicles, and eleven households did not change the number of vehicles. Among the 9 households in the experimental group and the 11 households in the control group who did not change the number of vehicles, most changes occurred by replacing a vehicle with a newer model year. The complete list of the households with changes in vehicle holdings can be found in Appendix A.

Focusing on the 36 households that changed vehicles, 21 households are in the control group and 15 households in the experimental group (Table 32). The daily average CO_2 emissions for these 36 households went down from 13,970 grams to 11,731 grams after the opening of the Expo Line.

[10] Note: Four households had a model year change only, possibly due to errors in self-reporting, but we classify those households as changing vehicle holdings, also.

Table 32: Descriptive statistics of CO_2 emissions of households with vehicle changes across waves

	wave 1			wave 2		
	total	**control**	**experimental**	**wave 2**	**control**	**experimental**
Number of households with usable data	36	21	15	36	21	15
Number of vehicles with usable data	58	37	21	52	31	21
Average of daily household-level CO_2 emissions (grams)	13969.95	14046.10	13863.34	11731.43	13824.23	8801.51
S.D. of daily household-level CO_2 emissions (grams)	8850.82	8615.56	9475.33	15070.53	18899.97	6460.40
Max. of daily household-level CO_2 emissions (grams)	35363.02	33615.49	35363.02	92596.30	92596.30	23421.19
Min. of daily household-level CO_2 emissions (grams)	150.33	150.33	1094.75	1425.62	2239.58	1425.62

The changes in CO_2 emission levels in the experimental group were an order of magnitude larger than the changes in the control group, but this change is not significant at the 5% level. According to Table 33, the experimental group has only 1.3% less CO_2 emissions than the control group in Wave 1. In Wave 2, the CO_2 emissions from the experimental group are 36.33% lower than that from the control group. While this difference is large, it is not statistically significant, possibly due to the small number of households that changed vehicle holdings.

Table 33: CO_2 emission between two groups in wave 1 and 2 for households with vehicle change across waves

	wave 1		**wave 2**	
	control	experimental	control	experimental
Number of households with usable data	21	15	21	15
Number of vehicles with usable data	37	21	31	21
Average of daily household-level CO_2 emissions (grams)	14046.10	13863.34	13824.23	8801.51
Difference: experimental-control	-182.76		-5022.72	
% Difference: (experimental-control) / control	-1.30%		-36.33%	
p-value of two-sample t-test (double-sided)	0.953		0.269	

In Table 34, the CO_2 emission levels in the control group are 1.58% lower in Wave 2 than in Wave 1; this difference is not significant. In the experimental group, the CO_2 emission levels fell by 36.51% from Wave 1 to Wave 2, and this reduction is significant at the 10% level. Note that the data in Table 34 are for households that changed vehicle holdings and, as in Table 33, the sample size is small.

Table 34: CO_2 emission between the two waves for households with vehicle changes across waves

	control		experimental	
	wave1	wave2	wave1	wave2
Number of households with usable data	21	21	15	15
Number of vehicles with usable data	37	31	21	21
Average of daily household-level CO_2 emissions (grams)	14046.10	13824.23	13863.34	8801.51
Difference: wave2-wave1	-221.87		-5061.83	
% Difference: (wave2-wave1)/wave1	-1.58%		-36.51%	
p-value of paired t-test (double-sided)	0.96		0.07	

4.4. Summary of findings in CO_2 emission patterns

The emission analysis showed that the opening of the Expo Line is associated with a reduction in household-level daily CO_2 emissions, from 12,329 to 11,449 grams for the entire study sample (experimental and control groups.) The reduction in CO_2 emissions largely comes from the households living near the Expo Line stations. The experimental group has 30.8% lower daily CO_2 emissions than the control group in Wave 2, while there is no significant difference in Wave 1. Average daily CO_2 emissions decreased by 25.6% from Wave 1 to Wave 2 for the experimental households. Those households living far from the Expo Line stations did not show significant change in their emissions level across the waves.

Similar patterns emerge when we look at the households with and without vehicle changes. Comparing the two groups of households at the same time point, there are no differences in CO_2 emissions between the two groups before the opening of the Expo Line; while the households near the Expo Line stations have smaller emissions than those far from the stations after the opening. The difference is 28.92% for the households with no vehicle changes, and 36.33% for the households with vehicle changes. Also, there are no significant changes in CO_2 emissions after the opening of the Expo Line in the households far from the stations, while there are reductions in emissions levels for those households near the stations. The reduction is 22.11% for the households with no vehicle changes and 36.51% with the households with vehicle changes.

Overall, the emissions analysis provides evidence that the Expo Line is associated with a large reduction in CO_2 emissions in the experimental group relative to the control group, on the order of a 30 to 35 percent reduction. This result appears to be driven by the changes in VMT levels documented earlier in this report.

IV. Land use characteristics of the Expo corridor

1. Land use characteristics around the Expo light rail corridor

This section reports descriptive analyses of employment and land use data. The employment data come from InfoUSA 2011, a third-party provider of commercial data. The InfoUSA data were provided by SCAG by agreement as part of related research on the Expo Line funded by SCAG. To identify employment patterns, we used a 2-digit North America Industrial Classification System (NAICS) code for a broad category of businesses. The raw land use data come from the countywide parcel-level land use data for 2008 in Los Angeles County, provided by Southern California Association of Governments (SCAG).

1.1. Employment patterns

To understand the spatial pattern of the employment, we used the geocoded location of the business establishments to map the distribution of major businesses by sector (Figure 6). The six major businesses include “accommodation and food services”, “construction”, “health care and social assistance”, “professional, scientific, and technical services”, “retail trade”, and “other services”, each of which have more than 5% share of the total business establishments in the study area.

Most businesses are clustered along the major arterials, such as Jefferson and Adams Boulevards, and Crenshaw and Western Avenues. Directly along the Expo Line, the only area that shows a visible concentration of employment is the intersection between Expo and Washington Boulevard. Many restaurants and retail businesses are clustered around Venice and Washington Boulevard, and the Expo Line passes through this busy intersection.

