



Connecting Sacramento: A Trip-Making and Accessibility Study

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Contents

Introduction.....	1
Study area.....	1
Traffic analysis zones and transit catchment areas	1
Jobs, households, and demographic data	2
LRT ridership.....	7
Data, metrics, and methods	8
Accessibility metrics	8
Access to jobs by transit	8
Station area accessibility.....	9
Station utility	10
Potential utility improvement.....	10
Impact score	11
Trip-making data.....	12
Teralytics.....	13
StreetLight Data	13
Analysis.....	14
Station area prioritization.....	14
Accessibility impacts	14
Zinfandel station	16
Swanston station	17
Meadowview station	18
Trip generation and mode share.....	18
Priority areas by trip generation.....	23
Priority areas by LRT mode share	29
Case studies.....	31
Swanston Station.....	31
City College Station.....	39
Stockton Boulevard bus corridor	43
Multi-modal trip-making around stations	48
Hazel station	48
Zinfandel and Cordova Town Center stations	50
Royal Oaks and Swanston stations	53
Automobile trips from LRT stations	57
I-80 stations.....	58
Historic Folsom station	59
Glenn station	60
Iron Point station.....	61
Florin station	62
Meadowview station	63
Equity analysis	64
Appendix A. Geographic relationships	A-1
Appendix B. Teralytics validation	B-1
Appendix C. StreetLight Data validation.....	C-1

Introduction

Conventional data and metrics rarely paint a complete picture of how a transportation system serves its communities and sometimes point toward decisions that don't necessarily lead us to our desired outcomes. For example, we might measure or observe traffic delay and subsequently add highway capacity to move cars more efficiently, but this may not significantly improve people's ability to get where they need to. We might measure transit system performance in terms of on-time arrivals or operation costs, without fully understanding how well the transit system meets people's daily travel needs.

In many cases, our ability to make informed decisions is limited by the information that is available to us. However, newer data sources and more advanced analytic tools can potentially change that drastically. This study incorporates a variety of new tools and data sources to understand how they can inform smarter transportation investments and more impactful improvements – particularly related to improving people's access to existing transit and increasing transit ridership.

The two main focuses of this study are: 1) accessibility metrics, which quantify people's ability to reach destinations, and 2) big data from mobile phone and GPS-enabled devices, which let us observe people's travel patterns. Using these technologies, this report identifies locations with poor connections to existing transit, explains people's travel behavior in those places, evaluates possible improvements at key locations, and quantifies the potential impacts.

The findings described in this report are meant to help guide decision-makers in the Sacramento area regarding specific opportunities there and to guide the general transportation community in how these emerging technologies can best be used.

Study area

Sacramento's light rail transit system is the principal focus of this study. However, at the study's kick-off meeting, local stakeholders also showed a strong interest in the Stockton Boulevard bus corridor, the busiest corridor in the city and one that has long been considered for bus rapid transit service. Therefore, this study focuses on the city's two radial light rail lines (the Blue and Gold lines) and Stockton Boulevard.

Traffic analysis zones and transit catchment areas

For this work, the study area is divided into 250 traffic analysis zones (TAZs), a limit established through our data purchases. These zones, developed specifically for this study, are organized as follows:

- Census geographies (blocks, block groups, and tracts) form the rough basis of zones.
- Zones near transit corridors are more granular; zones farther from transit corridors are more general.
- Zones are designated around LRT parking lots.
- Zone boundaries are often designated along physical barriers (e.g., rail lines).
- Zone boundaries are often designated along distinct changes in land use (e.g., retail versus residential).

- Zone boundaries form an approximate 0.25-mile buffer along Stockton Boulevard, representing a bus catchment area.

For many of the analyses in this study, transit catchment areas are defined using the predefined TAZs. These six catchment areas, including the Downtown and Downtown South – an area served by both the Gold Line and the Stockton Boulevard bus line – are pictured in Figure 1.

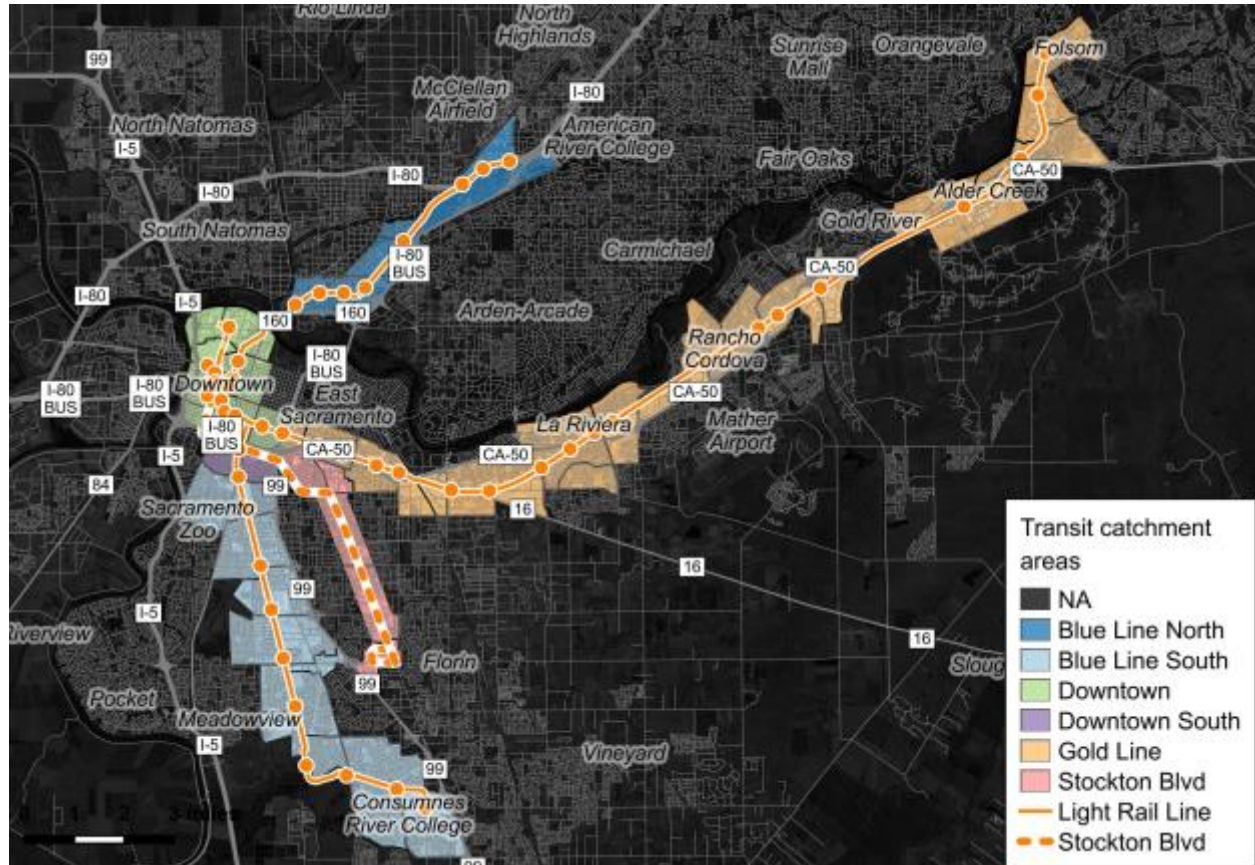


Figure 1. Transit catchment areas

Jobs, households, and demographic data

The U.S. Census provides data on jobs in the LEHD Origin-Destination Employment Statistics (2014) and data on households in the American Community Survey (2011-2015). Jobs data are provided at the block level and aggregated to the block group level. Household data are provided at the block group level. These data are reallocated to TAZs and other large areas based on the methods described in Appendix 1.

The distribution of households and jobs are depicted in Figure 2 and Figure 3, respectively.

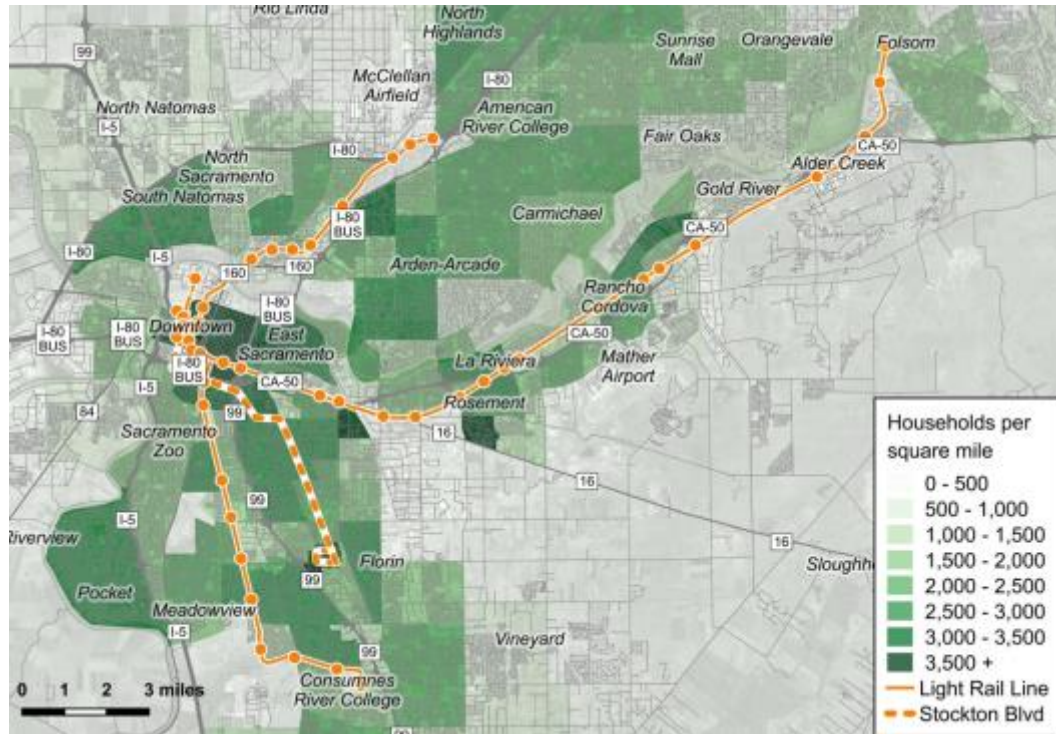


Figure 2. Households per square mile (2015, five-year average)

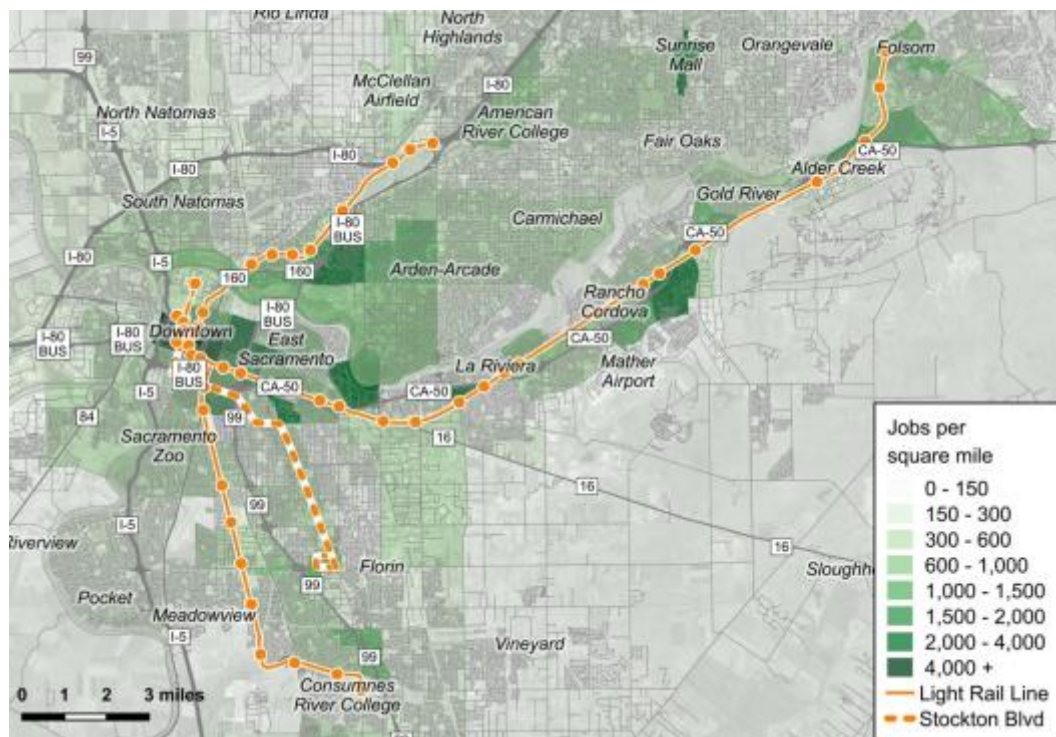


Figure 3. Jobs per square mile (2014 estimates)

Demographic information for the entire study area is shown in Figure 4 through Figure 8, along with summaries for each study corridor shown in Table 1.

Table 1. Demographic information by study area (2015, five-year average)

Study area	Median income	Household ownership rate	Median age (adults)	Children per adult	Vehicles per household
Downtown	\$37,500	11%	37	0.08	1.0
Downtown South	\$87,500	57%	42	0.20	1.5
Blue Line (North)	\$27,500	41%	47	0.30	1.5
Blue Line (South)	\$42,500	51%	42	0.40	1.7
Gold Line (East)	\$55,000	56%	42	0.27	1.7
Stockton Blvd (SE)	\$27,500	37%	42	0.34	1.4
All transit corridors	\$47,500	45%	42	0.30	1.6
Entire study area	\$67,500	56%	47	0.30	1.8

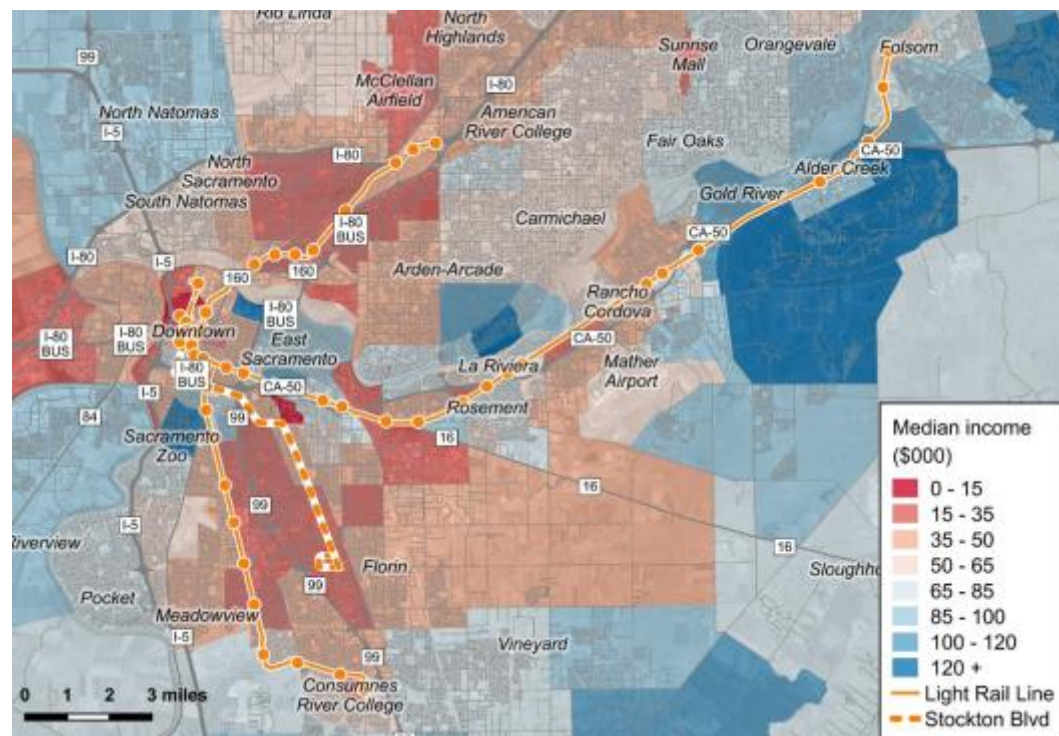


Figure 4. Median household income (2015, five-year average)

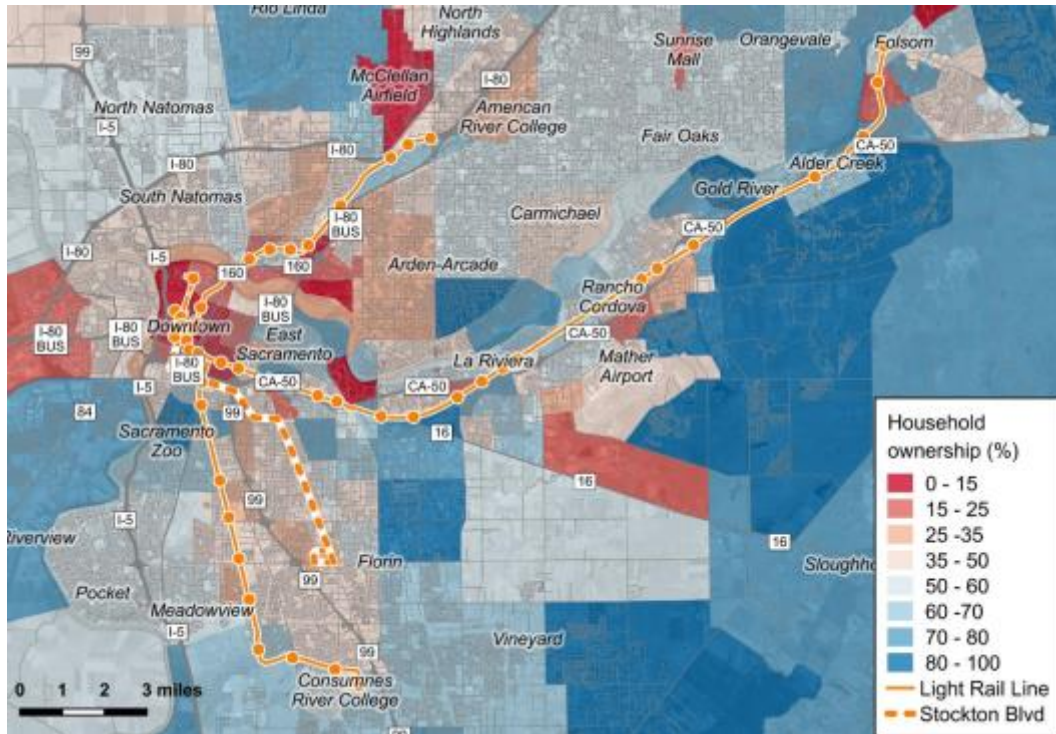


Figure 5. Household ownership rates (2015, five-year average)