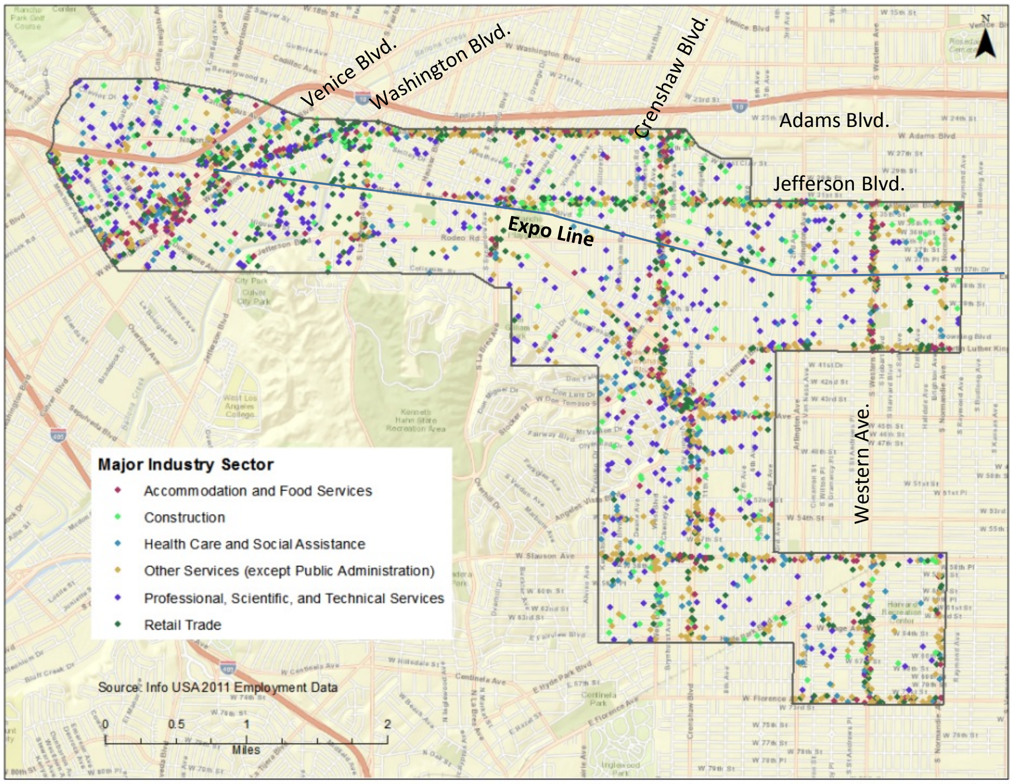


Figure 6: Distribution of major businesses by sector in the Expo study area

1.2. Land use patterns along the Expo line

The land use data come from the countywide parcel-level land use shapefile for 2008 in Los Angeles County, provided by Southern California Association of Governments (SCAG). In order to highlight the main characteristics of the land use type, we reclassified the 61 land use types into 18 groups.

Figure 7 provides an overview of the land use patterns along the Expo light rail corridor. The land use patterns also correspond to the employment patterns identified earlier. The western-most stations, which include Culver City and La Cienega/Jefferson stations, are characterized by commercial and light industrial land uses while the rest of the stations are predominantly residential neighborhoods. In particular, the Crenshaw and Western stations are occupied by single family residential use, implying that the current land use around these stations is not very supportive of transit-oriented development (TOD) strategy. Such land use patterns suggest that there is much potential for densification around these station areas. While TOD strategies are desirable in this neighborhood to promote more businesses and multi-family housing development around the station, it may cause some neighborhood change. Given that the neighborhoods around the Expo line are primarily occupied by non-white, low income population, some countermeasures to gentrification, such as provision of public housing, would be necessary.

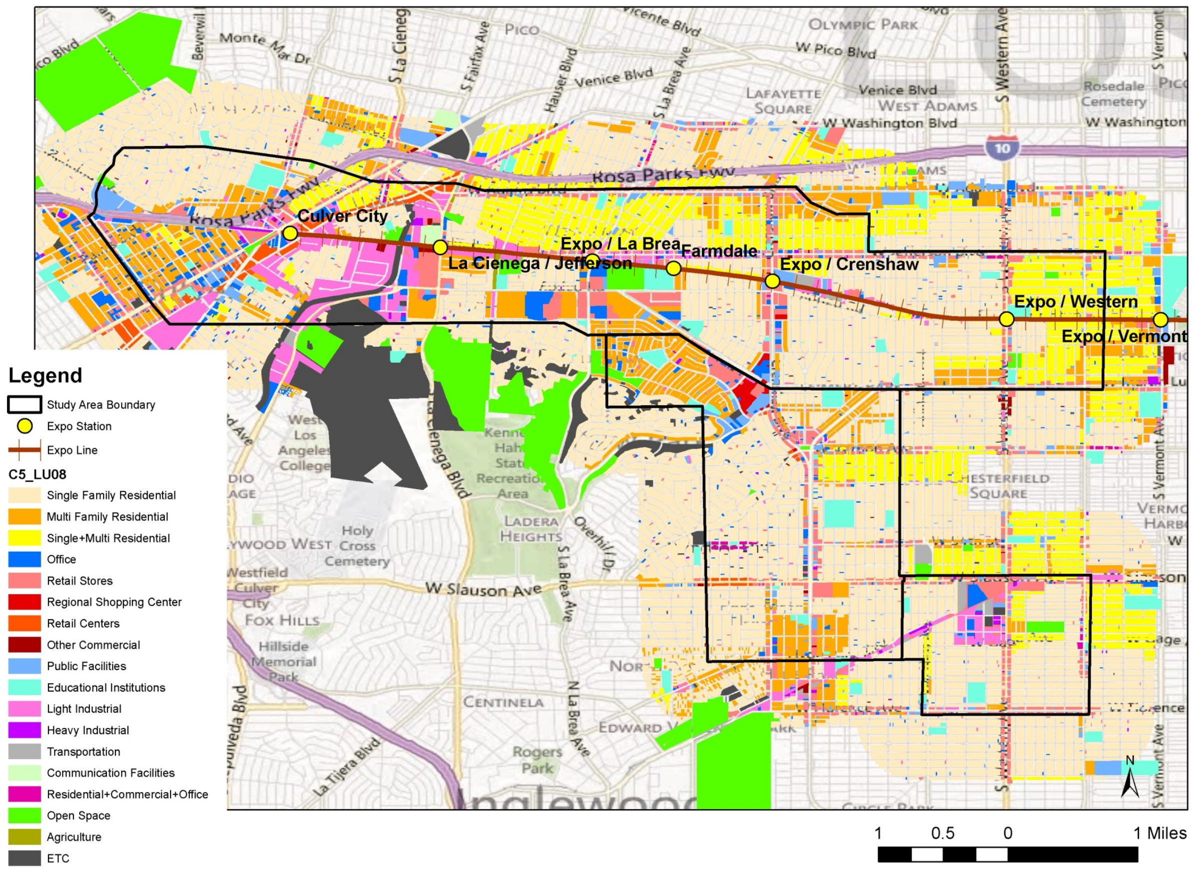


Figure 7: Land use of study area with a half-mile buffer

Figure 8 shows different types of major land uses along the Expo corridor. Residential land uses occupy more than half of the land area along the Expo corridor (Figure 8A). These uses include single-family, multi-family, and mixed residential uses. Multi-family homes (orange) are clustered near the Culver City, La Cienega, and La Brea Stations. Multi-family dwellings are located along heavily traveled regional roadways (e.g., Venice Boulevard, Crenshaw Boulevard, Martin Luther King Jr. Boulevard), while the majority of single-family dwellings (light yellow) are located off the major arterials. There is a mixture of residential uses (bright yellow) which include a combination of single family detached and multi-family dwellings. Most of these mixed residential homes are located in older neighborhoods, where duplexes, triplexes, and low-rise apartment buildings occur among single family houses.

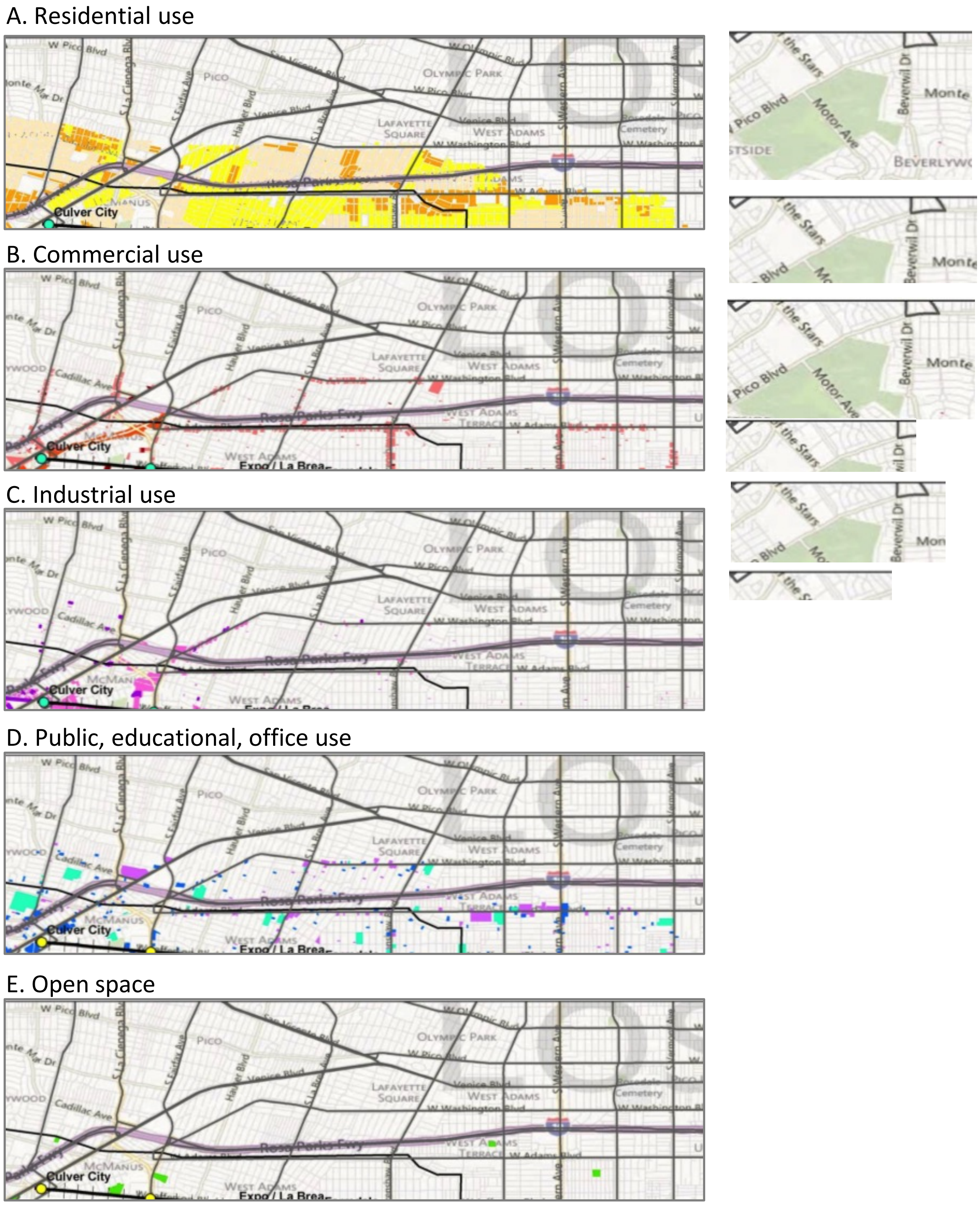


Figure 8: Major types of land uses along the Expo corridor

Commercial land uses are distributed along the heavily traveled regional roadways in the Expo corridor (Figure 8B). Most of the retail centers (orange) are located around the Culver City station. The category of retail centers includes large magnet store and strip development. These retail centers often have contiguous interconnected off-street parking areas or parking lots on the street side. The La Cienega station also has some retail stores, mostly the sale or trade of goods and services, examples of which include restaurants, convenience stores, and personal services and associated facilities and parking areas.

Light Industrial land uses (pink) occupy a small proportion along the Expo corridor, which includes manufacturing, assembly, packaging, and storage of products or materials, and other industrial services (Figure 8C). The areas adjacent to the Culver City station have a clustered zone of light industrial businesses, examples of which include motion picture and video production industries. Other industrial businesses occur together with commercial and office uses along the heavily traveled roads such as Jefferson Boulevard and Hyde Park Boulevard. Included are automobile repair shops, construction material merchant, plumbing fixtures and suppliers, and firms in packaging and storage of products. Few heavy manufacturing uses are in the Expo corridor. We speculate that this pattern is driven by the current zoning ordinances because heavy industry is usually incompatible with residential uses, predominant land uses along the Expo corridor.

Similar to industrial uses, office uses (blue) and education uses (light blue) occupy a small proportion around the station area (Figure 8D). Examples of such uses include financial, personnel, business, medical and other professional services. Educational institutions account for a small portion of land acreage in the corridor. Other educational institutions include public and private schools, seminaries, and training centers including athletic facilities. Public facilities occupy a relatively smaller land acreage than other uses, and are located around Crenshaw and Adam Boulevards.

There are little open spaces (green) along the Expo corridor (Figure 8E). Most of the large parks and open spaces are located outside of the Expo Line study area. In particular, the residences in the eastern part of the area do not have access to any large parks or public open spaces within a comfortable walking distance. If any transit-oriented development (TOD) strategies were to be pursued along the Expo corridor, there is potential to concurrently provide some green spaces around the Expo neighborhoods. Given that a typical TOD strategy includes some landscaping elements, it would be desirable to include appropriate landscape and urban design elements in the future planning process in order to provide pleasant walking environment to and from the stations.

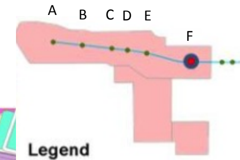
1.3. Land use characteristics around the station area

Station areas with high commercial and industrial uses

High commercial and industrial uses occupy two station areas, which are well suited for a more aggressive TOD strategy. The Culver City Station is located on Venice Boulevard, one of the City's busiest bus corridors (Figure 9A). The area closest to the station, along Venice Boulevard, is comprised of a mix of light industrial, commercial and office uses including automobile dealerships, auto repair shops, architectural firms, and retail stores.

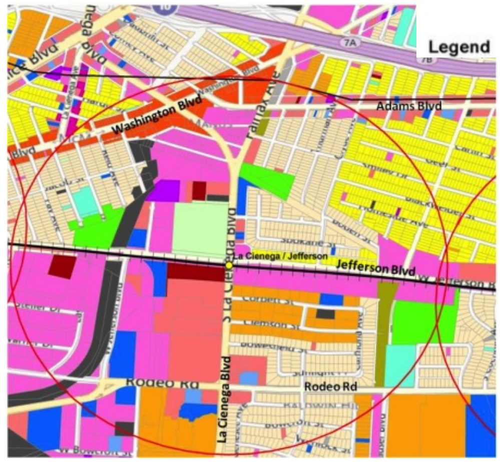
The Culver City station is close to Washington Boulevard, where many retail centers are located. Examples of these retail centers include a large magnet store with smaller retail stores and shopping centers or strip development with interconnected off-street parking. The majority of multi-family housing near the Culver City station is located along the Rosa Parks Freeway and Venice Boulevard, which are heavily traveled regional arteries. These multi-family residences are served with urban facilities such as educational institutions, offices, and public facilities.

Similarly, the La Cienega station lies within an active light industrial and commercial area, which includes uses such as motion picture industries, department stores, public storage, big-box retail and convenience stores (Figure 9B). This area has the greatest job density of any of the six western-most Expo Line Stations. With roughly 6,000 jobs within a half-mile radius of the station, there are 12 jobs per acre. The biggest employment share in the station area is confectionery retailing (See's Candies) and radio stations (KLOS, KABC), which account for about 23% of the total employment of the area. The neighborhood to the east of the station is largely single- and multi-family residential uses with retail and office uses along Adams Boulevard, and light industrial businesses along Jefferson Boulevard. Given the vibrant retail and businesses, these two station areas are well suited for more aggressive TOD strategies. However, some barriers to implementation include lack of easy pedestrian access due to elevated station designs. Lack of pleasant landscape elements around the station is another barrier that needs to be overcome in order improve walkability around the station areas.