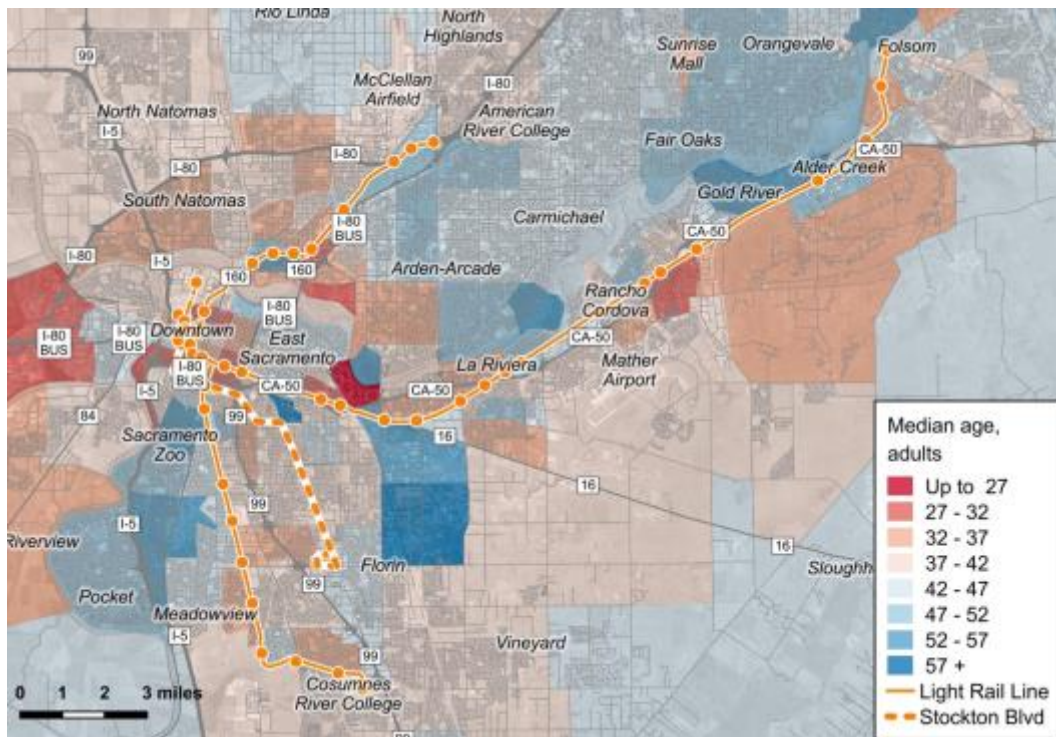
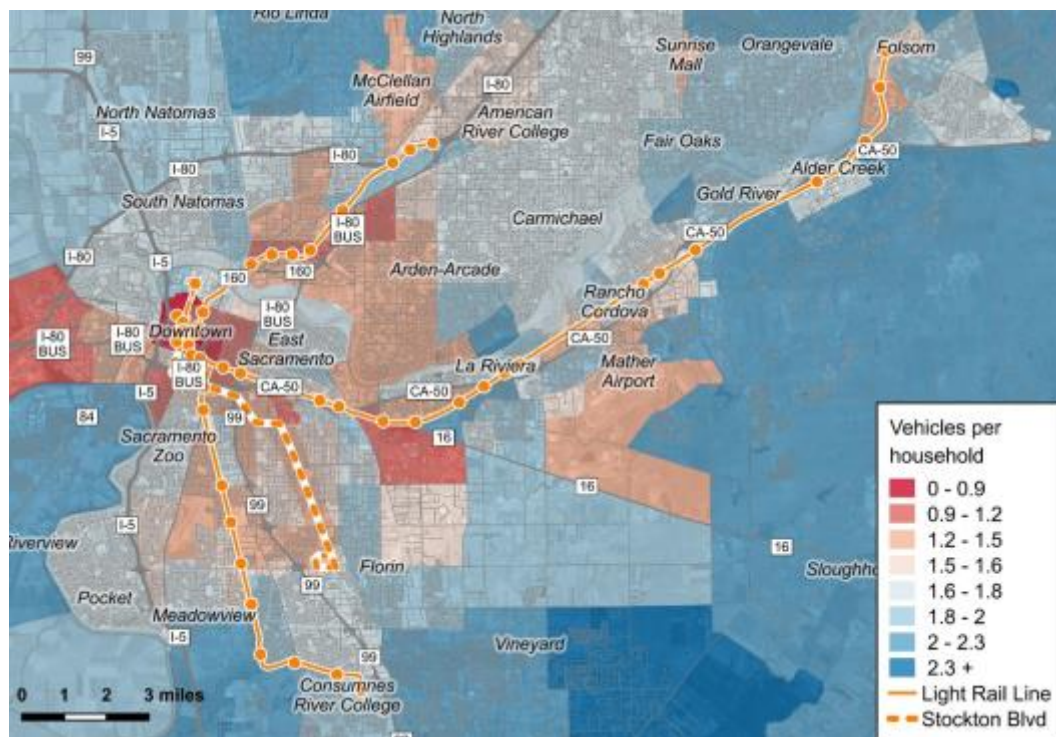
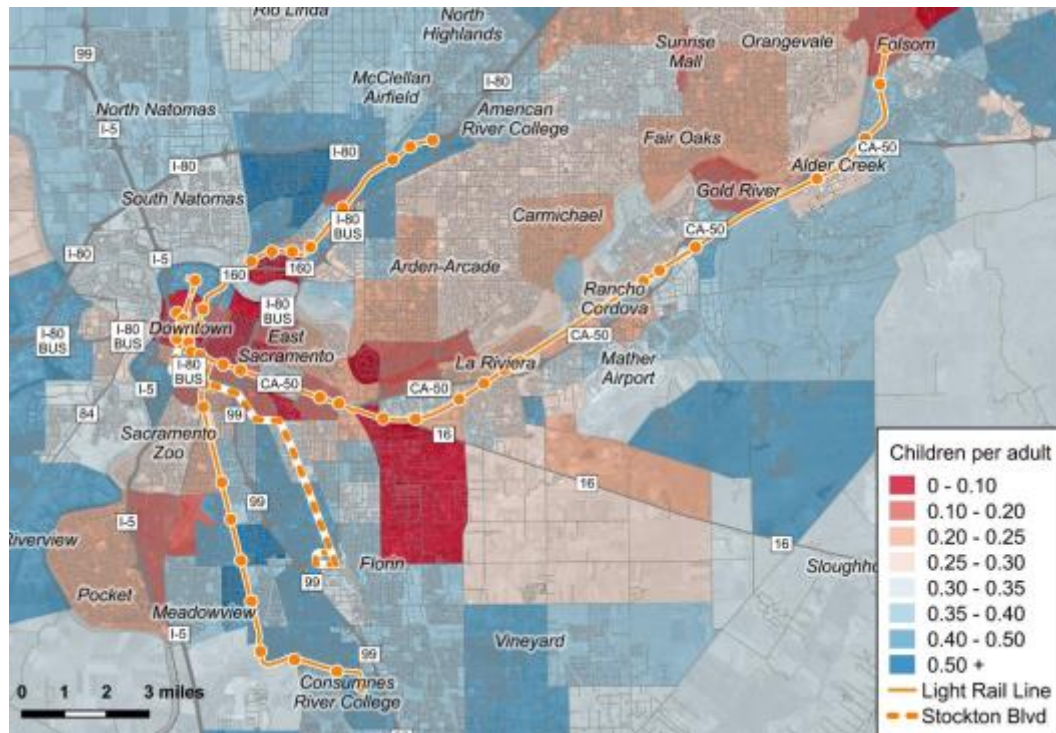


Figure 6. Median age for those ages 18 and older (2015, five-year average)



LRT ridership

This section provides an overview of ridership along the light rail system, based on data provided by Regional Transit.

During a typical weekday, there are approximately 44,100 system-wide boardings with roughly 38 percent of all boardings and alightings in the Downtown. The Gold Line accounts for 27 percent of riders; the Blue Line south accounts for 22 percent; and the Blue Line north accounts for only 13 percent.

The busiest station outside of the Downtown is Meadowview on the Blue Line south, with 3,700 boardings and alightings each weekday. At the beginning of the study period, Meadowview was the Blue Line's southernmost station; an extension opened in August 2015. The next busiest stations are Watt/I-80 (the northernmost station on the Blue Line) with 3,600 boardings and alightings, and Matherfield/Mills on the Gold Line, with 3,400 boardings and alightings. Figure 9 depicts the number of daily boardings throughout the system.

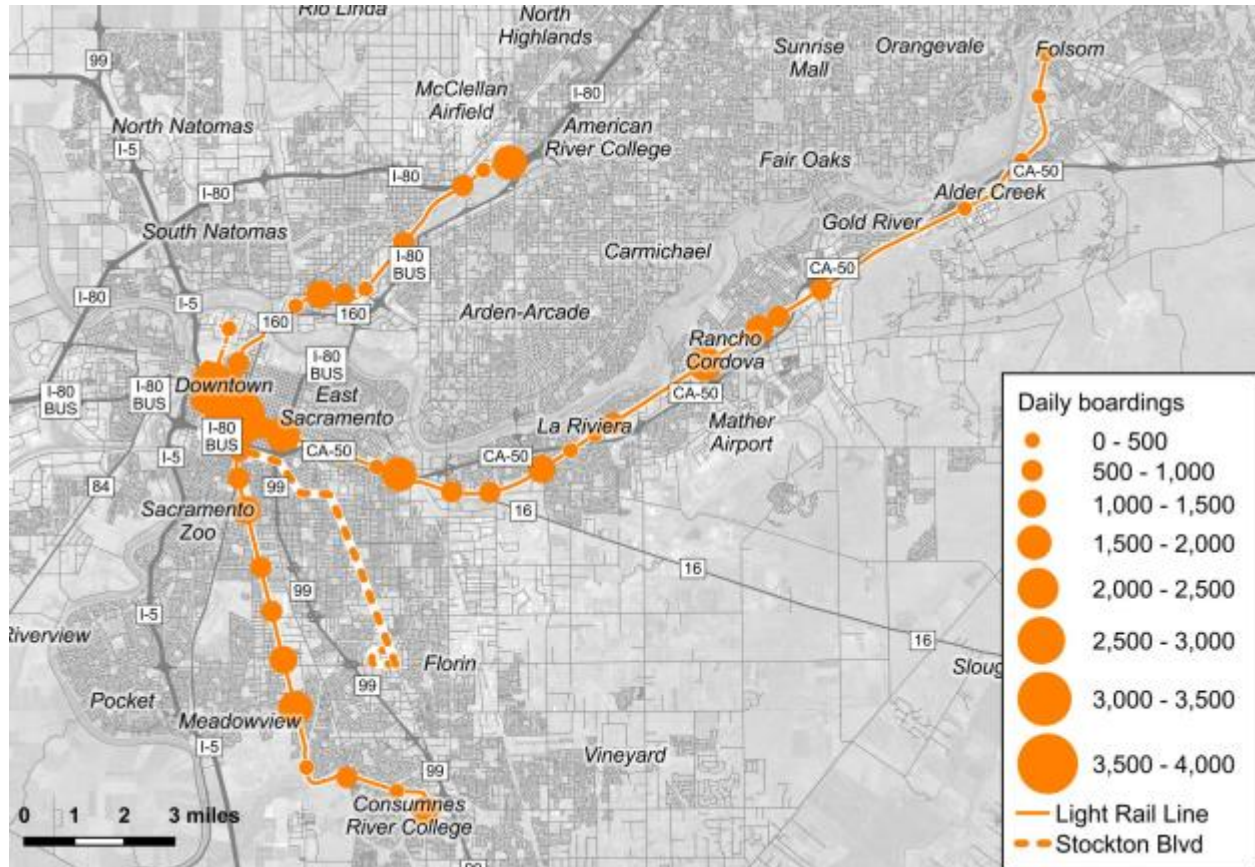


Figure 9. Average weekday boardings (2015, while in operation)

Data, metrics, and methods

Accessibility metrics

Accessibility metrics are an essential focus of this study. Accessibility represents the ease of reaching meaningful destinations by different modes, given the available transportation networks and land use configurations. In this case, it is measured in terms of travel time (and travel time-based utility). Accessibility calculations are made using Sugar Access software and data, provided by Citilabs.

Accessibility can represent access to a variety of destination types including jobs, stores, restaurants, services, schools, and public spaces. This study relies on access to jobs by transit – a commonly used accessibility metric – as a primary metric of transit accessibility. This metric includes the time needed to walk to transit stations from a given location, so we also consider access to stations by walking as a subset of transit accessibility and a key measure of last-mile connections to transit.

Access to jobs by transit

To gauge the variations in transit accessibility throughout our study area we measure access to jobs by light rail and bus transit in the morning period (7-10 AM). The reported number represents the number of jobs that are reachable from a given location. In this case, the reported number of jobs is decay-weighted, meaning that nearby jobs are assigned more utility than jobs further away, based on decay functions derived from the 2009 National Household Travel Survey (NHTS) in the state of California, depicted in Figure 10.

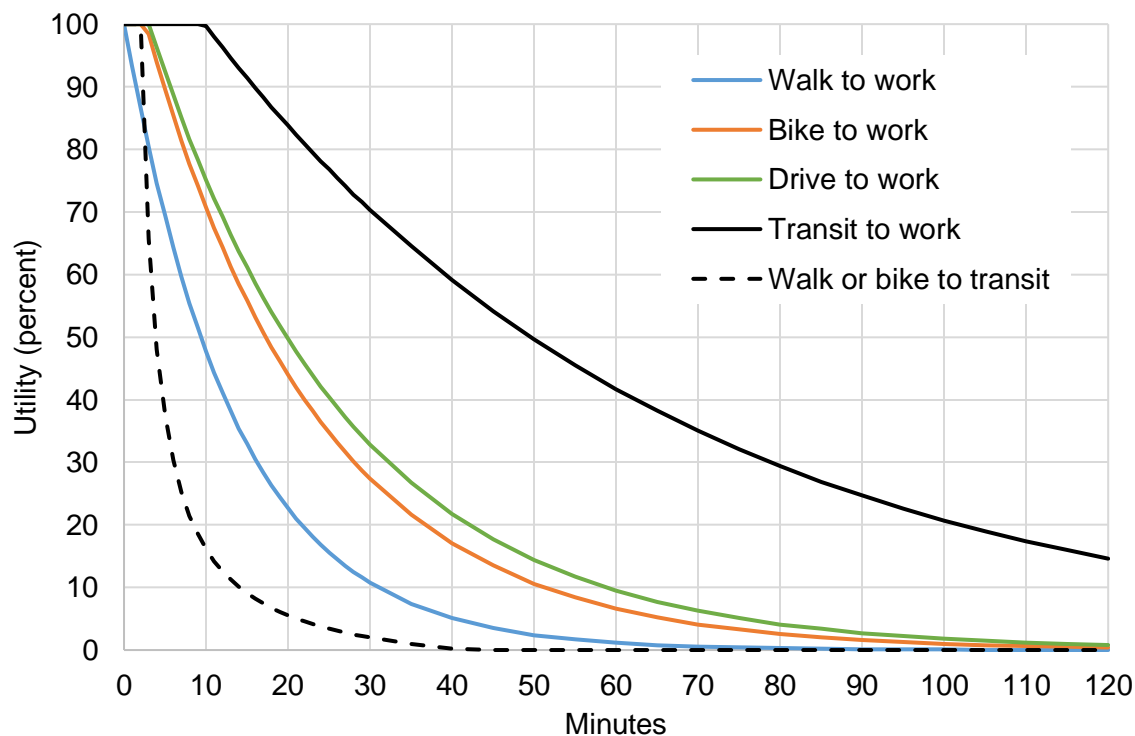


Figure 10. Travel time decay functions for work trips in California (walk or bike to transit represents entire U.S.), based on NHTS

As shown, the decay functions vary by mode. For transit, a job within 10 minutes has high utility and is counted as one full job. A job 40 minutes away, however, has less utility and only counts for 60 percent of a job. For driving, a job 40 minutes away counts for only 22 percent of a job. These numbers correspond with the share of commuters who travel that length of time or longer for work.

Figure 11 depicts variations in transit accessibility throughout Sacramento depending on the walking distance to transit, frequency of transit service, and location of jobs with respect to the transit network. This includes both buses and LRT. Downtown is the most highly accessible area, from which someone could reach upwards of 295,000 decay-weighted jobs by transit. Accessibility generally decreases as one moves outward from the Downtown, but remains high along the most frequent and direct transit lines.

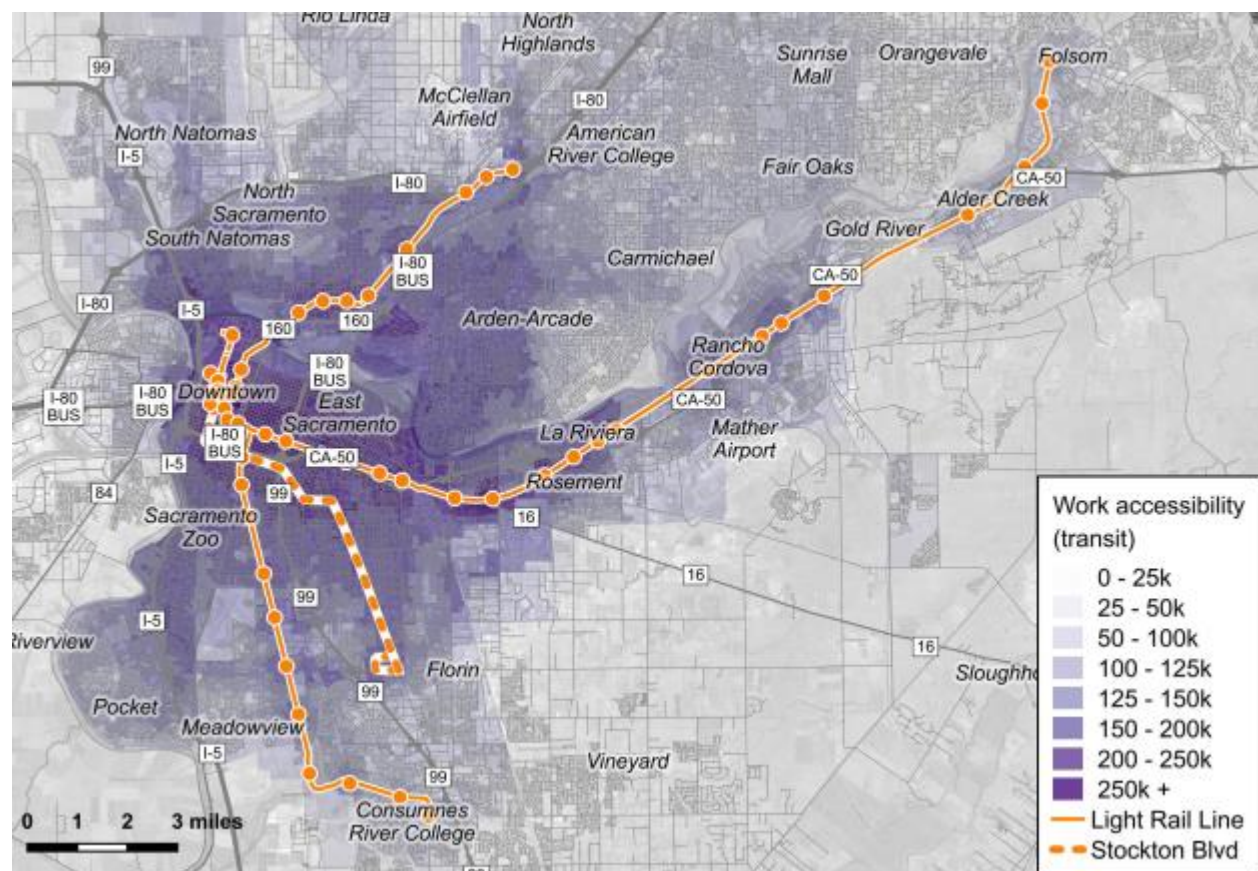


Figure 11. Access to jobs by transit

Station area accessibility

Since the ability to walk to a transit station is a key factor in transit accessibility, the following analyses are designed to identify locations along our study corridors with particularly poor access to transit stations by walking, which might benefit the most from new network connections or improvements existing ones, thereby attracting new riders. In this case, we focus solely on LRT stations. For this analysis, we introduce several novel concepts, described below.

Station utility

The station utility is estimated for each block, with respect to its nearest LRT station. Utility is based on walking distance to the nearest station, with an assumed walking speed of 2.8 miles per hour, and a decay function derived from the 2009 NHTS as described above. The NHTS contains far fewer observations of people walking to transit than commute trips, so the decay function is based on travel times to transit by walking or biking for the entire U.S. This decay function is depicted in Figure 10 as a broken line. The function indicates that a station within a two-minute walk has 100 percent utility, but a station 15 minutes away has less than 10 percent utility.

Utility estimates along the Gold Line near Rancho Cordova are shown in Figure 12.