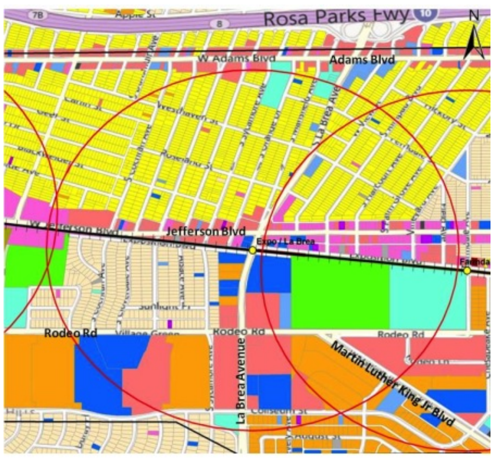
A. Culver City Station

B. La Cienega/Jefferson Station

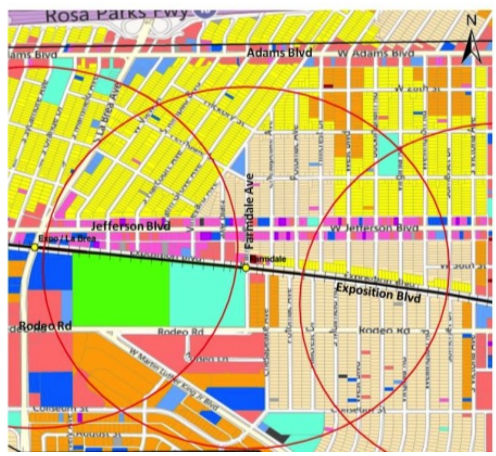


Legend

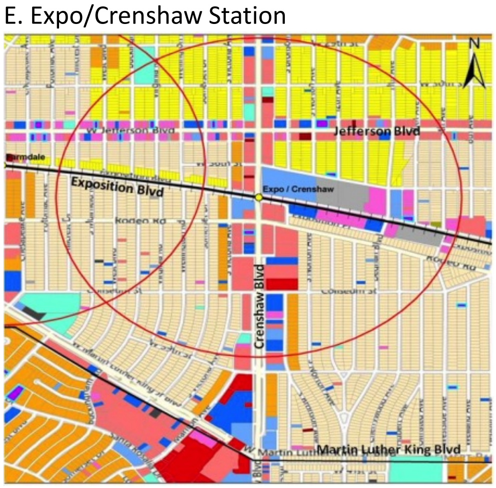
C. Expo/La Brea Station



D. Farmdale Station



E. Expo/Crenshaw Station



F. Expo/Western Station

Figure 9: Detail land uses around station area

Station areas with medium industrial and educational/open space uses

Two station areas east of La Cienega station are characterized by medium industrial and education uses with some open space, suggesting some opportunities for a TOD strategy. The La Brea station is located at the intersection of Exposition Boulevards and La Brea Avenue (Figure 9C). The neighborhood to the south of Rodeo Road is largely multi-family residential with commercial and office uses along La Brea Avenue. Exposition Boulevard has a large concentration of retail and light industrial businesses and neighborhood-serving amenities including Dorsey High School, Rancho Cienega Sports Center and public storage. North of Jefferson Boulevard is a mix of single- and multi-family residential uses with retail and public facilities along Adams Boulevard. This is an older neighborhood, where duplexes, triplexes and low-rise apartments occupy among single family houses.

Another station area with medium industrial uses is the Farmdale station (Figure 9D). That station is located at the intersection of Exposition Boulevard and Farmdale Avenue. One block to the north of the station, beyond the single-family residential uses, is Jefferson Boulevard, largely comprised of light industrial businesses, retail and office uses, such as trade contractors, supermarkets, grocery stores and restaurants. The neighborhood to the north of Jefferson Boulevard is a mix of single- and multi-family residential with retail stores and public facilities along Adams Boulevard. The neighborhood also includes multi-family homes south of Rodeo Road, and single-family homes, which are largely south of Jefferson Boulevard. The Rancho Cienega Sports Center is located adjacent to Dorsey High School, within a comfortable walking distance from the multi- and single-family homes south of Exposition Boulevard.

Station areas with low commercial and industrial uses

Compared to the four stations described above, the Crenshaw and Western stations lack adequate commercial uses to implement a TOD strategy immediately. The area directly to the south of the Crenshaw station is largely comprised of large-footprint commercial uses including big box retail stores, gasoline stations, and banks along Crenshaw Boulevard (Figure 9E). A regional shopping center, the Baldwin Hills Crenshaw Plaza, exists within three-quarters of a mile from the station. Two blocks to the north of the station is Jefferson Boulevard, with typical strip mall development, comprised of light industrial, community organizations, groceries and beauty salons. The predominant type of residential is single-family homes in the Crenshaw station area. The station area includes a mix of single- and multi-family residences north of the Jefferson Boulevard and multi-family homes a block adjacent to Crenshaw Boulevard. There are no park or public open space within a half mile of the Crenshaw station. While there are relatively few commercial uses immediately near the Crenshaw station, surface parking lots and low density development provide opportunities for up-zoning and higher density TOD development in the future. With the development of the Crenshaw light rail line, the Crenshaw station may become a ripe location for future TOD development.

The Western station lacks a critical mass of commercial activities (Figure 9F). This station area is primarily residential neighborhood. The area to the west of the station is largely comprised of single-family homes with limited multi-family parcels north of Martin Luther King Boulevard. This neighborhood also provides a number of educational institutions and public facilities, including Martin Luther King. Jr. Elementary School, Foshay Learning Center, Exposition Park Library, and Martin Luther King. Jr. Park, along Western Avenue. However, it lacks green spaces and public parks, and future TOD strategy should plans for better landscaping and provision of more open spaces around the station.

2. Street environment based on the built environment audit

2.1. The Irvine Minnesota Inventory

We used the Irvine Minnesota Inventory (IMI) to assess the built environment in the areas surrounding the six stations west of Western. The Irvine Minnesota Inventory (IMI) was designed to measure environmental characteristics that may be related to physical activity. Studies have shown that the IMI has a high inter-rater reliability (Day, Boarnet, Alfonzo, & Forsyth, 2006). The IMI is available in both full and reduced formats.

For this project, we used a reduced form of the IMI protocol for rapid assessment of the Expo line corridor. Boarnet, Forsyth, Day and Oakes (2011) offered a detailed study of the reduced format of the IMI. Using the reduced format, we audited the built environments of all the street segments within 1/8 mile radius of the six stations west of Western, including the Western station, and audited 20% of the segments in the areas between 1/8 mile and 1/4 mile of each of the six stations.[11] We selected 199 segments in total, including 117 segments within a 1/8 mile radius of the six stations, and 82 segments in areas between a 1/8 mile and a 1/4 mile radius of the six stations.

[11] Systematic sampling was used in order to get the 20% of all segments. We used Google Map and first defined the area between 1/8 mile radius and 1/4 mile radius of each station. We randomly started from a street segment and then every 5th segment was selected.

Table 35: The distribution of studied segments

Station name	Number of segments within 1/8 mile radius	Number of segments between 1/8 mile and 1/4 mile radius
Culver City	17	12
La Cienega/Jefferson	13	8
La Brea/Expo	18	12
Farmdale/Expo	21	17
Crenshaw/Expo	29	19
Western/Expo	19	14

The built environment audit was conducted by a research assistant who was trained to use the IMI before entering the field. The training included reading the codebook, studying the training protocol, reading the draft inventory and on-site field testing. Complete IMI analyses are presented in Appendix B. Each table presents items in the reduced IMI, the average score of each item on segments within 1/8 mile of each station (X_1), the average score of each item on segments between 1/8 mile and 1/4 mile of each station (X_2), and the estimated score calculated with the formula: X_3=(X_1+5* X_2)/6.

2.2. Characteristics of the built environments

Although the areas surrounding the stations have high pedestrian traffic and are ideal for commercial activities, commercial buildings were rarely present. Of the 199 segments, 169 do not have any restaurants, and many segments occupied by commercial buildings have low density land uses. Only 20 segments are characterized as having a few restaurants. Of the 199 segments, 194 do not have any coffee shops, and only one segment has "some or a lot of coffee shops". Thirty-two segments have strip malls or shopping centers.

The general maintenance of buildings on segments surrounding the stations can be characterized as neutral. Only three of the six stations have an average score slightly higher than 2 (representing neutral) in the assessment of building maintenance. The other three average station area scores for maintenance of buildings are all less than 2 (i.e. less than neutral, indicating poorly maintained buildings based on external appearance.) Only 25 out of 199 segments received a score of 3 which represents "attractive" and 110 segments had a score of 2. The average maintenance score of segments between 1/8 mile and 1/4 mile radius is higher than that of the segments within 1/8 mile radius of the stations. Buildings on segments that are close to stations are often used for industrial or commercial purposes, and they are generally not maintained as compared to residential buildings that are farther away from the stations, when assessed by views from the street. Only a few segments have buildings that contain vertical-mixed use.

Pedestrian facilities are generally installed and maintained well on the studied segments. There are curb cuts at places where pedestrian crossing is expected to occur. A score of 3 represents that all places where crossing is expected to occur have curb cuts, and the average scores of the six stations are all above 2.5 with one exception. Only 22 segments do not have any curb cuts at places where pedestrians are expected to cross streets. Sidewalks are generally complete and well maintained. Most segments have sidewalks on both sides. Some alleys or streets on which light rails are built have no sidewalks or sidewalks on one side. Of 199 segments, 185 got a score of 1 which represents the status of "moderate or good" in the assessment of the maintenance of sidewalks. The fieldwork also shows that traffic signals are provided in all major road crossings, and pedestrian activated signals are also provided in most cases. Most segments have adequate street buffers such as street parking space and planting strips between the road and sidewalks, with 166 segments having buffers in some form, which can make it safer for pedestrians to walk. The average scores of this item are very close to 1, suggesting an adequate buffer. The majority of the segments do not have mid-block crosswalks for pedestrians. Public spaces such as a playing or soccer field, plaza or square were not very often seen on the studied segments. The scores for these items are very close to 0. Only 3 segments have a playing or sport field, and 16 segments have plaza or squares, but only one of them is characterized as "attractive".

2.3. Comparison between stations

Comparisons across stations reveal some differences. Each station varies in the number of business establishments such as restaurants and coffee shops. The Culver City station and the Western stations rank as the top two in the average score of restaurants within 1/8 mile radius of the stations; the scores are 0.71 and 0.84 respectively with 2 representing "few restaurants" and 3 representing "some or a lot restaurants". The Crenshaw and the Farmdale stations have the lowest average score for the number of restaurants. The Culver City station and the La Cienega station have the highest average score for coffee shops, and interestingly, there are no coffee shops on the segments of the other four stations. The areas surrounding these stations are similar in commercial land use in the form of strip malls/rows of shops with only one exception -- there is no such commercial land use on the inventoried segments surrounding the Farmdale station. The scores for the other five stations range from 0.18 to 0.28.

The Culver City Station has four segments (13.8%) that are characterized as having few or some buildings that contain vertical-mixed use, the La Brea station has two such segments (6.7%), and the Crenshaw station has one such segment (2.1%). The other three stations do not have any segments that contain buildings with vertical-mixed use. These stations also differ in the general maintenance of the buildings on their segments. The Farmdale station has an estimated score of 1.88, which is the lowest among all stations. The La Cienega station has the highest estimated score of 2.66.

Traffic signal systems differ across stations. The Culver City station has the highest density of traffic signal systems; 82% of all segments within 1/8 mile radius provide traffic signal systems along with pedestrian activated signal systems. The incidence of traffic signal systems generally goes down from west to east with the Western station having the lowest fraction of traffic signal systems on inventoried streets. Only 42% of the segments within 1/8 mile radius provide traffic signal systems. In contrast, segments surrounding the Western/Expo station have the highest density of stop signs, while the Culver City station has the lowest density of stop signs.

2.4. Findings of the IMI analysis

We found some similarities and differences across the stations. Segments surrounding the stations are similar in sidewalk maintenance, curb cuts, building maintenance, and public spaces. Differences existed in traffic signal systems, the number of gathering places such as restaurants and coffee shops and buildings with vertical-mixed use.

Based on this field investigation, more commercial activities would be needed in the surrounding areas of the six stations. The density of commercial buildings is quite low around some stations such as the Farmdale station, although high pedestrian traffic occurs in the surrounding areas. With the completion of the second phase of the Expo Line, more commuters may use the light rail. Further increases in pedestrian traffic will create more opportunities for commercial activities. More restaurants, coffee shops, and strip malls would attract more people visiting the surrounding areas, and these "eyes on the streets" may make it more safe and pleasant for people to walk and use the transit more.

We found that sidewalks are usually complete and well maintained; traffic signals and curb cuts are generally in place; pedestrian crossings at major interactions are marked. Buildings on all major roads such as Western Avenue, Crenshaw Boulevard and Jefferson Boulevard are at times not very well maintained based on the external physical appearance, and there is at times litter on the sidewalks along these major roads. The physical environment along these roads is at times not very pleasant and sometimes looked a little dilapidated.[12] Better maintenance of these roads may be necessary to make the environment more pleasant and inviting for pedestrians and transit users, and to encourage nearby residents to engage in more physical activity around the station areas.

[12] Again, all of these assessments are judgments of the research assistant using the IMI tool, but that research assistant had been trained in the IMI assessment. That training included instruction in how to classify characteristics of the built environment using materials developed in conjunction with the IMI.

3. Station-area built environment impact on travel outcomes

3.1. Descriptive statistics of the land use variables

After completing the built environment audit, our next step was to determine whether the land use variables have an impact on travel outcomes before and after the opening of the Expo Line. We chose the land use variables that are most likely to affect travel behavior. Table 36 is the description of the four main land use variables that we entered into a land use regression model that explained before-after travel change. The first two variables pertain to the pedestrian environment, and the last two variables mostly reflect traffic environment characteristics around the station area.