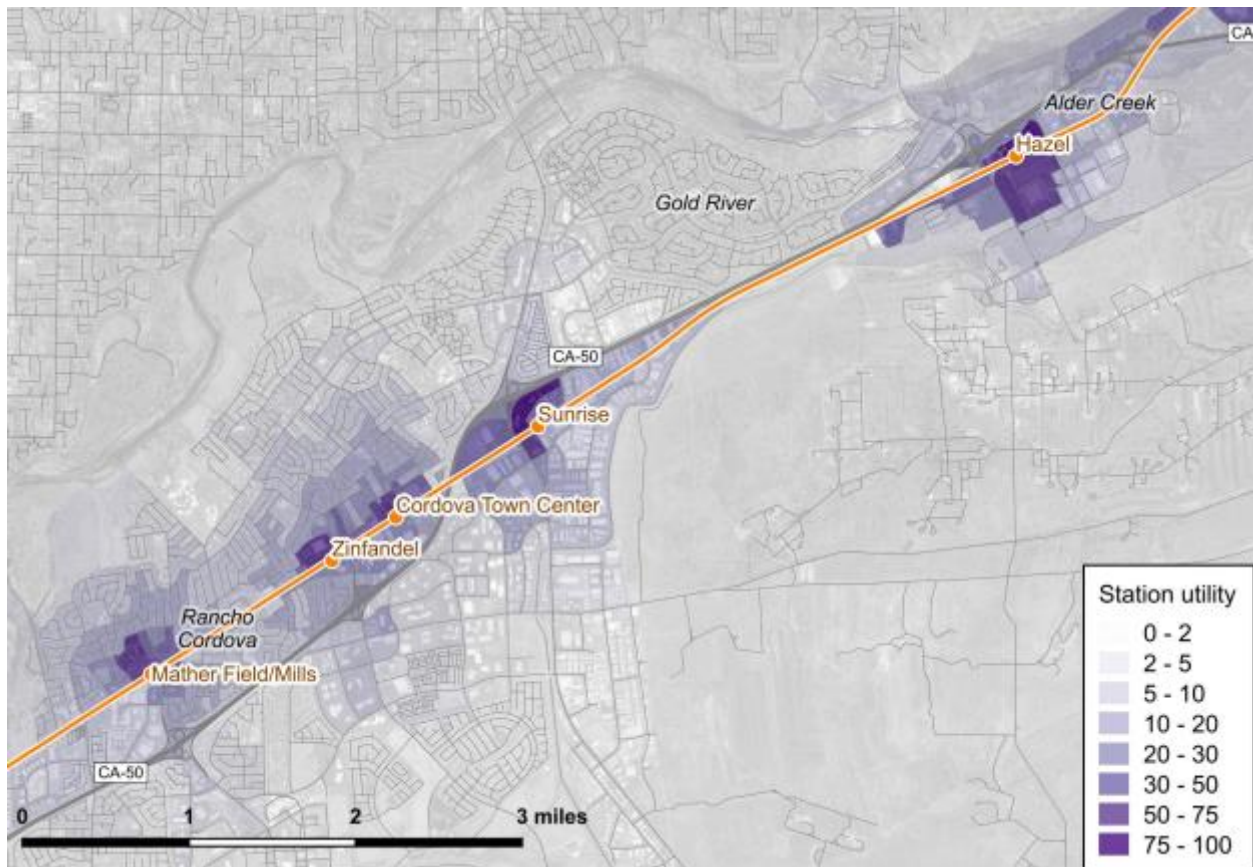


Figure 12. Station utility (0 to 100) for Rancho Cordova area

Potential utility improvement

Proximity is a key factor in station utility, but the directness of network connections is equally important. A station that is near a block but has poor connections to that block may have low utility, but a high potential utility.

The potential utility of a station is estimated by measuring the straight-line distance from each block to the nearest station, estimating the straight-line walking time, and converting that to utility based on the decay function described above. This metric represents the theoretical utility

of a station, assuming a direct connection can be made. The difference between the potential utility and the actual utility of a station represents the potential utility improvement that could be gained by adding a connection. This is meant to be used only for scanning and comparing locations generally, since direct connections are not always feasible given the existing network and physical obstacles. Potential utility improvements along the Gold Line are shown in Figure 13.

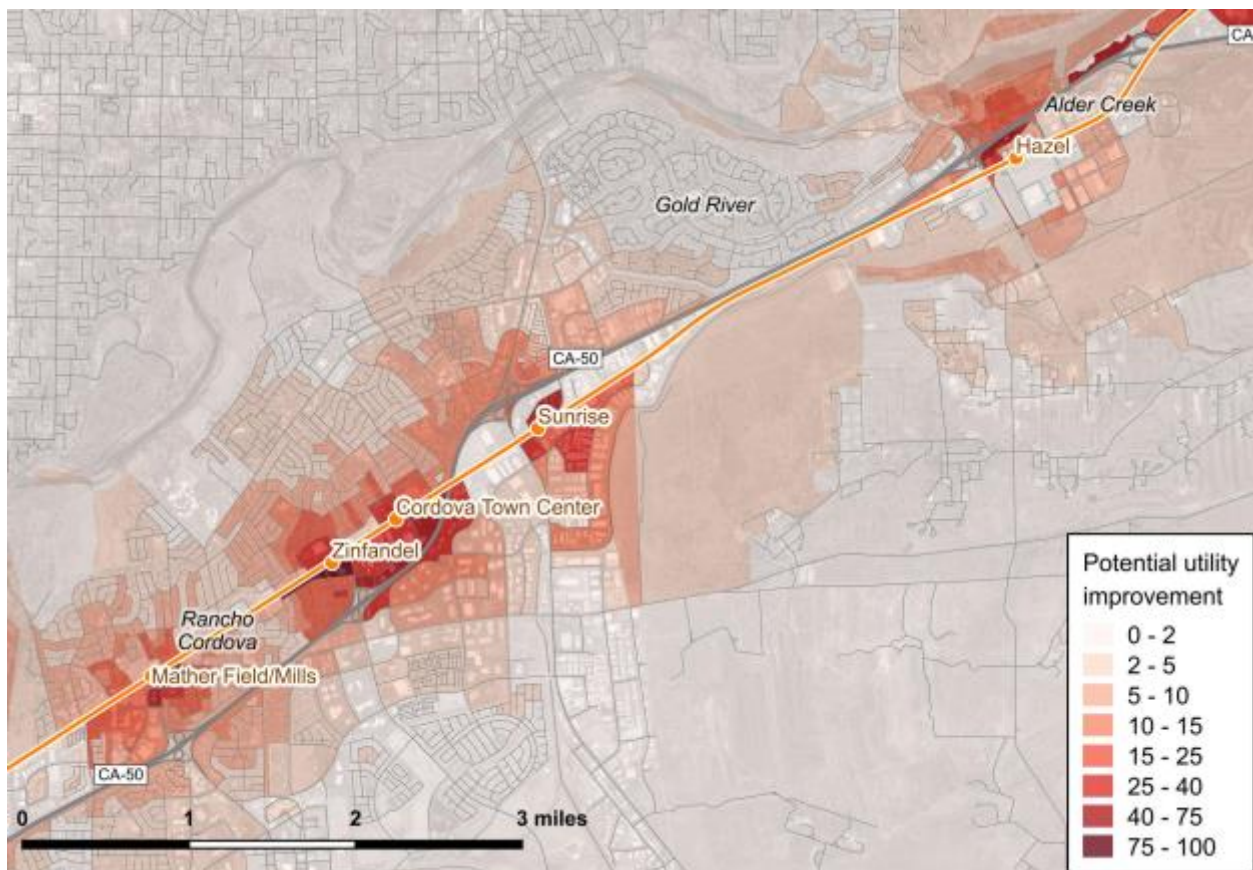


Figure 13. Potential utility improvement (0 to 100) for Rancho Cordova area

Impact score

Based on the potential utility improvement metric, there are many opportunities to improve station connections. Those improvements are only meaningful if there are households, jobs, or other destinations in a block that are worth connecting to.

The potential impact of new connections at any given block is reported as an *impact score* that accounts for both the potential utility improvement and the number of people affected by the change, including residents and employees. This score is calculated as follows:

$$\text{Raw impact score} = \text{Potential utility improvement} \times [\log(\text{Households}) + \log(\text{Jobs})]$$

The logarithmic terms adjust for skewness and bring households and jobs to a similar scale. Without this step, the large number of jobs in some blocks heavily influence the scores. The final

impact score is scaled between 0 and 100. Impact scores along the Gold Line near Rancho Cordova are shown in Figure 14. Some high-impact areas can be seen around Zinfandel station.

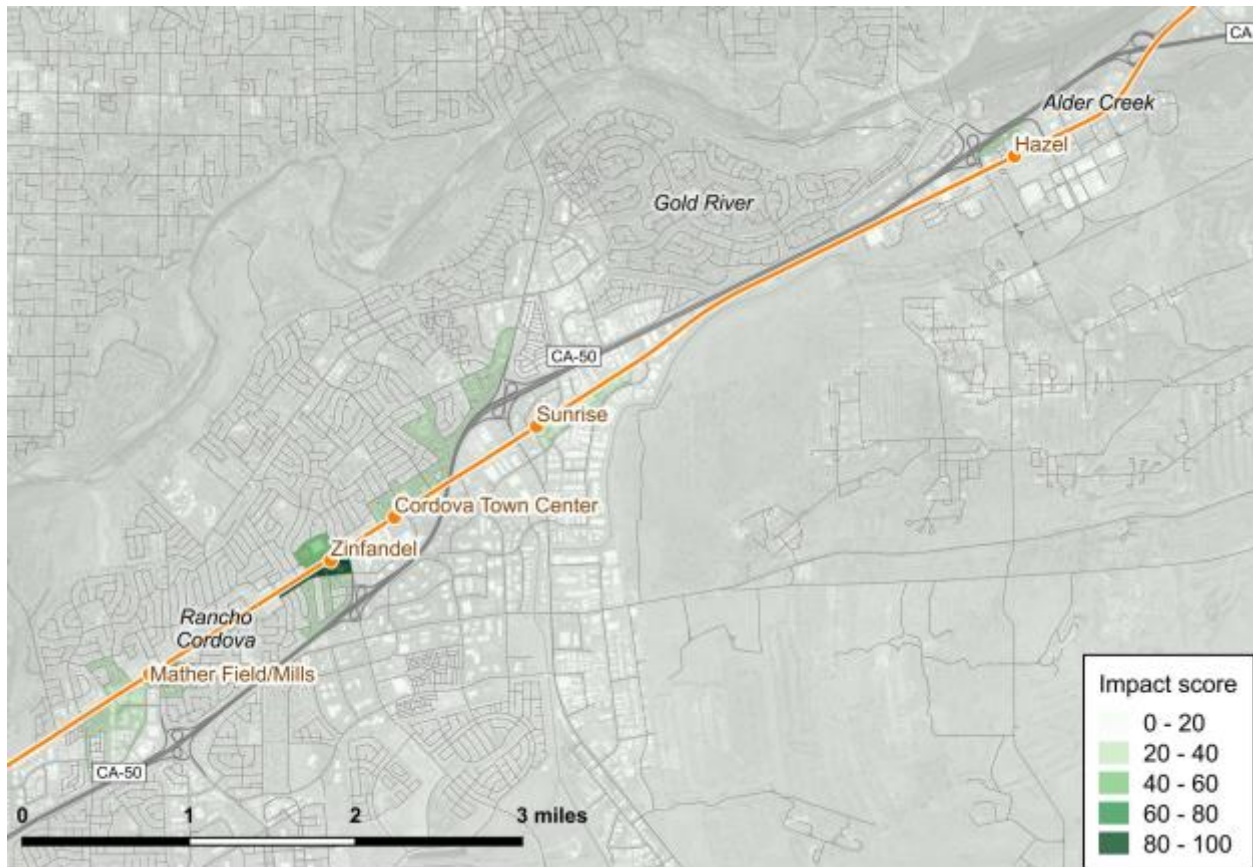


Figure 14. Potential impact (0 to 100) for Rancho Cordova area

Trip-making data

This study also incorporates passively collected location data from multiple sources to better understand trip-making patterns along transit corridors and throughout the Sacramento study area. These data represent a recent breakthrough in our ability to observe travel patterns by multiple modes, without needing to initiate capital- and resource-intensive studies of the area in question.

Conventionally, our best understanding of trip-making patterns comes from travel demand models, which incorporate data regarding land use and transportation networks to simulate people's movement between TAZs along major routes. Other data used to calibrate or augment those models include traffic counts and origin-destination studies using license plates, Bluetooth sensors, or Time Lapse Aerial Photography (TLAP).

The rising prominence of cell phones and other GPS-enabled devices presents new opportunities for rich and robust travel data. For example, many people have begun using Strava – a mobile fitness app – for data about people's movements on bicycle or on foot. These data let us

understand common origins, destinations, and route choices for a segment of the population where data is typically scarce. The data is not passive, however, in that people must consciously carry a mobile device and activate the app for their movements to be recorded. For this reason, the data over-represents recreational travel and route choices.

Passive data is collected whenever a device is active, without any explicit actions by the user. Therefore, it theoretically represents a full spectrum of trip purposes and travel modes. This study incorporates two sources of passive data, described below.

Teralytics

Teralytics relies on cellular location data from mobile phones to explain people's movement between TAZs. Cellular location data typically has low spatial and temporal resolution, because locations are triangulated from cellular towers whenever information is transmitted. A major benefit of these data, however, is the relatively high penetration rate and sample size, which also lets the data providers extrapolate observed patterns to the full population of a region.

To account for the data's lower spatial resolution, the providers analyze the data and distribute observations among TAZs based on their most likely precise location. For this study, the data are also combined with General Transit Specific Feed (GTFS) data regarding light rail transit routes and schedules to classify trips as either LRT or non-LRT. A discussion of Teralytics data validation is provided in Appendix 2.

StreetLight Data

StreetLight Data relies on GPS-based location data from navigational devices and mobile devices, including phones. GPS data provides much higher spatial and temporal resolution than cellular data, but its penetration rate and sample size are typically lower. Since the data come from multiple sources, the provider must clean, analyze, and aggregate the different sources. This is like the processing of cellular data.

Due to its high resolution, GPS data can be used to identify specific routes and trip ends (based on dwell time) more accurately. The data provider reports the distribution of trip lengths, travel speeds, and trip circuitries (the straight-line distance divided by the actual travel distance) for any given flow.

The primary sources of data are in-vehicle GPS units – including commercial vehicles and personal vehicles with built-in GPS – so the best use of the data has been for understanding vehicle movements. Personal and commercial vehicles can be distinguished explicitly from their data sources. However, data also exists for handheld units, such as phones, and one significant outcome of this study is the advancement of methods for identifying non-vehicular trips in the data and distinguishing their travel modes. These methods were in research and development phases during the time of this study.

StreetLight Data are reported using a *StreetLight Index*, which is meant to be consistent across different geographies and over time but does not represent actual trip numbers. Based on a comparison of StreetLight Data to observed traffic counts on 30 highways, we recommend multiplying reported Streetlight Index values by 0.85 to approximate actual trips. A discussion of StreetLight Data validation is provided in Appendix 3.

Analysis

In this study, all measures of LRT trip generation, LRT mode share, and LRT origins and destinations are derived solely from Teralytics. All measures of vehicle trip generation, vehicle origins and destinations, and other vehicle trip characteristics are derived solely from StreetLight Data. While this study relies on both data sources, none of the measures mix data sources. More cross-validation would be needed, to do so. These measures are all commercially available.

In all cases, trip ends are defined by the data providers – e.g., a signal is stationary for five minutes or longer – and trips could represent a single segment in a longer trip chain (or tour). For example, if somebody stops at a coffee shop on their way to work, their commute trip will be represented as two separate trips. Cellular technology and other technologies that StreetLight Data recently acquired could potentially allow for future identification of trip chains in the data.

For most of this study, analysis of passive trip-making data is limited to trips that begin and end within the transit catchment areas, depicted in Figure 1. These trips represent those that could theoretically be made by LRT without the use of another vehicle (some unknown portion of those trips are part of a longer trip chain, making them less likely candidates for LRT). Within that universe of trips, we can then describe trip generation, mode share, flow patterns, and other trip characteristics by TAZ.

Station area prioritization

Using the sources described above – accessibility metrics and passive GPS data – we identify blocks, TAZs, and station areas that have high potential for improvements and increased ridership. Based on this approach, stations fall into three categories:

1. Those that could benefit the most from accessibility improvement (i.e., high potential impact);
2. Those that produce a larger number of vehicle trips that could be made by LRT (i.e., trip generation);
3. Those where few trips are currently made by LRT (i.e., mode share).

Accessibility impacts

Table 2 lists the 20 blocks with the highest accessibility impact scores. The top three blocks are pictured and described below

Table 2. Census blocks ranked by accessibility impact scores

Nearest station	Block ID	House-holds	Jobs	Walking time (minutes)			Impact score
				Actual	Ideal	Diff.	
Zinfandel	060670090082001	47	98	8	1	7	100
Swanston	060670055021012	4	818	16	2	13	90
Meadowview	060670049031018	74	13	10	1	8	85
Archives Plaza	060670012001008	165	1,336	5	3	3	75
College Greens	060670052043019	7	173	5	1	4	67
Mather Field/Mills	060670090081006	88	32	5	2	2	59
48th Street	060670017001030	22	26	7	2	5	57
Starfire	060670091051000	211	15	17	4	13	55
Fruitridge	060670035023000	56	47	9	3	6	50
Amtrak Station	060670007001003	263	458	4	3	1	47
Marconi/Arcade	060670062021022	9	58	5	2	2	46
Center Parkway	060670096332005	70	3	4	1	4	46
59th Street	060670016003013	155	121	7	3	3	45
48th Street	060670017001037	26	14	8	3	5	43
Zinfandel	060670089052008	23	415	3	2	1	42
Cathedral Square	060670011011028	14	332	3	1	2	41
Broadway	060670023001018	19	72	6	3	3	41
Butterfield	060670091072016	165	38	5	3	2	41
Cordova Town Center	060670089081021	197	36	3	2	1	39
Tiber	060670091063001	174	7	4	2	2	39

Zinfandel station

At Zinfandel station (Figure 15), the high impact score just south of the station is due partly to the configuration of the block. However, field verification shows that this score reflects a true accessibility issue for residents living southwest of the station who cannot access the station directly through the adjacent shopping plaza. This block represents approximately 98 jobs and 47 households, which could benefit by reduced travel times of up to seven minutes through better connections to the station.

Field verification suggests the medium-high impact score north of the station might be due partly to the available network data, which does not accurately represent an existing crosswalk connecting to the north just west of the station. This highlights the importance of field verification, after identifying high impact scores.



Figure 15. Impact scores near Zinfandel station

Swanston station

At Swanston station (Figure 16), the high impact score just east of the station is due to rail lines that obstruct access to the block. The block contains few households, but more than 800 jobs with walking times that are up to 13 minutes longer than the ideal straight-line path to the station. This station is the subject of a detailed case study later in this report.



Figure 16. Impact scores near Swanston station

Meadowview station

At Meadowview station (Figure 17), the high impact score just east of the station is due to rail lines that obstruct access to the block. The block contains approximately 74 households with walking times that are up to 8 minutes longer than the ideal straight-line path to the station. The main access point to the station is a 700-car parking lot to its west.



Figure 17. Impact scores near Meadowview station

Trip generation and mode share

Vehicle trip generation (from StreetLight Data) and LRT mode share (from Teralytics) along the LRT corridors are shown in Figure 18 and Figure 19, respectively. Vehicle trip generation ranges from 100 to 12,210 during a typical weekday. The highest LRT mode share is 20 percent and the lowest is less than one percent.