Table 36: Description of the four Irvine-Minnesota Inventory (IMI) land use variables

Variable	IMI Questions	Response	Average score within 1/8 mile radius (X_1)	Average score between1/8 mile and 1/4 mile (X_2)	Final variable calculation
imi_2a_qtmi	2a. Consider the places on the segment that are intended for pedestrians to cross the street. Are these places marked for pedestrian crossing?	all = 3; some = 2; none = 0;	X1	X2	X=(X1+5X2)/6
imi_4_qtmi	4. What type of traffic/pedestrian signal(s)/system(s) is/are provided? Mark all that apply.		X1	X2	X=(X1+5X2)/6
	Pedestrian activated signal	yes = 1; no = 0			
imi_10_qtmi	10. How many vehicle lanes are there for cars? (Include turning lanes).	six or more = 6; five = 5; four = 4;three = 3; two = 2; one = 1	X1	X2	X=(X1+5X2)/6
imi_42_qtmi	42. Is there a freeway overpass/underpass connected to this segment?	under a freeway overpass =3; next to freeway = 2; IS a freeway overpass = 1; none of the above = 0	X1	X2	X=(X1+5X2)/6

In addition to these IMI variables, other land use variables were separately obtained from a GIS analysis around the stations area (Table 37). These variables mostly reflect commercial activities and the transit environment around the stations. Note that the variables related to the transit environment (lineden_qtmi, linden_hfmi) only include characteristics of bus lines around the station areas, and are defined in Table 37.

Table 37: Additional land use variables around the six Expo stations

Variable	Descriptions
lineden_qtmi	Density of bus line in a quarter mile radius
cmlupct_qtmi	Proportion of commercial land use type (code 1220, 1221, 1222, 1223, 1224, 1230, 1231, 1232 and 1233 from SCAG) in a quarter mile radius.
lineden_hfmi	Density of bus line in a half mile radius
cmlupct_hfmi	Proportion of commercial land use type (code 1220, 1221, 1222, 1223, 1224, 1230, 1231, 1232 and 1233 from SCAG) in a half mile radius.

The correlation between the IMI variables and the additional variables is shown in Table 38 and Table 39. As expected, some of the variables were highly correlated. For example, the variables indicating pedestrian crossing (imi_2a_qtmi) and pedestrian signal (imi_2a_qtmi) were highly correlated with over 95% correlation. Interestingly, connection to freeway overpass/underpass (imi_42_qtmi) was also highly correlated with pedestrian signal (imi_2a_qtmi) with over 90% correlation.

Table 38: Correlation matrix of land use variables for quarter-mile radius

	lineden_qtmi	cmlupct_qtmi	imi_2a_qtmi	imi_4_qtmi	imi_10_qtmi	imi_42_qtmi
lineden_qtmi	1					
cmlupct_qtmi	0.1127	1				
imi_2a_qtmi	0.368	0.6621	1			
imi_4_qtmi	0.3066	0.4841	0.9531	1		
imi_10_qtmi	0.0182	0.7341	0.8681	0.8652	1	
imi_42_qtmi	0.2508	0.7819	0.9035	0.7782	0.8714	1

Table 39: Correlation matrix of land use variables for half-mile radius

	lineden_hfmi	cmlupct_hfmi
lineden_hfmi	1	
cmlupct_hfmi	0.2746	1

Each household was assigned the IMI or land use variables (as shown in Table 36 and Table 37) for the nearest station to their residence. Table 40 shows the descriptive statistics of the land use variables for the experimental households. No major patterns emerged from the descriptive statistics. The standard deviations are mostly smaller than the mean values, except for the freeway connection variable (imi_42_qtmi). This suggests that there is high variation in the number of freeway connections across the station areas. Most station areas are not directly connected to freeways, therefore, no freeway overpass or underpass may be present in most study area. However, the Culver City station area intersects a freeway, possibly increasing the number of freeway connections only in this area, and thus driving up the standard deviation.

Table 40: Descriptive statistics of station-specific land use characteristics – experimental households only

Variable	Obs	Mean	Std. Dev.	Min	Max
lineden_qtmi	211	0.103	0.022	0.048	0.127
cmlupct_qtmi	211	0.164	0.060	0.070	0.233
imi_2a_qtmi	211	0.962	0.500	0.390	1.630
imi_4_qtmi	211	0.370	0.157	0.080	0.550
imi_10_qtmi	211	2.725	0.532	1.980	3.410
imi_42_qtmi	211	0.144	0.214	0.000	0.460
lineden_hfmi	211	0.065	0.012	0.052	0.082
cmlupct_hfmi	211	0.102	0.029	0.044	0.141

3.2. Results of the land use regression analysis

Using the land use variables, we conducted a regression analysis to examine whether the built environment characteristics have any impact on household travel behavior before and after the opening of the Expo Line. Table 41 is the result of the Tobit regression of household VMT using a difference-in-difference approach as in Section III. We used a Tobit regression left-censored at 0 in order to account for zero observations for VMT in the sample. In addition, we used clustered standard errors to adjust for the possibility of correlated errors within the groups because the same land use variables were applied to the households in the same station area. In the table, each column represents the effect of each land use variable interacted with the treatment effect of the Expo Line (land use variables x experimental effect x time effect).[13]

[13] For example, the interaction for lineden_qtmi and the experimental and Wave 2 dummy variables is lineden_qtmi_exp_wv, and similar for the other interaction terms.

Table 41: DID Tobit Regression (left-censored with 0) of household daily average VMT with clustered SEs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	vmt	vmt	vmt	vmt	vmt	vmt	vmt	vmt
experiment	2.623	2.623	2.623	2.623	2.623	2.623	2.622	2.623
	(3.053)	(3.053)	(3.053)	(3.053)	(3.053)	(3.053)	(3.053)	(3.053)
wave	4.832***	4.832***	4.832***	4.832***	4.832***	4.832***	4.832***	4.832***
	(1.335)	(1.335)	(1.335)	(1.335)	(1.335)	(1.335)	(1.335)	(1.334)
wavexp	-0.117	-16.650*	-12.760*	-13.753*	-19.252	-12.689***	-26.118***	-19.655
	(7.262)	(6.942)	(5.417)	(5.728)	(11.019)	(3.153)	(7.098)	(10.366)
lineden_qtmi_exp_wv	-128.509*							
	(63.783)							
cmlupct_qtmi_exp_wv		20.566						
		(41.279)						
imi_2a_qtmi_exp_wv			-0.487					
			(3.955)					
imi_4_qtmi_exp_wv				1.405				
				(12.043)				
imi_10_qtmi_exp_wv					2.196			
					(4.236)			
imi_42_qtmi_exp_wv						-3.698		
						(6.097)		
lineden_hfmi_exp_wv							198.264	
							(124.567)	
cmlupct_hfmi_exp_wv								62.410
								(90.444)
_cons	24.582***	24.580***	24.580***	24.580***	24.580***	24.581***	24.583***	24.582***
	(0.130)	(0.130)	(0.130)	(0.130)	(0.130)	(0.131)	(0.130)	(0.128)
sigma								
_cons	32.154***	32.170***	32.167***	32.167***	32.168***	32.163***	32.142***	32.153***
	(1.096)	(1.093)	(1.096)	(1.092)	(1.093)	(1.100)	(1.090)	(1.072)
N	397	397	397	397	397	397	397	397

Standard errors in parentheses
Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

All models show a negative treatment effect on VMT (wave x experimental, or wavexp), and they are statistically significant in most regressions, except models (1), (5), and (8). In terms of the land use effect, only model (1) shows significant effect of bus line density in a quarter mile radius of the Expo stations (lineden_qtmi_exp_wv). The coefficient is rather large, suggesting that for each additional bus line density within the quarter mile radius, average daily household VMT drops by as much as 129 miles per day. A similar effect size is observed with the same variable measured within a half-mile boundary, but it is not statistically significant (Column 7 in Table 41). In model (1), it is interesting to note that when the bus line density variable becomes significant, the treatment effect diminishes to almost zero with little statistical significance. It is possible that the bus line density either absorbs or moderates the treatment effect of the Expo Line on household VMT.