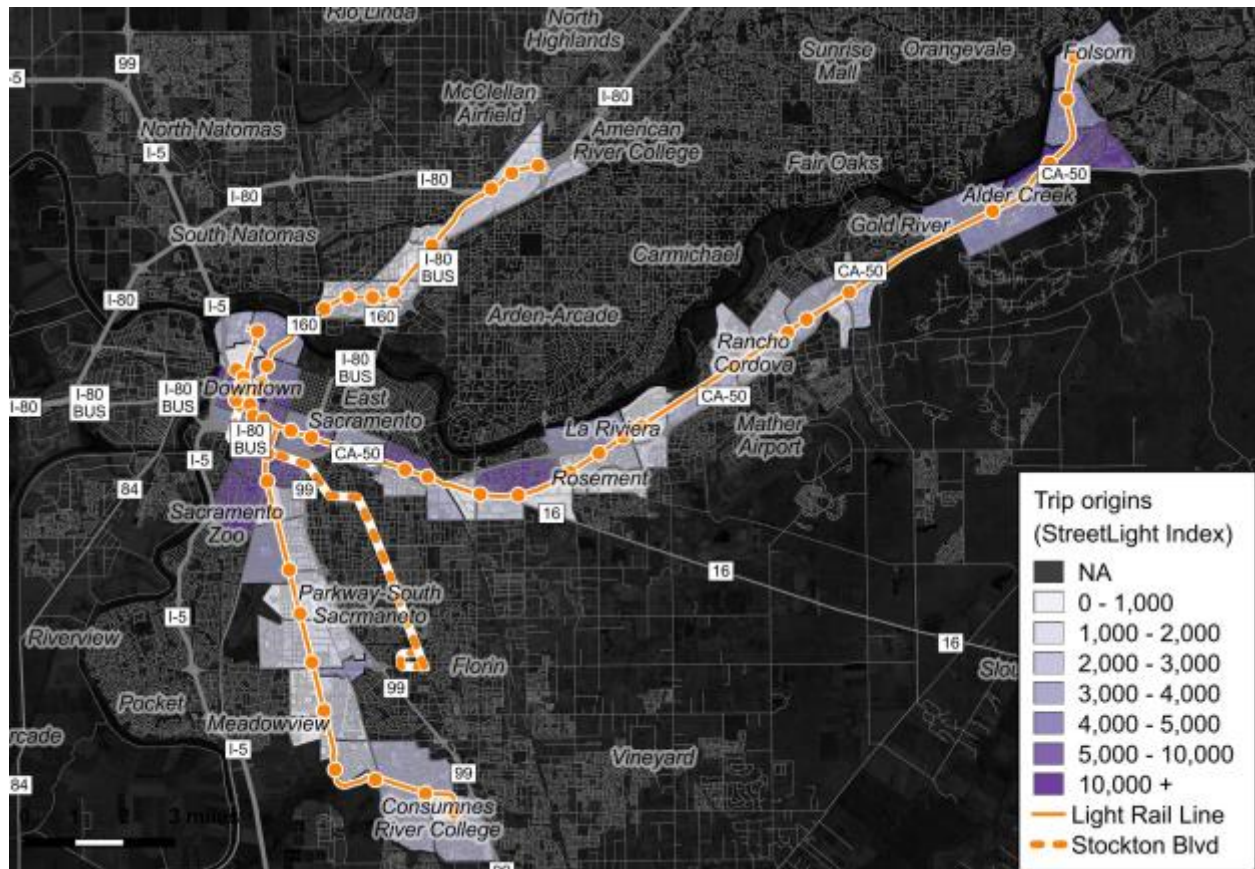


Figure 18. Vehicle trip generation for trips along the LRT system (StreetLight Data)

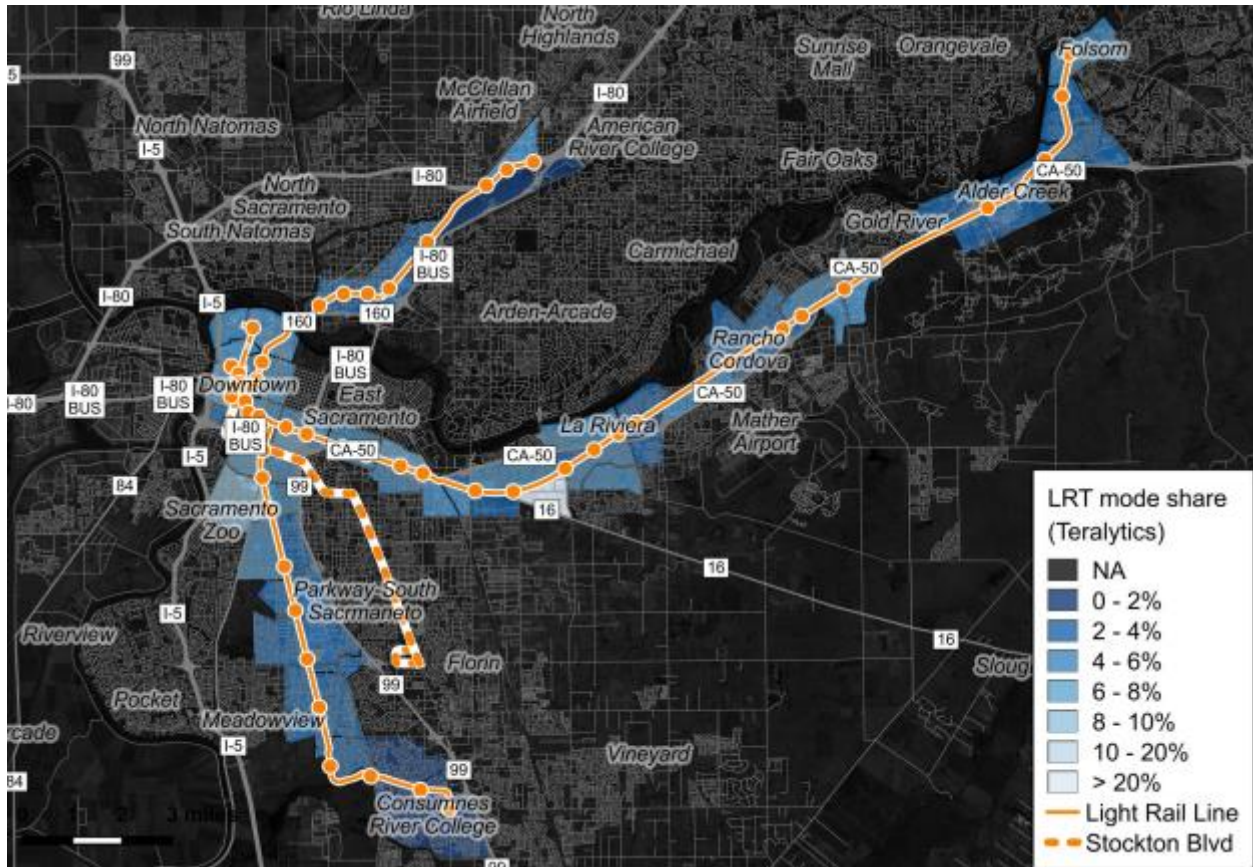


Figure 19. LRT mode share for trips along the LRT system (Teralytics)

Table 3 represents the TAZs with the 15 highest vehicle trip generation rates and the 15 lowest LRT mode shares. These TAZs are locations with the most potential transit riders and where transit is most underused, respectively. There is no overlap between these two groups. Demographic information for each of the top-ranked TAZs are shown in Table 4 and their locations are depicted in Figure 20.

Table 3. TAZs ranked by vehicle trip generation and LRT mode share

Nearest station	Zone	Trips generated (StL Index, from StreetLight Data)		LRT mode share (from Teralytics)	
			Rank		Rank
12th & I St	4028	12,210	1	5%	45
16th Street	4029	7,420	6	6%	65
16th Street	4030	6,680	8	5%	43
23rd Street	4025	3,820	14	5%	52
23rd Street	4026	3,790	15	7%	68
29th Street	4069	7,000	7	4%	42
4th Ave/Wayne Hultgren	4033	5,140	12	5%	46
4th Ave/Wayne Hultgren	4077	6,590	9	9%	72
59th Street	4068	5,300	11	7%	70
7th & K St	4070	12,030	2	7%	69
8th & O St	4031	9,500	3	7%	67
Alkali Flat/La Valentina	4071	4,970	13	5%	52
Broadway	4032	7,440	5	6%	66
Butterfield	3954	1,770	44	3%	14
Butterfield	4130	1,090	57	1%	4
Center Parkway	4076	2,390	33	1%	4
Center Parkway	4078	2,640	32	1%	3
College Greens	4112	5,440	10	5%	59
Cosumnes River College	3906	610	68	1%	1
Cosumnes River College	4002	2,790	25	1%	2
Florin	3930	3,060	22	2%	8
Florin	4107	1,890	38	2%	11
Glenn	4046	3,730	16	3%	14
Iron Point	4106	8,710	4	4%	29
Marconi/Arcade	3945	640	66	2%	7
Marconi/Arcade	3970	220	73	2%	8
Power Inn	4000	1,220	54	2%	8
Power Inn	4015	1,880	40	2%	11
Swanston	4115	1,720	48	3%	14
Swanston	4118	450	70	3%	13
Watt/I-80 West	4054	1,930	37	2%	6

Note: Shading corresponds with rank.

Table 4. Demographic information for top-ranked TAZs

Zone	Median income (\$000)	Household ownership rate	Median age (adults)	Children per adult	Vehicles per household	Households	Jobs
4028	\$33	11%	42	0.06	0.78	1080	3090
4029	\$38	9%	42	0.02	0.78	1650	1170
4030	\$33	14%	42	0.10	1.03	1040	1010
4025	\$48	9%	32	0.06	1.20	1790	450
4026	\$38	14%	37	0.12	1.15	1390	320
4069	\$68	41%	47	0.16	1.37	990	510
4033	\$68	48%	47	0.21	1.38	1620	840
4077	\$138	81%	61	0.27	1.78	1810	520
4068	\$68	46%	37	0.14	1.58	550	520
4070	\$13	4%	37	0.01	0.36	770	3920
4031	\$43	10%	47	0.05	0.84	1290	3840
4071	\$43	15%	37	0.15	1.15	2120	690
4032	\$88	66%	52	0.19	1.57	1880	420
3954	\$55	48%	52	0.28	1.61	720	170
4130	\$55	54%	57	0.27	1.73	290	200
4076	\$43	42%	52	0.41	1.70	3910	650
4078	\$55	58%	52	0.39	1.94	2350	70
4112	\$48	37%	52	0.33	1.43	1530	280
3906	\$28	40%	52	0.52	1.91	220	70
4002	\$55	61%	52	0.41	1.96	1880	310
3930	\$33	38%	52	0.38	1.57	640	190
4107	\$23	36%	52	0.51	1.34	1370	530
4046	\$68	22%	42	0.39	1.30	300	520
4106	\$113	74%	52	0.40	1.93	1410	1550
3945	\$18	31%	52	0.21	1.46	480	120
3970	\$28	48%	47	0.18	1.86	510	20
4000	\$28	73%	61	0.07	1.08	50	220
4015	\$28	71%	61	0.09	1.07	10	60
4115	\$18	8%	42	0.47	1.10	280	570
4118	\$33	38%	52	0.39	1.45	650	190
4054	\$48	67%	61	0.40	1.82	530	310

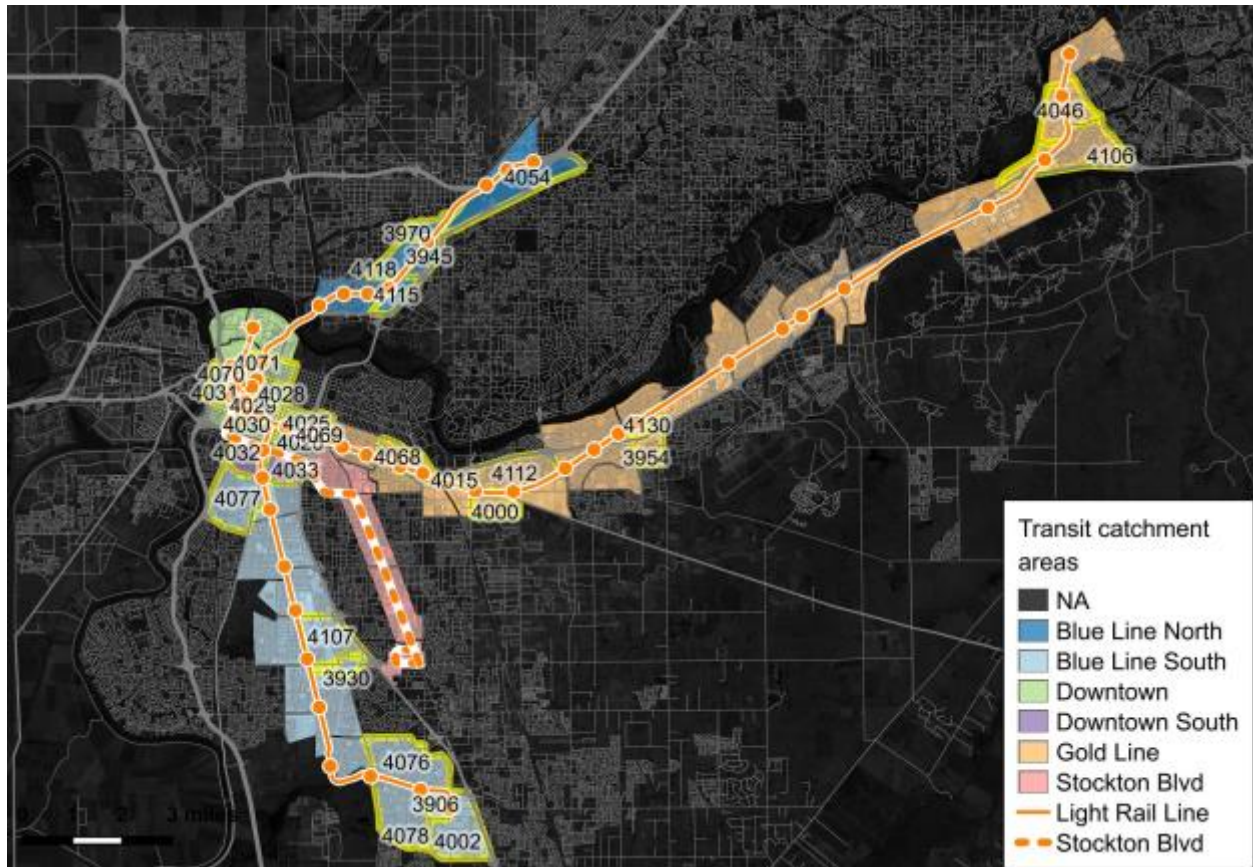


Figure 20. Locations of top-ranked TAZs

Priority areas by trip generation

As shown in Table 3, the highest vehicle trip generation rates are generally downtown, because the TAZs include major central activity centers. These trip generation rates are depicted in Figure 21.



Figure 21. Vehicle trip generation (StreetLight Data) – Downtown

The highest vehicle trip generation rate outside of the downtown is in a TAZ near Iron Point station, which produces 8,710 StreetLight trips (7,400 vehicle trips) per day that end within the LRT catchment area. This area is depicted in Figure 22 and Figure 23.



Figure 22. TAZ 4106 near Iron Point Station

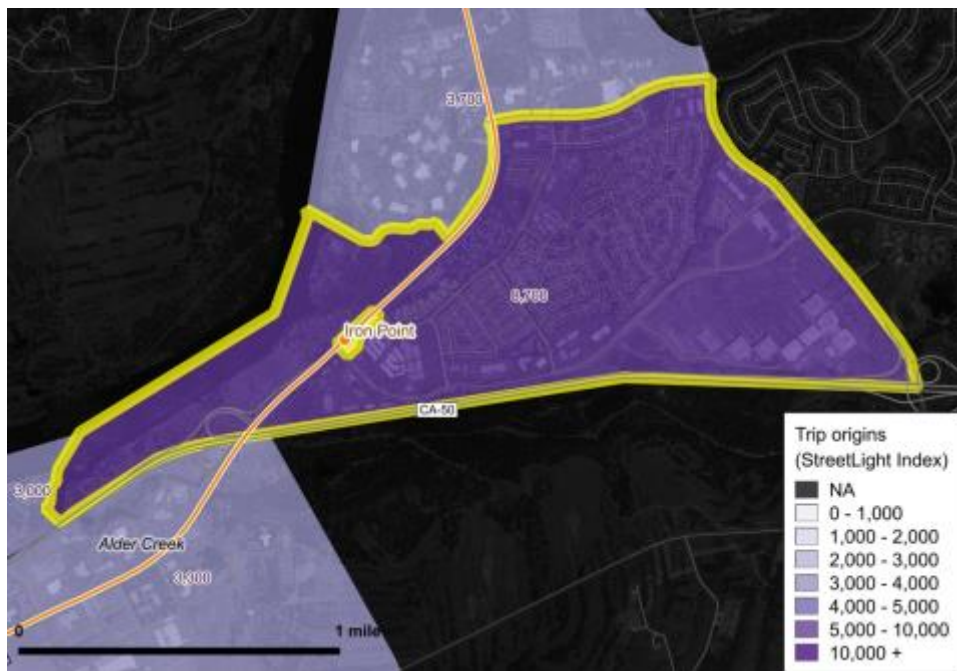


Figure 23. Vehicle trip generation (StreetLight Index) – TAZ 4106 near Iron Point Station

Using the same data we can determine where most of those trips are ending along the LRT line. As shown in Figure 24, most of the trips beginning near Iron Point station end near the three closest stations: Hazel, Glenn, and Folsom. These short trips might be difficult to shift to transit unless service is frequent, access to the stations is excellent, and parking near the stations is managed appropriately. Close to 1,700 StreetLight trips (1,400 vehicle trips) end elsewhere along the Gold Line, including roughly 450 StreetLight trips (380 vehicle trips) ending near Downtown. As described above, some portion of these trips are part of a longer trip-chain, which makes them less likely candidates for LRT.

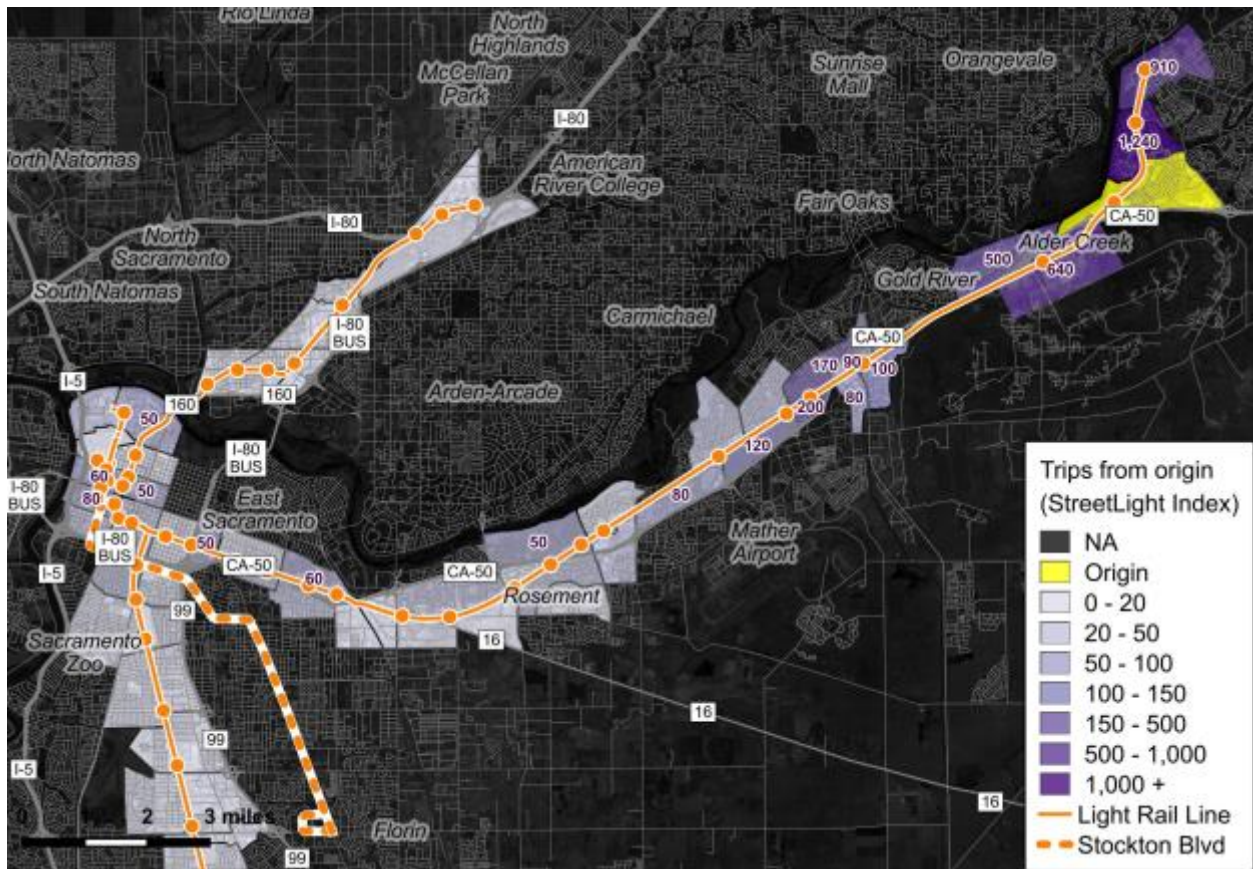


Figure 24. Vehicle trip destinations (StreetLight Data) – TAZ 4106 near Iron Point Station

Following the TAZ near Iron Point Station, the next highest trip generation rate outside of the downtown is a TAZ near College Greens station, which produces 5,440 vehicle trips per day that end within the LRT catchment area. This area is depicted in Figure 25 and Figure 26.