In addition to the household VMT, we ran another regression with average daily household train trips. We used the same specification and analysis strategies from the previous model (Tobit regression with a clustered standard error). Table 42 shows the result of this new model using train trips as the dependent variable. Models (2), (3), (5), and (6) have significant treatment effects. The bus line density within a quarter mile boundary has a significant positive effect on train trips. Each additional bus line within the quarter-mile around a station increases daily train trip frequency by almost 20 trips. Similar to the previous model, this bus line variable appears to absorb or moderates the treatment effect of the Expo Line.

Table 42: DID Tobit Regression (left-censored with 0) of household train trips with clustered SEs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	train	train	train	train	train	train	train	train
experiment	0.152	0.153	0.153	0.153	0.152	0.153	0.153	0.153
	(0.424)	(0.428)	(0.429)	(0.429)	(0.426)	(0.428)	(0.428)	(0.430)
wave	0.196***	0.196***	0.196***	0.196***	0.196***	0.196***	0.196***	0.196***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
wavexp	-1.118	1.492**	1.027*	1.055	2.314***	1.093***	0.080	0.269
	(0.838)	(0.451)	(0.464)	(0.538)	(0.415)	(0.268)	(1.462)	(1.285)
lineden_qtmi_exp_wv	19.960**							
	(6.552)							
cmlupct_qtmi_exp_wv		-3.044						
		(2.459)						
imi_2a_qtmi_exp_wv			-0.023					
			(0.323)					
imi_4_qtmi_exp_wv				-0.136				
				(0.921)				
imi_10_qtmi_exp_wv					-0.489**			
					(0.189)			
imi_42_qtmi_exp_wv						-0.665		
						(0.694)		
lineden_hfmi_exp_wv							14.069	
							(17.795)	
cmlupct_hfmi_exp_wv								7.033
								(9.425)
_cons	-2.261***	-2.290***	-2.300***	-2.299***	-2.274***	-2.291***	-2.292***	-2.302***
	(0.241)	(0.250)	(0.249)	(0.247)	(0.245)	(0.253)	(0.260)	(0.251)
sigma								
_cons	1.641***	1.662***	1.668***	1.668***	1.650***	1.662***	1.663***	1.669***
	(0.165)	(0.171)	(0.170)	(0.169)	(0.168)	(0.173)	(0.178)	(0.172)
N	408	408	408	408	408	408	408	408

Standard errors in parentheses

Significance codes: *** 0.001, ** 0.01, * 0.05, ° 0.10

Another significant land use variable in this model is the number of vehicle lanes within a quarter-mile boundary. For every additional two unit increase in the vehicle lane variable within a quarter mile (imi_10_qtmi), train trips decreases by almost one trip. The significant and negative effect of this variable suggests that presence of more vehicle lanes has a negative effect on train trips, possibly reflecting barriers to accessing the station across broad streets.

3.3. Findings of the built environment analysis

The purpose of the analysis in Table 41 and Table 42 is to examine whether characteristics of the built environment, as measured by the IMI and land use variables, moderate the effect of the Expo Line on travel. We found evidence that bus lines and wide streets moderate the Expo Line's "treatment effect." A higher density of bus lines increases the amount that the Expo Line reduces VMT and increases the amount that the Expo Line increases rail travel among households within a half mile of the stations. While this sounds complex, the meaning can be restated more simply. The Expo Line was more effective at shifting travel from driving to rail ridership near stations with more bus service (measured by the number of lines) and narrower streets (measured by the number of street lanes.) This is evidence that the built environment affects the functionality of rail transit lines. Wide streets that impair pedestrian traffic and lower levels of bus line service reduce the impacts of the Expo Line among the experimental households.

V. Summary of the results

In Southern California, AB 32 and SB 375 provides policy framework for pushing the transit agenda. One goal of implementing transit projects is to change people's travel behavior from automobile to transit. Such behavior change can lead to reduction in VMT and traffic-related emissions while contributing to neighborhood health by promoting active forms of transport. With this broad policy framework, our study investigated whether the new Expo Light Rail project generated the anticipated environmental and health benefits at the neighborhood level. Based on our longitudinal study looking at the neighborhood along the Expo corridor, we found evidence that the Expo Line influenced travel behavior and physical activity.

1. Changes and impacts on travel

First, the Expo Line intervention has a significant and immediate impact on vehicle travel. Our analysis indicates that 4-6 months after opening the Expo Line has a significant impact on the travel behavior of our sample households. In particular, households in the experimental group, which lie within ½ mile of an Expo Line station, reduced their daily household VMT by approximately 10 miles per day compared to the control households that were located more than ½ mile away from a station. Rail ridership increased, and in some specifications that effect was statistically significant.

Although comparisons of daily mean walk and bicycle trips indicate some increase among the experimental households, those changes were not statistically significant. The sampled individuals near the Expo Line that were least physically active had increases in physical activity relative to the control group that were statistically significant. Those individuals in the experimental group were roughly at the bottom 36th to 46th percentile in terms of their baseline (before opening) physical activity level.

Our analysis indicates that opening the Expo Line had a significant impact on average daily CO_2 emissions from motor vehicles. The CO_2 emissions of households who reside within ½ mile of an Expo Station was 38.8% smaller than those living more than ½ mile from a station after the opening of the light rail. We found consistent results even when we confined our analysis to the households who did not change their vehicle holdings before-after the Expo Line opening, suggesting that the CO_2 emission reduction resulted from travel behavior change near the new light rail line.

2. Land use and street environment along the Expo light rail corridor

This project focused on examining travel behavior associated with land uses and street environments adjacent to the Expo light rail stations and corridors. Our analysis suggests that there is some TOD potential based on the existing employment and land use patterns. Geographically, businesses are concentrated near Culver City, south of Interstate 10, and along major arterials including Crenshaw. The land use patterns also correspond to the employment patterns. The western-most stations including Culver City and La Cienega stations are characterized by commercial and light industrial land uses, implying that the current land uses around these stations are major trip generators that could leverage the development potential of TOD. On the other hand, the rest of the stations are predominantly residential neighborhoods. In particular, single family residential land uses occupy a large proportion of the areas in the vicinity of the Crenshaw and Western stations, suggesting that there is a capacity for future development and land use change around these station areas.

To further understand the built environment features that may be associated with physical activity and particularly walking, we used a reduced form of Irvine Minnesota Inventory. Through this inventory, we found that pedestrian facilities (i.e., sidewalk, curb cuts, and traffic signals) surrounding the station areas are generally well maintained. However, many buildings on the major arterials including Western, Crenshaw, and Jefferson Boulevard were not in good condition, potentially creating unpleasant walking environments. We also found that the majority of the station areas did not have parks or open space within a comfortable walking distance. In particular, the eastern most station areas lack adequate gathering places such as restaurants and coffee shops. This result is consistent with the employment and land-use data that show a lack of commercial activities in these areas, implying that further improvement needs to be made in order to promote development and innovation in the local economy, a key factor of successful TOD implementation.

Lastly, we conducted a regression analysis using the land use variables obtained through the Irvine Minnesota Inventory. Our intention was to examine whether the additional land use variables strengthen or moderate the treatment effect of Expo Line. The regression results suggest that some treatment effects remained strong after controlling for different land use interaction terms. Bus line density and the number of vehicle lanes in a quarter-mile boundary of Expo stations have significant interaction effects. These land use effects imply that light rail investment can potentially have larger impact on travel behavior if pursued with an appropriate bundle of land use strategies, some of which may include convenient connection to bus service and reduction of barriers (e.g. large multi-lane streets) that may impede pedestrian access to stations.