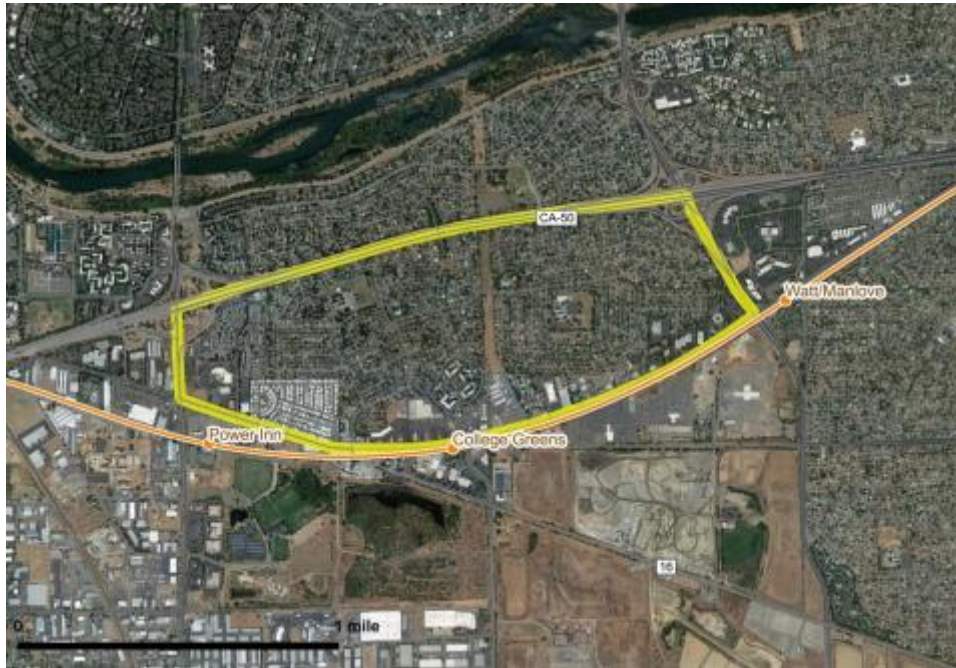


Figure 25. TAZ 4112 near College Greens Station

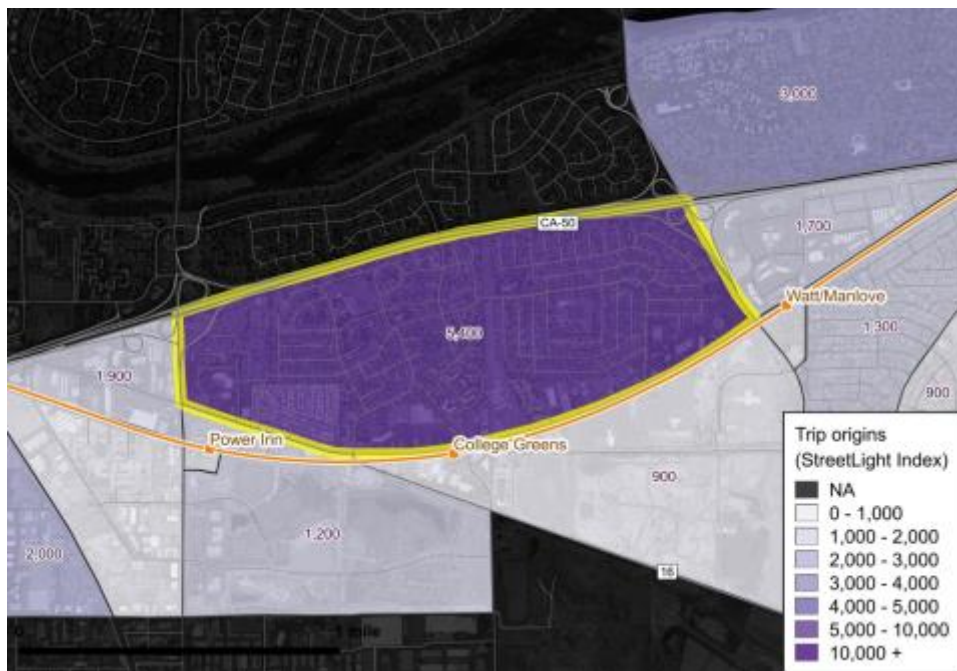


Figure 26. Vehicle trip generation (StreetLight Data) – TAZ 4112 near College Greens Station

For this TAZ we can also determine where most of the vehicle trips are ending, along the LRT line (Figure 27). These trips are mostly concentrated along the Gold Line – Downtown or within a short distance from College Greens.

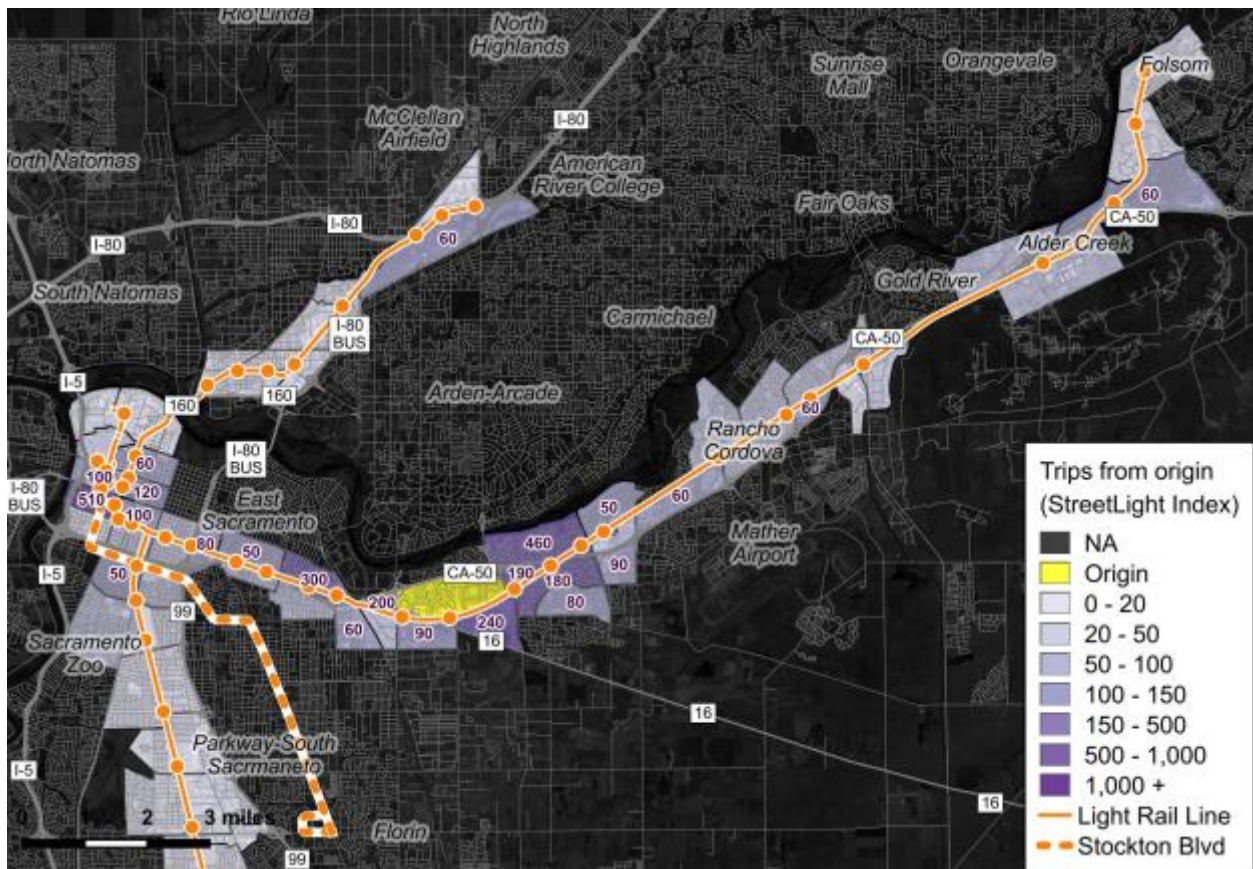


Figure 27. Vehicle trip destinations (StreetLight Data) – TAZ 4112 near College Greens Station

In this case, there are a large enough number of transit trips for us to determine where most of the LRT trips are ending as well (Figure 28). These, too, are largely Downtown or within a short distance of College Greens.

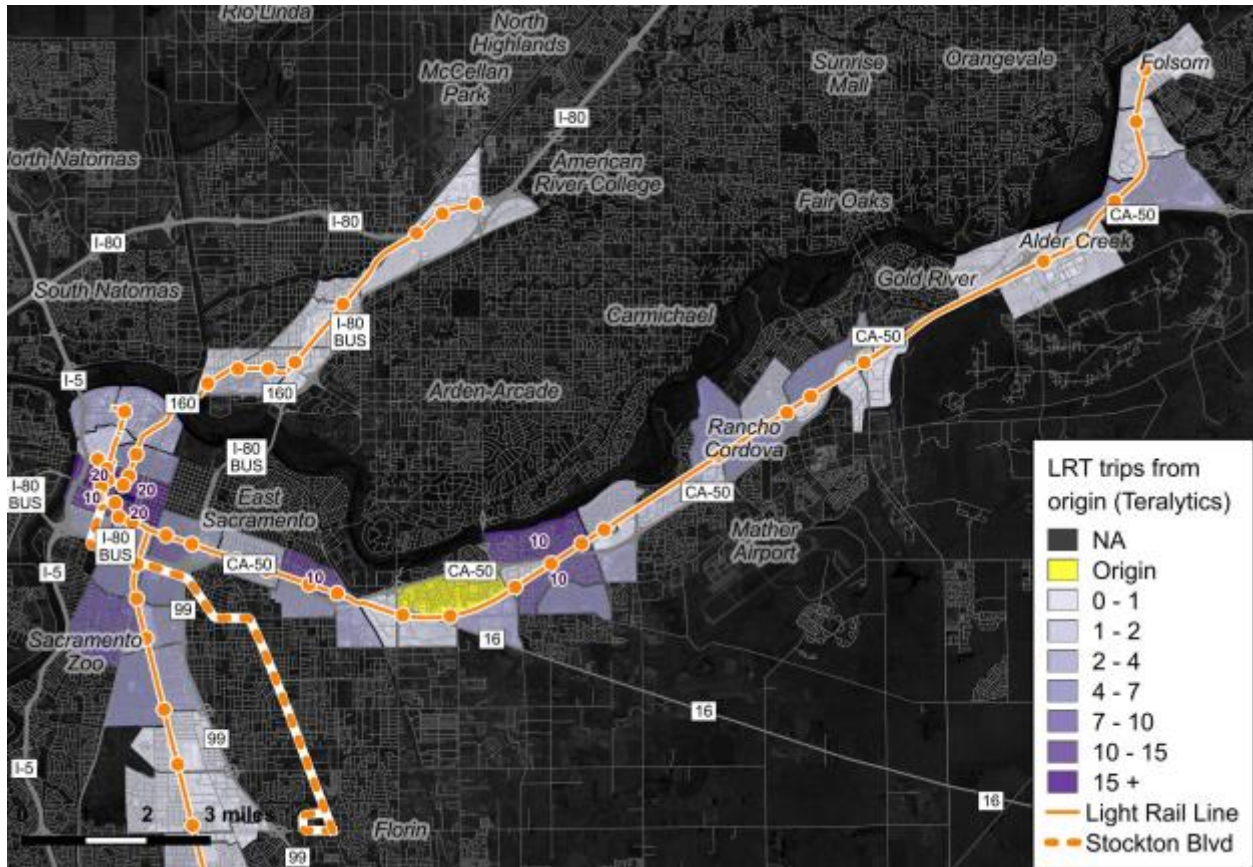


Figure 28. LRT trip destinations (Teralytics) – TAZ 4112 near College Greens Station

Priority areas by LRT mode share

As described above, LRT mode shares are generally low along the LRT corridor. The four TAZs with the lowest share (around one percent) are clustered around Consumnes River College, served by the Consumnes River College and Center Parkway stations. These mode shares are low partly because the station did not open until partway through the study period (August 2015). More recent data is needed to understand the current use of the Blue Line extension.

The fifth lowest LRT mode share, however, is near Butterfield station, as shown in Figure 29 and Figure 30. The area includes several large office buildings served by abundant parking, which likely encourages driving and makes walking to the station less appealing.



Figure 29. TAZ 4130 near Butterfield Station



Figure 30. LRT mode share (Teralytics) – TAZs 4130 near Butterfield station

Case studies

Based on the information provided above, local stakeholders may choose to prioritize particular station area improvements, given their potential to attract large numbers of riders. For the purposes of this study, several opportunities in existing plans have been identified by local stakeholders. The following section provides a summary of these station areas based on the data described above and analysis of proposed changes.

Swanston Station

Figure 31 shows the current utility of Swanston station and other nearby stations by walking. For most of the stations in the area, utility spreads out evenly into the surrounding neighborhoods. At Swanston station, however, the highest station utility is concentrated west of the station. The low utility just to the east is due to freight rail lines that separate the station from those neighborhoods, as shown in Figure 32. The nearest crossings are Arden Way to the south and El Camino Ave to the north – neither of which is particularly pedestrian accessible. Further east, the station is also separated by Interstate 80 Business, the Capital City Freeway, which creates exceptionally poor walking conditions, as shown in Figure 33.



Figure 31. Station utility (0 to 100) around Swanston station

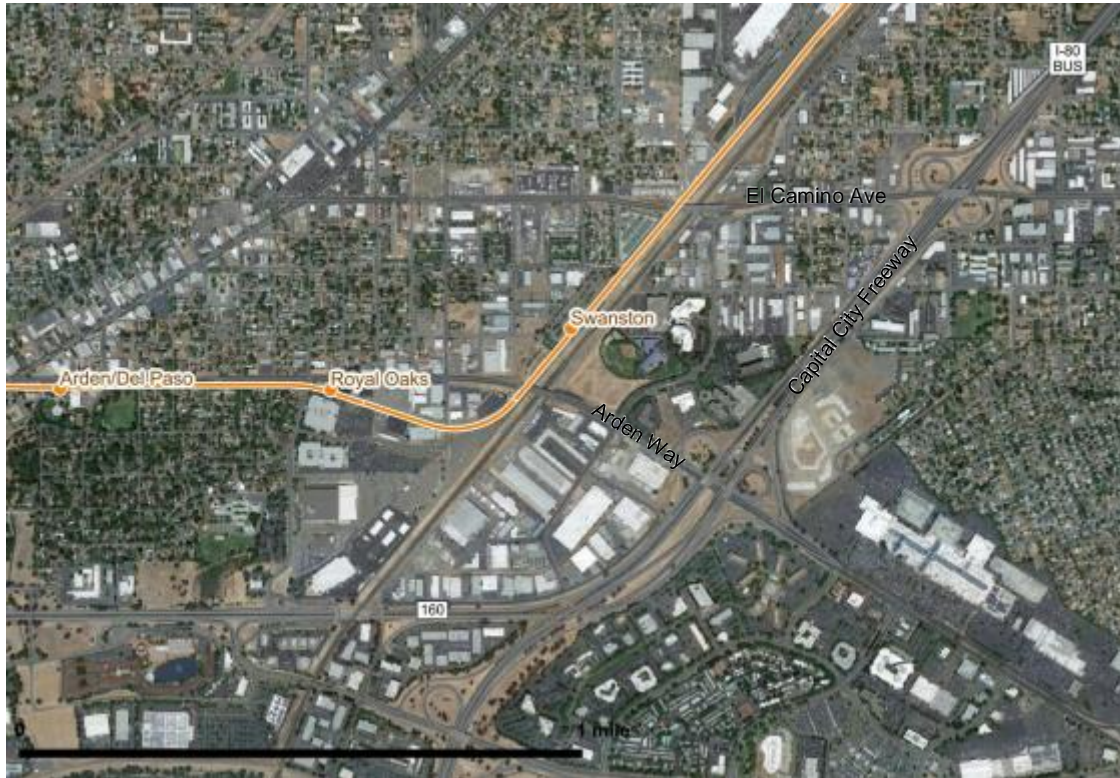


Figure 32. Existing conditions around Swanston station



Figure 33. Walking conditions at Capital City Freeway underpass

As shown in Figure 34, a direct connection from Swanston station to the eastern, adjacent neighborhood could improve the station's utility by 74 percentage points – from 9 to 83. Figure 35 depicts the potential impacts of the connection on residents and employees in the area, which

are also substantial. Most of the impact is due to the large number of employees there. Additional connections to east, across I-80B, could also impact the employees and residents there.

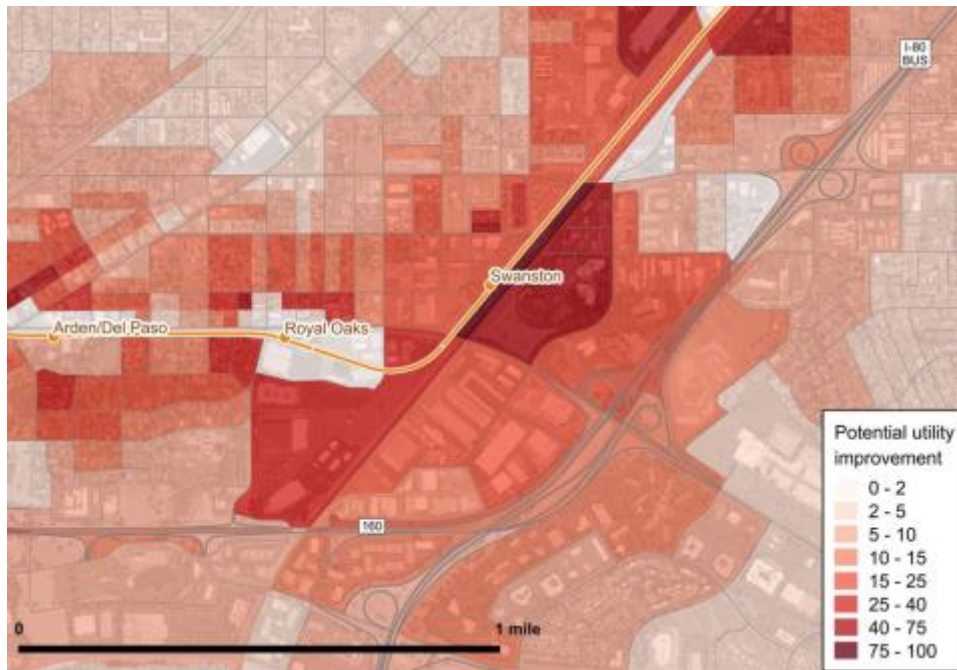


Figure 34. Potential utility improvement (0 to 100) around Swanston station



Figure 35. Potential impact (0 to 100) around Swanston station

Proposed connection

The accessibility analysis shown above is much more than an abstract exercise. Recognizing the accessibility issues around Swanston station, the City of Sacramento proposed new connections to the east in a Transit Village Specific Plan from 2007. The plan, developed through a series of public workshops, is meant to enhance the area around the station as a highly-connected transit oriented development and maximize development potential. The plan proposes a dense network of bicycle and pedestrian connections including a bridge across the existing freight line to the east, as shown in Figure 36.



Figure 36. Proposed bicycle and pedestrian connections around Swanston station (source: City of Sacramento)

Using the same analysis tools described above, we can quantify the impacts of the new connections proposed by the City of Sacramento. Figure 37 shows how the proposed connections would improve travel times for those walking to the station (assuming the Capital City Freeway underpass is also passable). From the neighborhood immediately to the east, travel time to the station decreases by 10 minutes. From neighborhoods further east, travel times decrease by around five minutes. Additional connections west of Swanston station also reduce travel times in the vicinity.

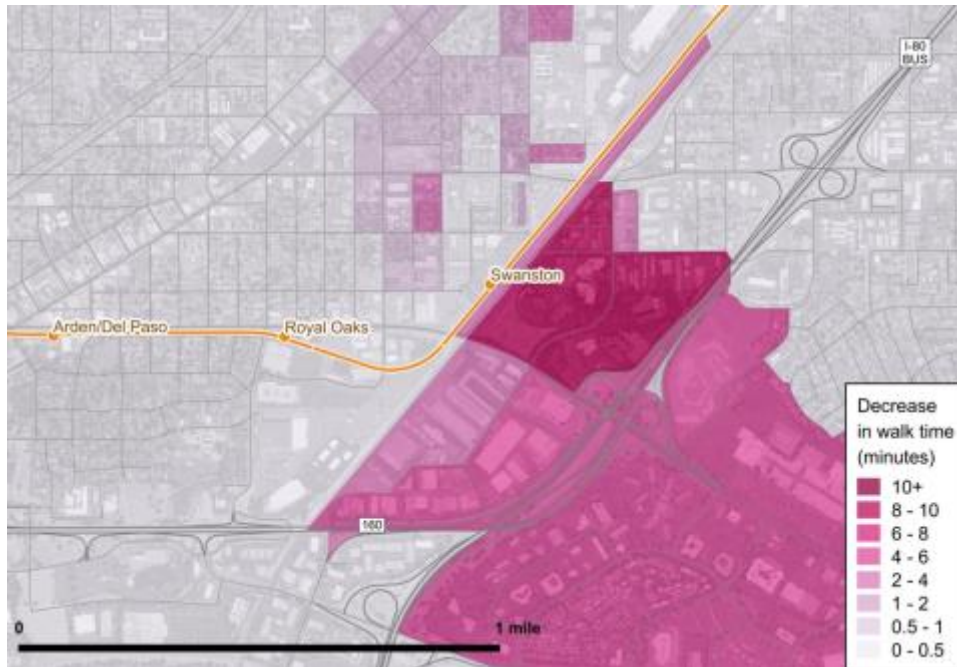


Figure 37. Walk time improvements due to proposed connections to Swanston station

As shown in Figure 38, these improved connections to Swanston station have a pronounced impact throughout the transit system. Those living immediately to the east gain access to an additional 15,000 to 30,000 jobs by transit from the improvements. Within a half-mile of the station, the average increase is 1,600 jobs. Because the connections also improve access to jobs near the station, the impacts spread citywide. In total, roughly 33,000 households gain access to an additional 250 jobs or more. Those impacts are experienced north along the Blue Line as far as McClellan Park; south to Pocket, Meadowview, Parkway, and North Laguna; Downtown; in West Sacramento; and even in some areas around North Natomas, which are served by the Route 11 bus.



Figure 38. Improvements in access to jobs by transit due to proposed connections to Swanston station

Trip-making

Trip-making data from StreetLight Data and Teralytics provide insight about the number of vehicle trips and the LRT mode share, respectively, in the areas affected by the proposed improvements. The TAZ just east of Swanston station generates roughly 1,700 daily vehicle trips that end somewhere within the LRT catchment area. This is the highest trip generation rate of any TAZ near Swanston station, as shown in Figure 39. Many of these trips represent potential transit trips, given that those individuals could reach the station conveniently by walking.

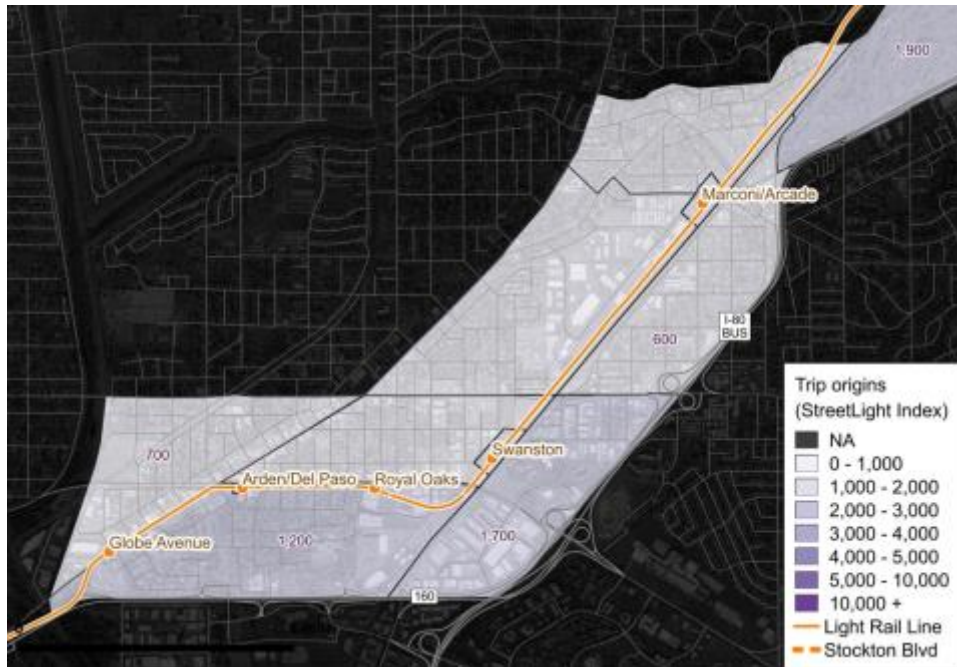


Figure 39. Vehicle trip generation near Swanston Station (StreetLight Data)

As shown in Figure 40, LRT use is low (three percent of trips that end within the LRT catchment area) in the TAZ east of Swanston station, but not markedly different from other nearby zones.

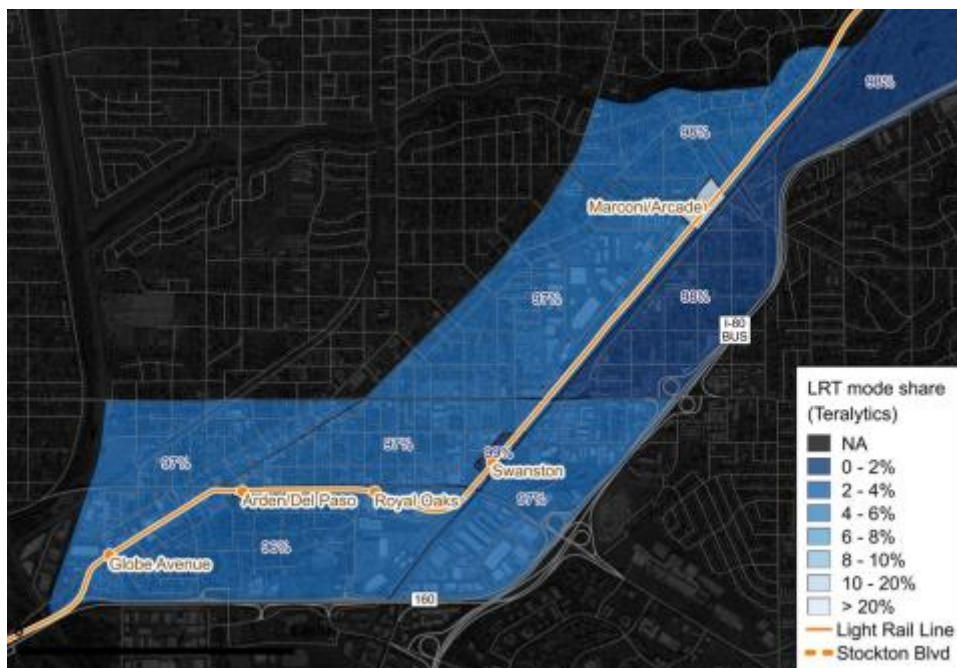


Figure 40. Non-LRT mode share near Swanston Station (Teralytics)

Figure 41 and Figure 42 show the destinations of trips beginning in the TAZ east of Swanston Station by automobile and by LRT, respectively. A large share of those trips – roughly 600 by automobile and 60 by LRT – end in the Downtown. Many other trips end elsewhere along the Blue Line, north of Downtown.

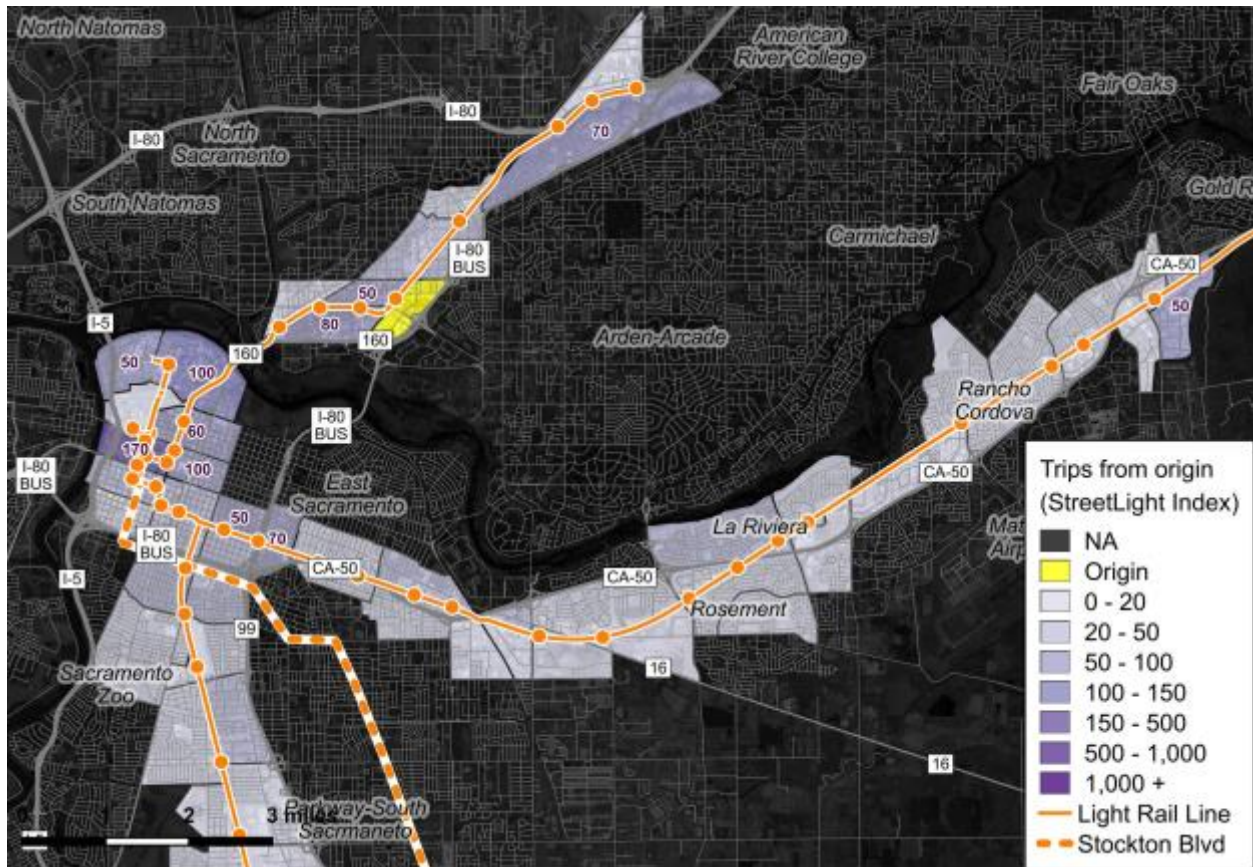


Figure 41. Vehicle trip destinations (StreetLight Data) – TAZ 4115 near Swanston Station

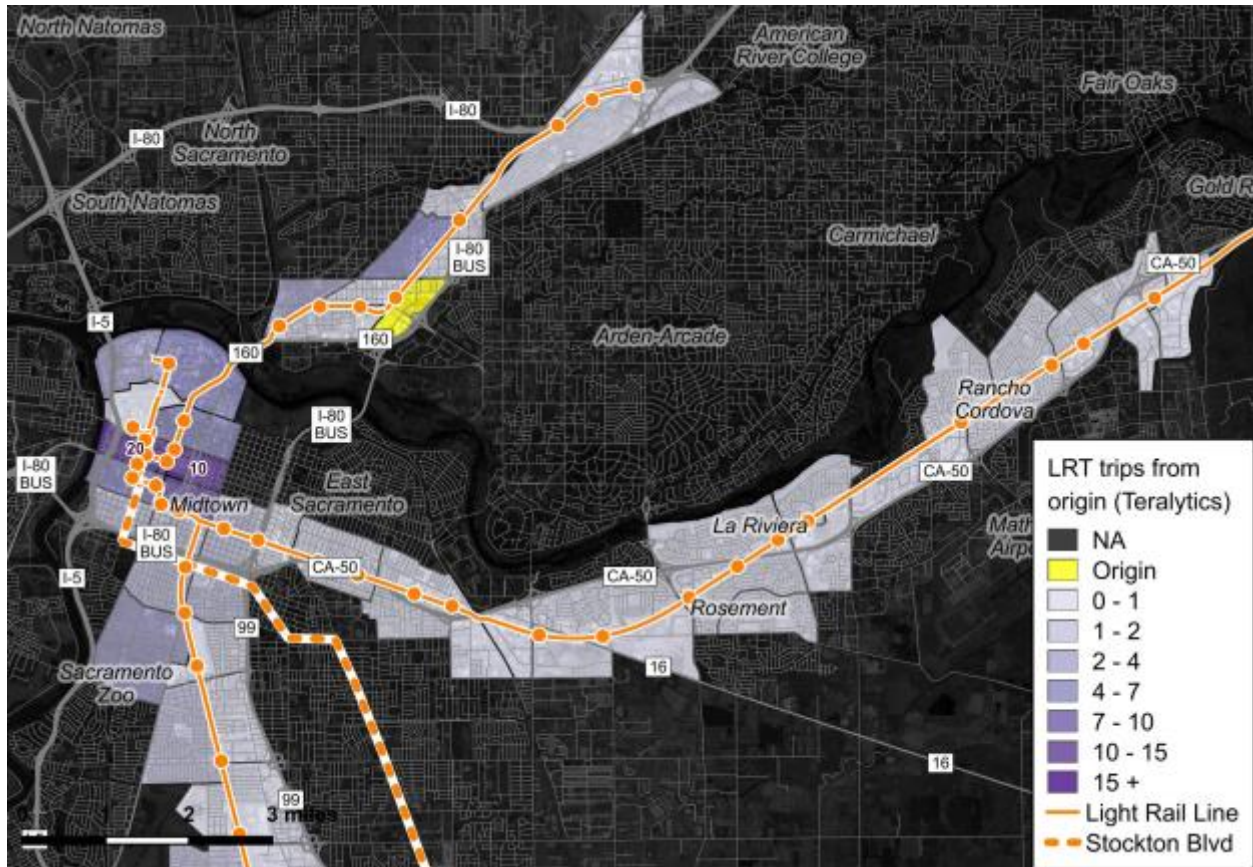


Figure 42. LRT trip destinations (Teralytics) – TAZ 4115 near Swanston Station

City College Station

In May 2016, a new bridge opened connecting the Sacramento City College to Curtis Park located east of the college on the opposite side of the LRT tracks. Plans for the bridge are shown in Figure 43. As our accessibility analysis shows, the City College station has particularly low utility from the Curtis park area and the potential utility improvement is high (see Figure 44 and Figure 45), suggesting that the newly constructed bridge will have a considerable effect.



Figure 43. Plans for newly constructed bicycle and pedestrian bridge at City College station (source: City of Sacramento)

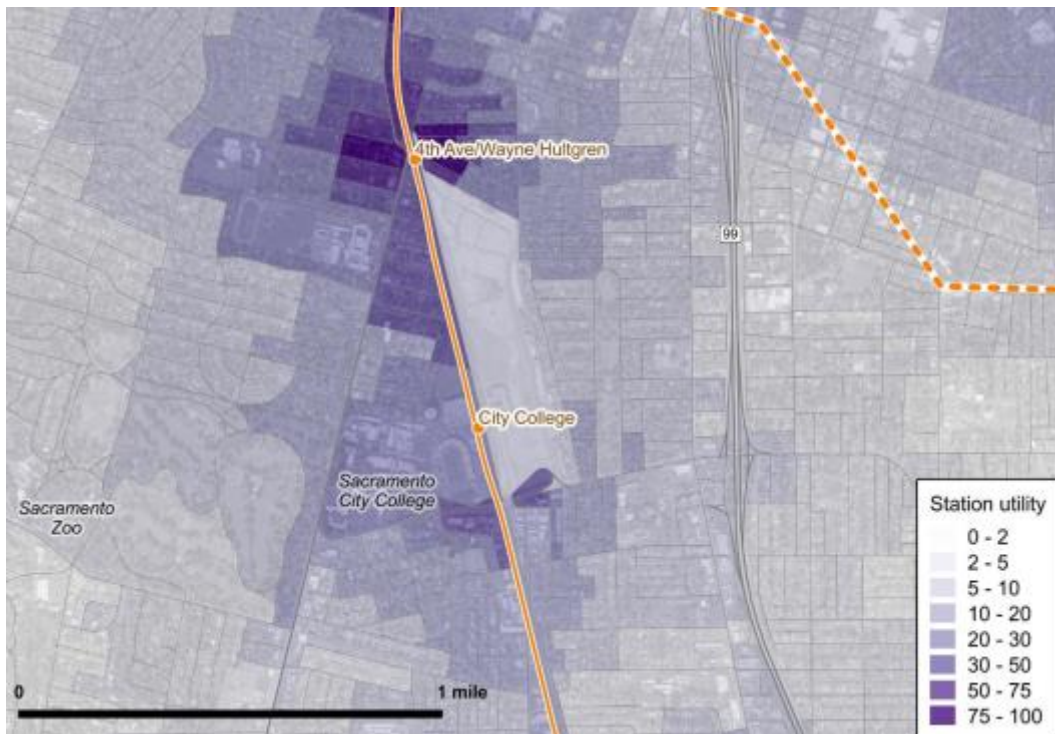


Figure 44. Station utility (0 to 100) around City College station

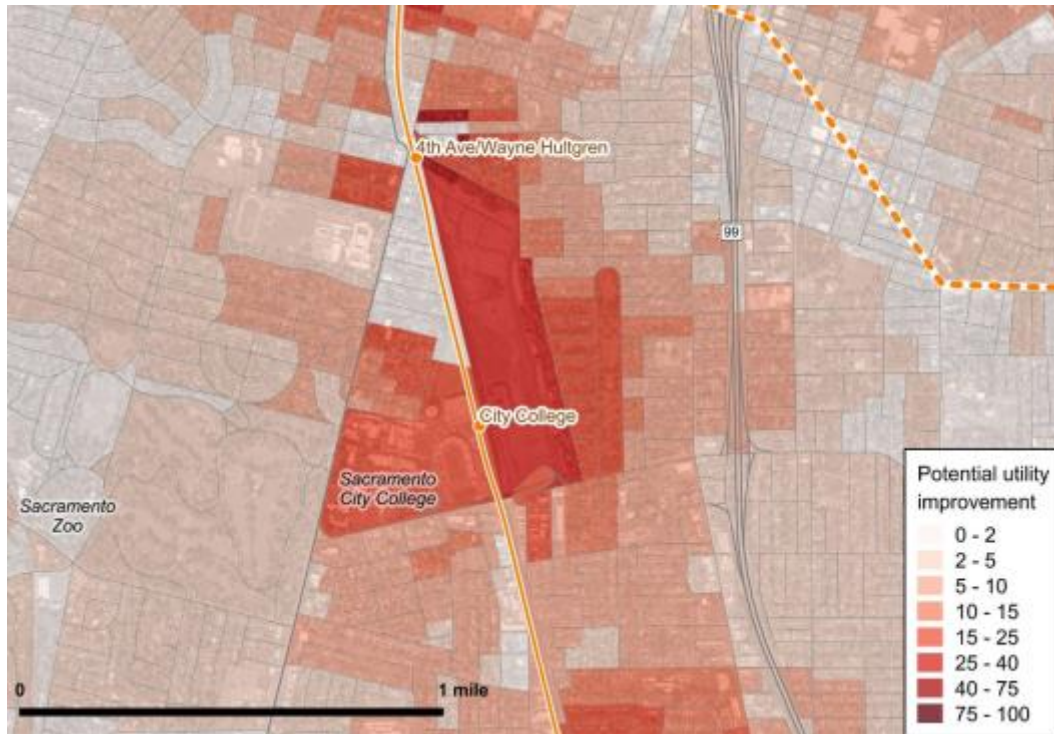


Figure 45. Potential utility improvement (0 to 100) around City College station

Figure 46 shows the increased access to jobs by transit that the new connection provides for neighborhoods east of City College station. The greatest benefit will go to those living in Crocker Village – a new infill development project abutting the bridge – who gain access to 17,000 jobs because of the bridge. Unlike the proposed Swanston station connections, the City College bridge does not offer substantial, system-wide accessibility improvements since the newly connected neighborhoods are mostly residential. However, Crocker Village is planned as a mixed-use transit oriented development with additional retail and grocery stores, which will benefit the system at large.