3. Future Research Directions

The objective of the Expo Line Study was to conduct the first ever longitudinal, experimental-control group, before-after study of the impact of a major transportation investment in California. This approach represents a significant methodological improvement over previous research. However, there are still challenges remaining. Our current models deal with a short-term impact of a new light rail system on change in travel behavior and physical activity. It may take longer for people to fundamentally change the way they travel or modify their daily physical activity patterns. Partly for that reason, we are continuing this longitudinal study with funds from the California Air Resources Board, monitoring households in fall of 2013.

The results of this study help illuminate how the Expo light rail line is associated with changes in VMT, travel behavior, physical activity, and traffic-related CO_2 emissions in ways that can enhance the quality of life for residents along the Expo line. Beyond the Expo line itself, the Expo study paves the way for developing innovative techniques for neighborhood-level program evaluation. Such innovative studies are essential for Los Angeles and California to guide further implementation of bottom-up, neighborhood based transportation investments aimed at enhancing local quality of life while meeting state-mandated environmental goals.

For future study, there remain other potential areas for evaluation of the Expo light rail intervention. For example, it is uncertain whether the Expo line's opening have generated economic benefits such as an increase in land and housing values or commercial activities around the Expo Line corridor. Further, changes in travel behavior and physical activity may also influence other quality-of-life issues, such as employment access, physical safety (traffic volume and speed, air pollution), personal safety (crime), socializing (social capital and neighborhood cohesion), and the overall welfare of nearby residents. Although it is challenging to include all these dimensions in an evaluation, further efforts need to be made to understand the impact of the new Expo line in order to lead a successful TOD intervention, which is increasingly gaining momentum in the greater Los Angeles region.

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Appendix A: List of households that changed vehicle holdings

HHID	group	wave 1 vehicle count	wave 1 people count over 12	wave 1 daily average VMT	wave 1 vehicles	wave 2 vehicle count	wave 2 people count over 12	wave 2 daily average VMT	wave 2 vehicles
111A	control	2	2	30.7	1985 Honda Accord; 1992 Ford Crown Victoria	1	1	8.3	1995 Honda Accord
332A	control	2	2	38.9	2001 Ford ExplorerSport Trac; 2009 Toyota Prius	2	2	24.6	2007 Mercedes-Benz S550; 2009 Toyota Prius
359F	control	2	4	40.8	2008 Ford Fusion; 2005 Nissan Sentra	1	4	51.3	2008 Ford Fusion
35B2	control	2	2	83.1	2008 Toyota Camry Hybrid; 2009 Toyota Prius	2	2	17.7	2009 Toyota Corolla; 2009 Toyota Prius
35C5	control	2	2	32.7	2009 Toyota Camry; 2003 Ford Taurus	2	2	19.3	2009 Toyota Camry; 2006 Toyota Corolla
4677	control	3	2	38.4	2004 Honda Accord; 2011 Toyota RAV4; 2003 Vespa ET4	3	2	47.4	2013 Mini Cooper S; 2010 Toyota Rav 4; 2003 Vespa ET-4
90C6	control	2	2	66.7	2004 Hyundai Elantra; 2007 Ford Fusion	1	2	37.4	2007 Ford Fusion
90fa	control	2	1	43.5	1994 Mazda Miata; 2000 Isuzu Rodeo	1	1	44.4	1994 Mazda Miata
92C3	control	3	1	66.4	2006 Volkswagen Mini Cooper; 2001 Chevrolet Monte Carlo; 1999 Lexus RX300	2	3	39.3	1999 Lexus RX 300; 2001 Chevrolet Monte Carlo
934F	control	2	5	36.0	2002 Nissan Sentra; 1985 Ford Crown Victoria	1	5	22.1	2001 Nissan Sentra
93D1	control	3	4	73.9	1999 Porsche Boxter; 2005 Chevrolet Trail Blazer; 1973 Volkswagen S-Beetle	1	1	21.1	1999 Porsche Boxter
c179	control	1	2	23.4	2004 Ford Focus	2	2	32.0	2010 Volkswagen Beatle; 2011 Nissan Versa
C36C	control	1	1	9.1	2000 Honda Civic	1	1	14.4	2012 Honda Fit
D152	control	1	3	23.9	2008 Ford Fusion	1	3	22.3	2010 Dodge Journey
D872	control	1	1	7.3	1991 Honda Accord	1	1	8.1	2012 Honda Civic
DA98	control	1	1	35.0	2002 Hyundai Accent	1	1	12.1	2004 Hyundai Accent
DC2A	control	1	1	0.4	1986 Nissan Pick up	1	1	6.3	2001 Ford Ranger
DCE9	control	2	3	44.6	2004 Nissan Maxima; 1999 Toyota Forerunner	2	3	44.1	2005 Nissan Maxima; 1999 Toyota Forrunner
E2A6	control	1	1	4.3	1983 Mercedes-Benz 240D	1	1	57.7	2010 Dodge Avenger
E7AD	control	2	2	70.6	2009 Toyota Prius; 2006 For Focus	1	1	29.3	2009 Toyota Prius
F08E	control	1	1	25.3	2009 Kia Sportage	3	1	218.0	2009 Kia Sportage; 1989 Meredez-Benz

									260C
41B9	exp	2	2	46.3	2004 Toyota Camry; 2007 Toyota Scion TX	1	1	6.6	2004 Toyota Camry
4387	exp	1	1	38.1	2005 Land Rover LR3	1	1	16.9	2006 Land Rover LR3
45D4	exp	3	4	85.7	2009 Ford Fusion; 2002 Hyundai Accent; 2002 Pontiac Grand Prix	2	3	35.9	2003 Subaru Forester; 2002 Pontiac Grand Prix
498F	exp	2	2	46.0	2009 Volkswagen Jetta; 2004 Volvo 560	2	2	42.6	2002 Hyundai Sonata; 2012 Volkswagen GTI
4DD4	exp	1	2	17.4	2001 Nissan Sentra	2	2	13.3	2001 Nissan Sentra; 2002 Suzuki Bandit
5089	exp	1	2	2.9	1992 Toyota Corolla	1	2	4.0	1993 Toyota Corolla
50FA	exp	2	2	24.1	2000 Ford Focus; 1999 Subaru Outback	2	2	17.0	1996 Volvo 850
A149	exp	1	2	25.2	2008 Chrysler PT Cruiser	2	2	63.8	2008 Chrysler PT Cruiser; 2005 Nissan Altima
A8F6	exp	1	1	17.6	2003 Lincoln Aviator	1	1	11.1	2008 Ford Edge
AA8B	exp	1	2	43.7	2010 Hyundai Elantra	1	2	58.4	2011 Toyota Corolla
ac9d	exp	2	2	96.0	2005 Scion XA; 2006 Scion XA	1	1	14.6	2006 Scion XA
AD64	exp	1	2	39.1	2002 Volkswagen Jetta	2	2	32.6	2008 Honda NPS 50 Ruckus
B22D	exp	1	1	9.7	2005 Hyundai Elantra	1	1	8.3	1995 Hyundai Elantra
B2B3	exp	1	2	37.4	2009 Volkswagen Passat CC	1	2	47.0	2012 Volkswagen Passat SE
B873	exp	1	2	21.1	2007 Pontiac Bonneville	1	2	8.6	2005 Pontiac Bonneville