Figure 46. Improvements in access to jobs by transit due to new bridge at City College station

Stockton Boulevard bus corridor

The previous analyses treat all LRT lines as a collective transit catchment area. This approach ignores Stockton Boulevard, which carries express bus service and represents the city's busiest bus corridor. The analyses in this section treat the Stockton Boulevard bus corridor as an extension of the LRT system.

Figure 47 depicts existing transit accessibility along the corridor and nearby LRT corridors. As shown, transit accessibility along the north end of Stockton Boulevard and along Broadway (heading west) is comparable to transit accessibility at LRT stations along the Blue Line, running parallel to the west. However, levels of accessibility are more consistent along the corridor, as opposed to being concentrated around stations.

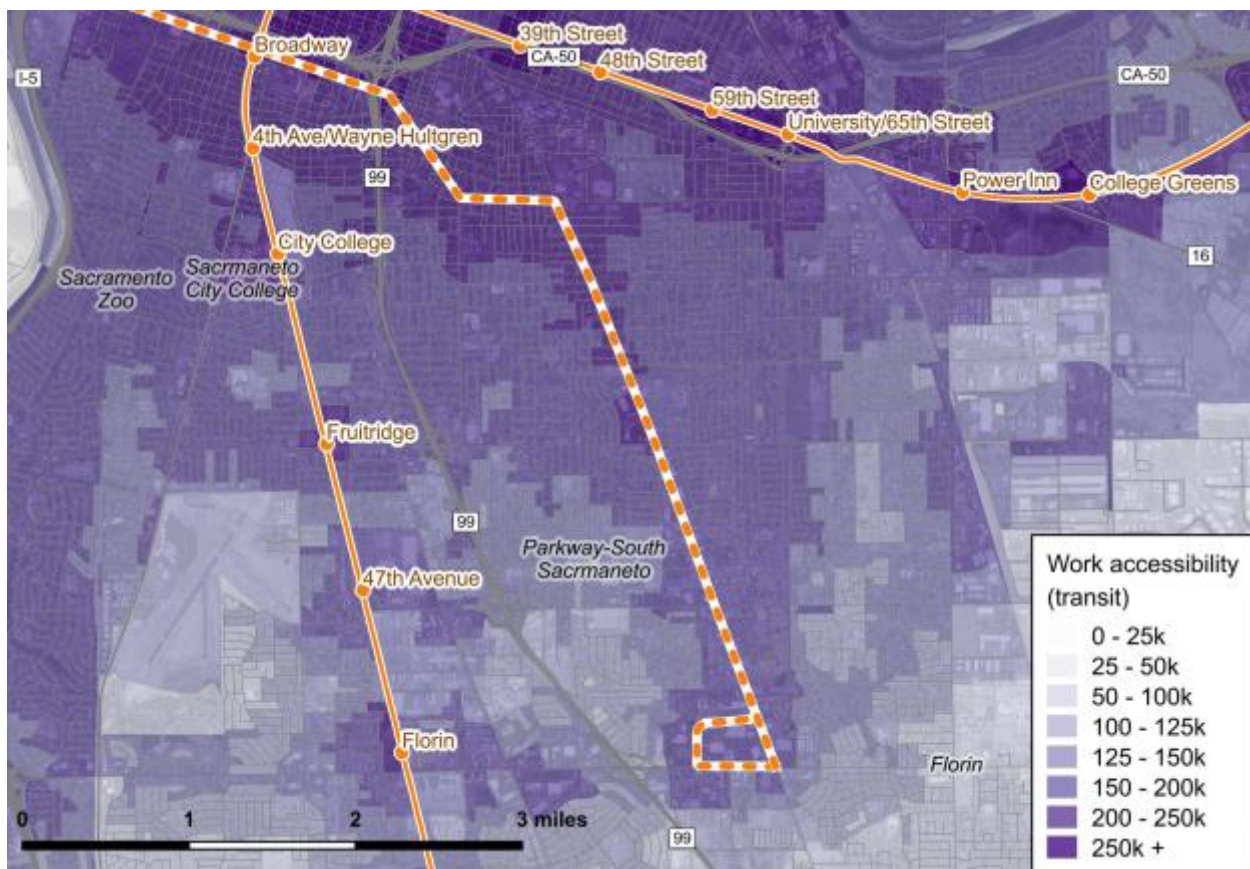


Figure 47. Access to jobs by transit along Stockton Boulevard

Because we're interested in bus trips, the transit trip-making data from Teralytics does not apply in this case. However, we can understand vehicle trip-making patterns along the corridor using StreetLight Data. Figure 48 shows the number of vehicle trips generated along Stockton Boulevard, ending within the combined Stockton Boulevard / LRT catchment area. As shown, the highest trip generation (6,300 trips per weekday) is at the end of the line, near the Florin Town Centre commercial area. Another 6,800 trips are generated along the rest of Stockton Boulevard.

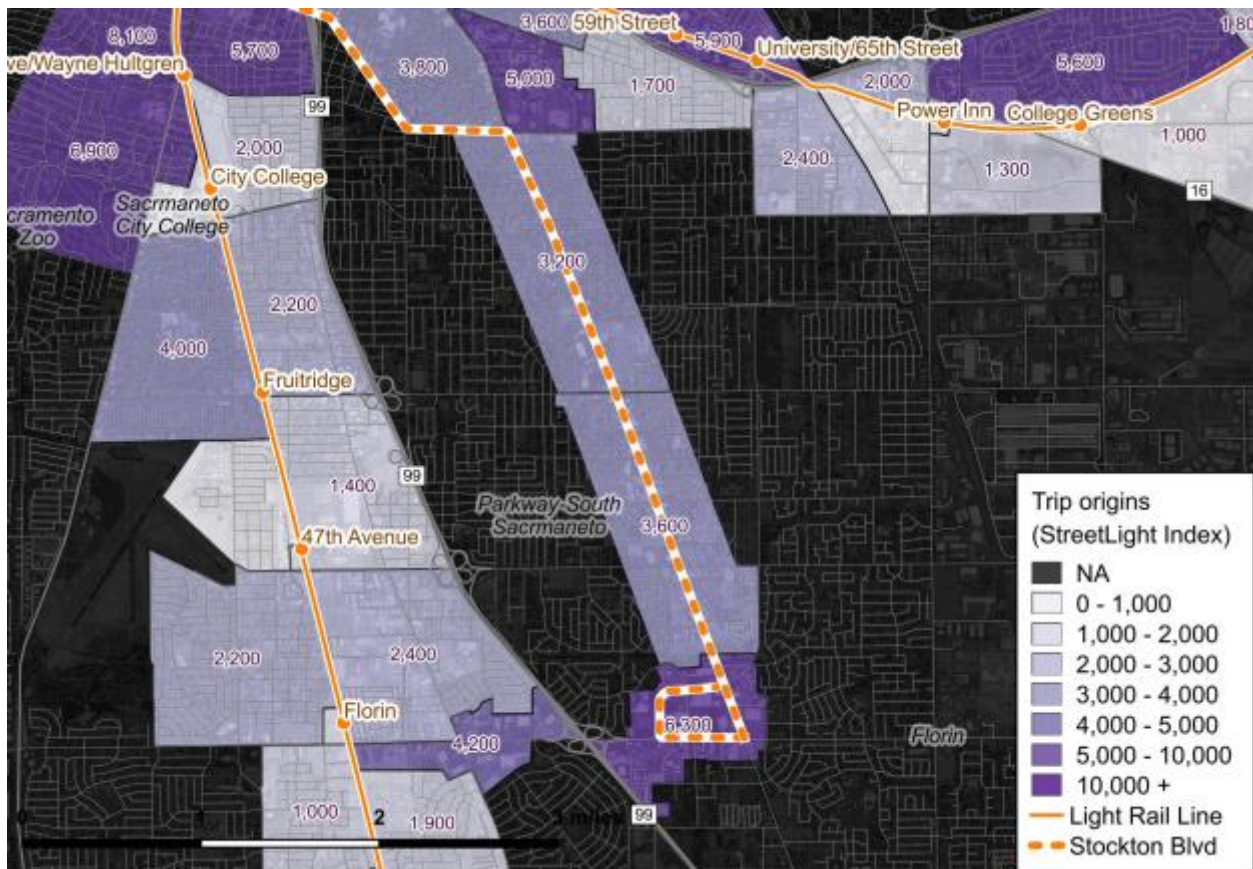


Figure 48. Vehicle trip generation for trips along Stockton Boulevard (StreetLight Data)

To better understand the potential to shift some of those vehicle trips to transit, we consider the trip destinations. Figure 49 shows the destinations of vehicle trips beginning at Florin Town Centre. More than 1,000 trips end somewhere along the Stockton Boulevard / Broadway bus corridor, meaning there is a high potential for those trips to be made by bus. Some additional trips end somewhere along the Gold Line and Blue Line north of Downtown, meaning they could be made by transit with a single transfer to LRT. Many trips, however, end south and west of Stockton Boulevard along the Blue Line, meaning they must be made by other local bus routes, which vary in frequency and directness. Again, some of these trips are part of longer trip trains and less likely candidates for LRT.

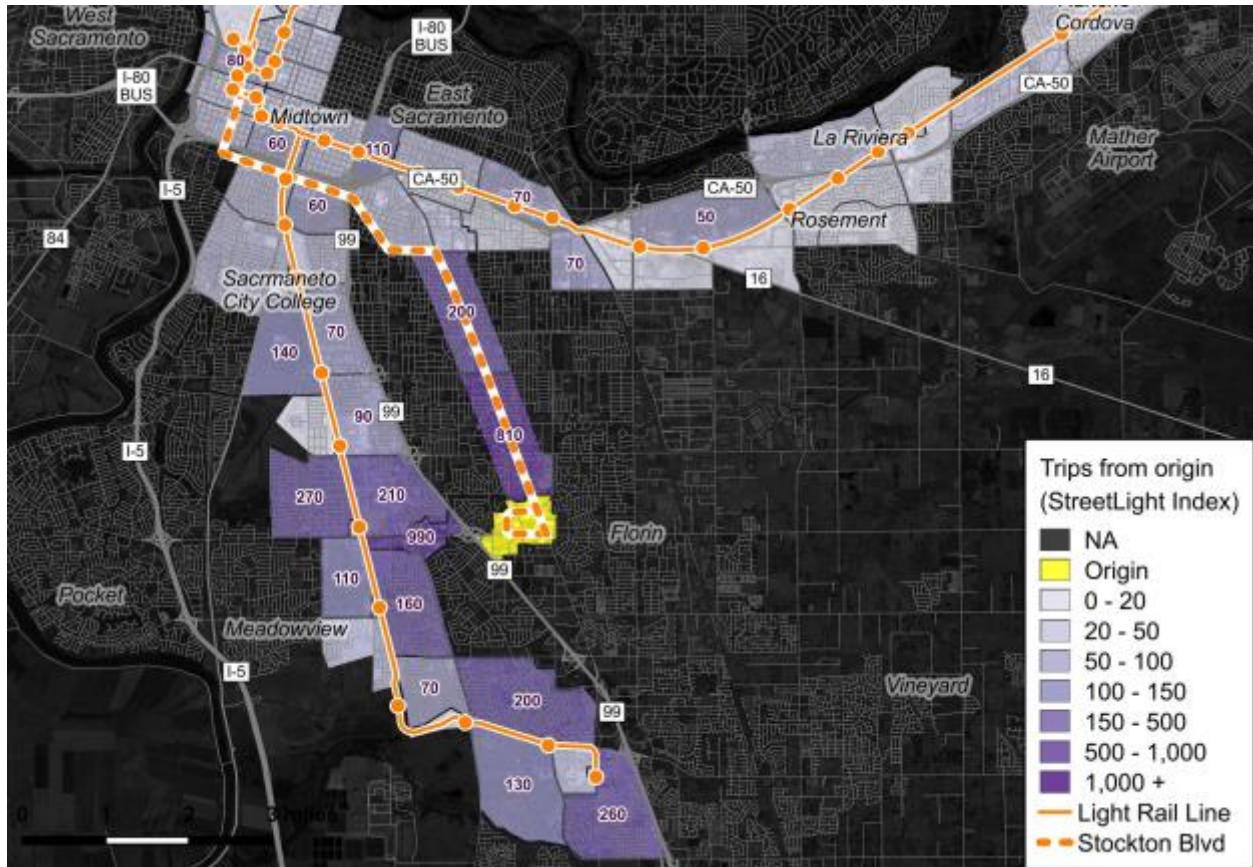


Figure 49. Vehicle trip destinations (StreetLight Data) – TAZ 3982 along Stockton Boulevard

Figure 50 and Figure 51 show the destinations of trips beginning elsewhere along Stockton Boulevard. These trip-making patterns suggest there is some potential for high-frequency bus service to capture short trips along the corridor.

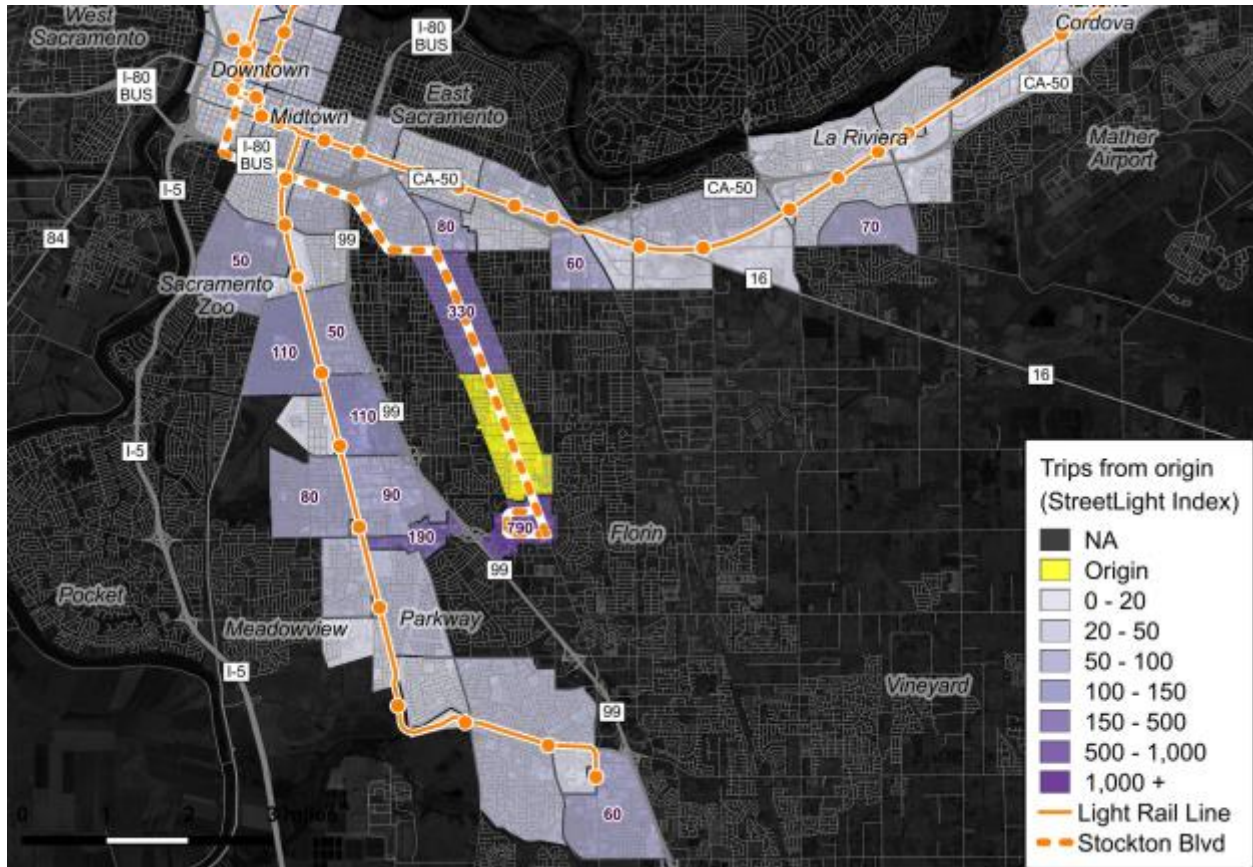


Figure 50. Vehicle trip destinations (StreetLight Data) – TAZ 4127 along Stockton Boulevard

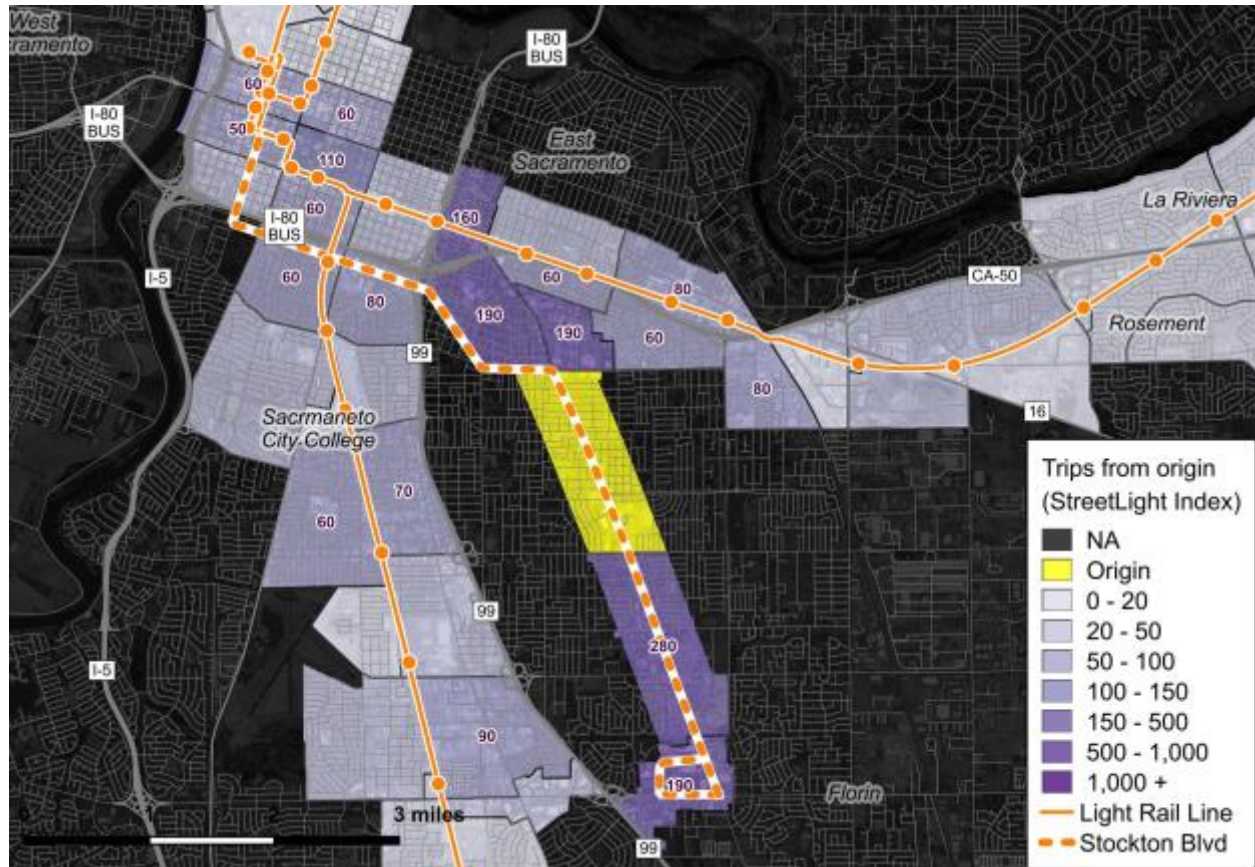


Figure 51. Vehicle trip destinations (StreetLight Data) – TAZ 3902 along Stockton Boulevard

Multi-modal trip-making around stations

An essential outcome of this project is the early development of methods for classifying observed GPS traces by mode. Previously, the data only let us characterize personal and commercial vehicle trips. This was possible because a large amount of data comes from in-vehicle GPS units. However, there is also abundant data from handheld GPS devices. The ability to detect pedestrian and bicycle trips using passive data is particularly valuable because of the profound scarcity of this type of data and the importance of planning and designing for those types of trips.

Early efforts to classify trips by simple speed characteristics – e.g. average and maximum speed – proved insufficient to separate modes consistently. However, by using machine learning techniques which assess interactions between more than 20 variables, and using a rich source of training data from outside of the study area, StreetLight Data has developed methods that can identify vehicle, bicycle, and pedestrian trip modes with promising accuracy. At the time of this study these methods were still in a trial phase, but trip metrics based on those methods are incorporated into this study on that basis.

One initial goal of this study was to incorporate field counts of pedestrian traffic to validate potential pedestrian trips observed in the GPS data. Those traffic counts came from continuous counters at 10 locations in downtown Sacramento collected using MotionLoft software. These data were provided by the Sacramento Downtown Partnership.

However, matching the field counts to GPS traces proved challenging. Field counts are taken at a precise location, while GPS traces are formed by connecting individual location pings, which vary in frequency. These traces rarely pass the precise field count location as needed. In the future, these traces may be locked to known pedestrian networks, like automobile traces, but these traces are more likely to stray from those networks.

For this study, comparing observed GPS traces to field counts gives us some sense of the penetration of GPS data. The penetration rate is still very low, but aggregated over several months or more, the data provides valuable insight about pedestrian trip-making patterns. In the following sections, we use the data to understand the relative number of pedestrian trips between light rail stations and nearby analysis zones. These analyses are based on two months of traces characterized as pedestrian trips. One temporary shortcoming of the data is that no traces shorter than 500 meters are counted as trips – an artifact of StreetLight’s vehicle trip classification methods.

At the time of this study, pedestrian trip-making data are still in research and development phases and only available on a trial basis. However, StreetLight Data plans to release a product before the end of this year. That product will rely on a larger sample and presumably address some issues, such as the exclusion of trips shorter than 500 meters.

Hazel station

Hazel station, identified by stakeholders at our initial kick-off meeting, serves as a useful introduction to station area pedestrian trip analysis. Figure 52 shows the relative number of trips passing through the Hazel station platform that begin or end in each of the surrounding analysis zones. These trips are expressed using a trip index, which is proportional to the observed number of trips. The trip index is consistent throughout this report. This lets us understand which areas generate the most transit riders system-wide, not only for a particular station, and understand

how factors like accessibility, the presence of households and jobs, and demographic characteristics potentially affect transit ridership.

The most frequent trips are those to and from adjacent zones to the north and south of the station. The large southern zone generates more than twice as many walking trips as any other zone. As shown in Figure 53, there is only a small concentration of activities (population and jobs) in the zones near the station. However, as shown in Figure 54, the station utility is very high from those two adjacent zones. This suggests that those at nearby apartments, businesses, and offices are more likely to walk to and from the light rail station than those across the Lincoln Highway (CA-50), immediately to the north or in other farther areas, as our accessibility analysis implies.

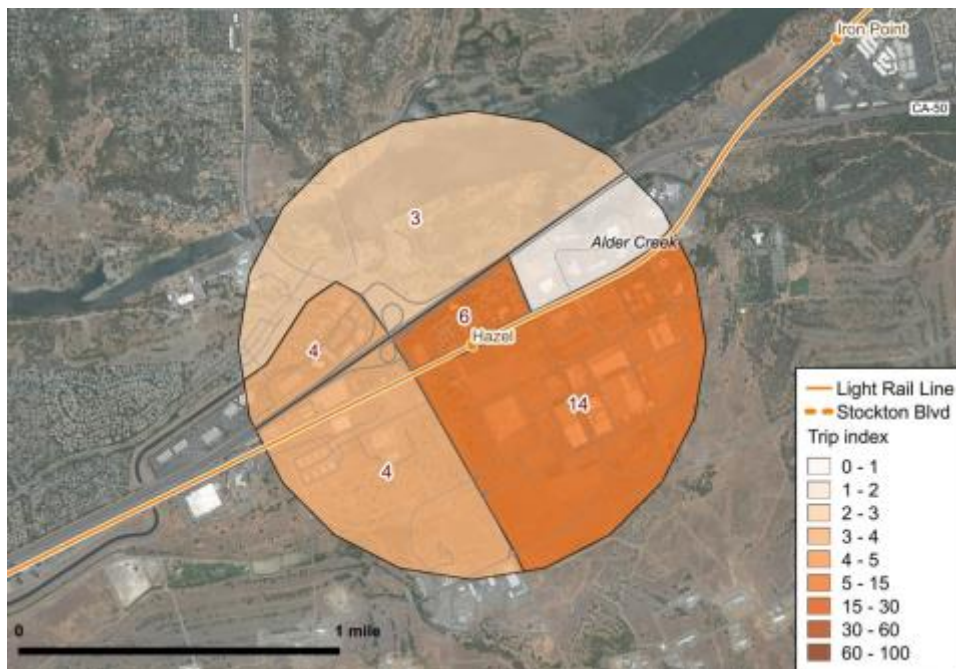


Figure 52. Relative walking trips to and from Hazel station platform

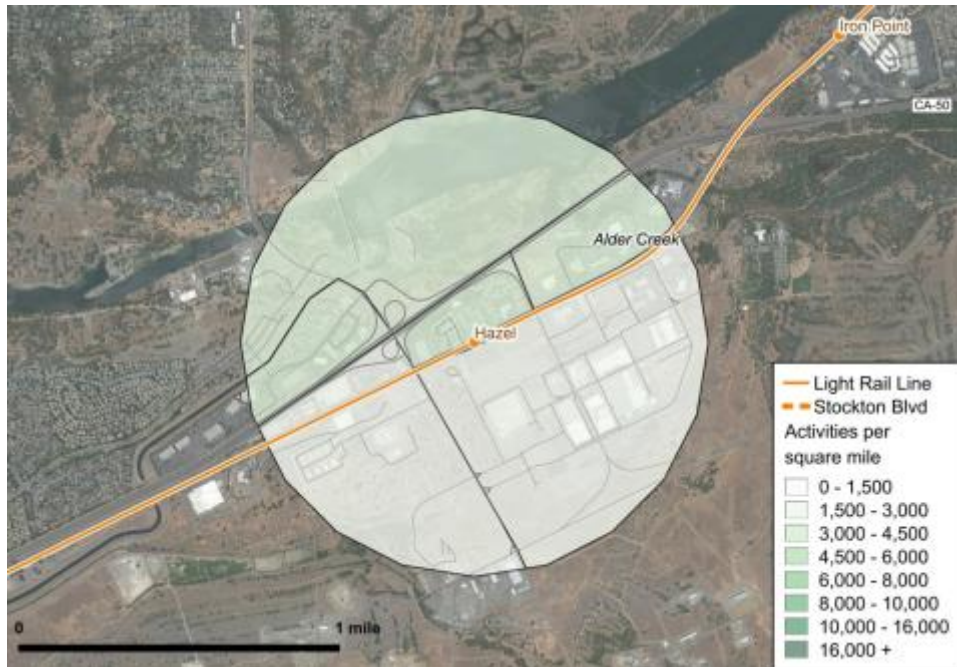


Figure 53. Activities (population + jobs) per square mile around Hazel station

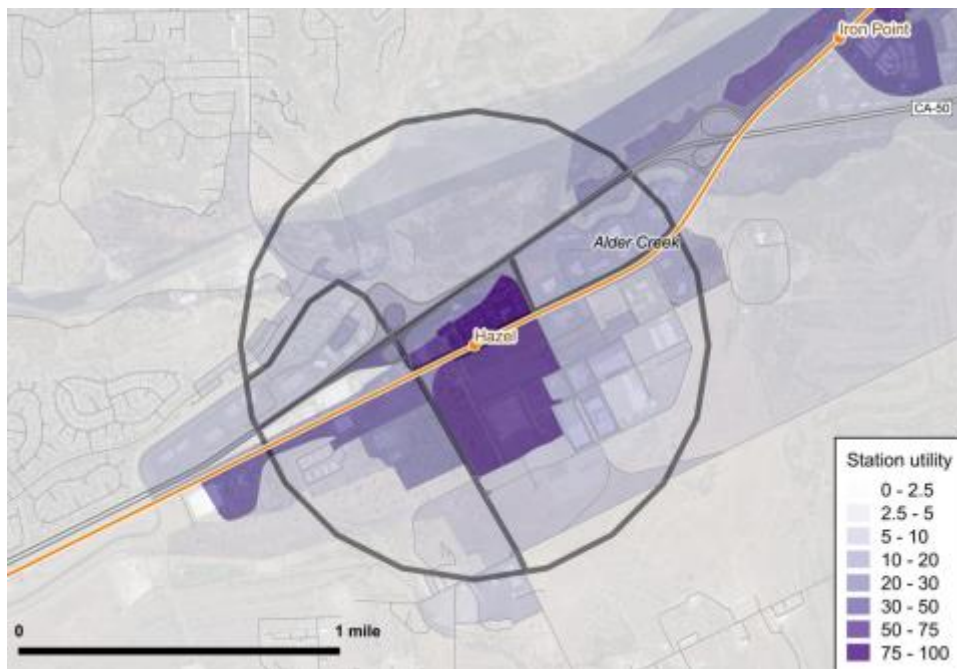


Figure 54. Station utility around Hazel station

Zinfandel and Cordova Town Center stations

The following analyses combine the results for Zinfandel and Cordova Town Center stations, which are less a half-mile apart. Figure 55 and Figure 56 show that Zinfandel station attracts

considerably more foot traffic than Cordova Town Center, but both stations attract most of their trips from adjacent zones to the northwest and southeast. Zinfandel station attracts more trips from the south and the west, while Cordova Town Center attracts more trips from the two zones to its north.

The large concentration of activities and the high station utility north of the light rail line explains the large number of trips to and from those areas. However, the large number of trips to and from zones to the south, including those across US-50, is unexpected. One possible explanation is that these are trips to and from jobs, as shown in Figure 59. In addition, people living in those southern zones are somewhat younger (median adult under 42) and have higher incomes (median above \$50,000).

Notably, the zone just north of Zinfandel station and the zone south of Cordova Town Center station (which both include large shopping plazas) produce more walking-to-transit trips than any other zone considered in this study.



Figure 55. Relative walking trips to and from Zinfandel station platform

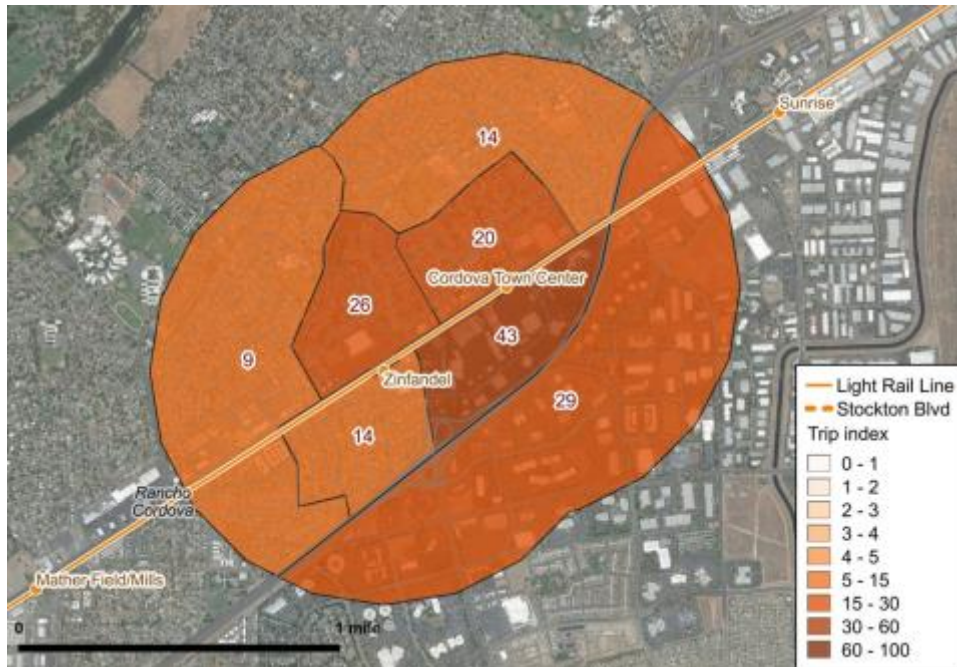


Figure 56. Relative walking trips to and from Cordova Town Center station

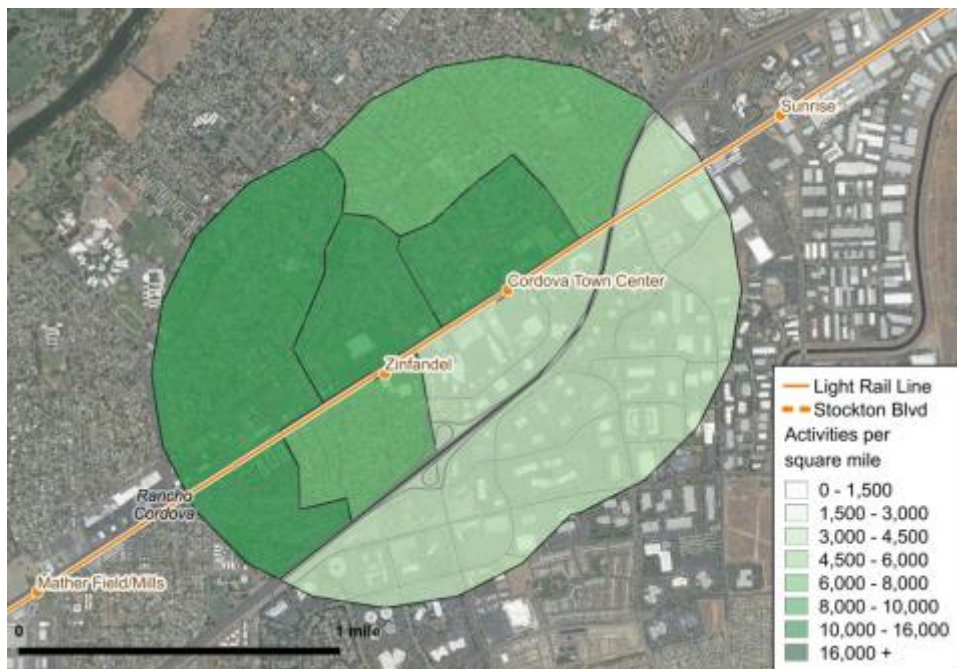


Figure 57. Activities (population + jobs) per square mile around Zinfandel and Cordova Town Center stations



Figure 58. Station utility around Zinfandel and Cordova Town Center stations



Figure 59. Jobs per square mile around Zinfandel and Cordova Town Center stations

Royal Oaks and Swanston stations

Royal Oaks and Swanston stations are also less than a half-mile apart. Royal Oaks station attracts many more walking trips than Swanston station, as shown in Figure 60 and Figure 61. Trips are

generally more frequent west of the freight line, where station utility is high (Figure 63), but some people do cross that line. East of the freight line, there is a high concentration of jobs, as well as a younger population (median adult under 42) and roughly 90 percent renters. The median income is under \$40,000 in most of the zones around either of these two stations.

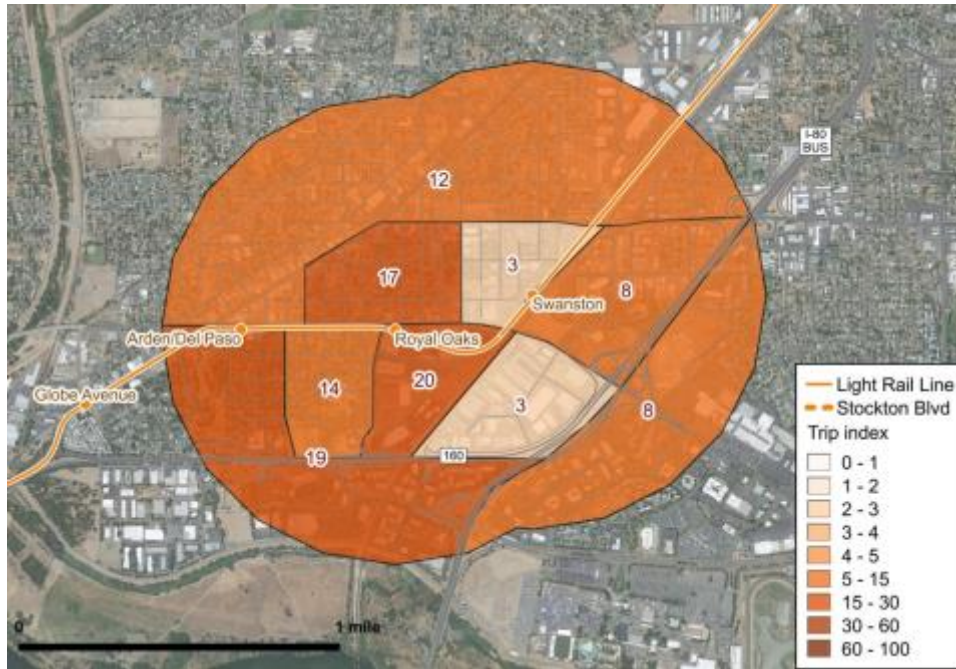


Figure 60. Relative walking trips to and from Royal Oaks station

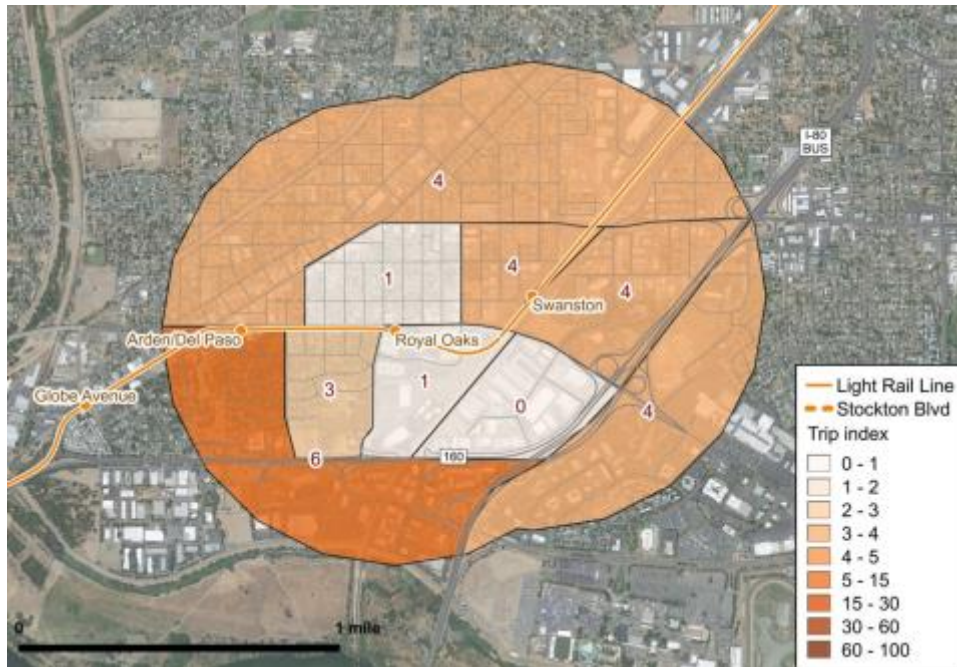


Figure 61. Relative walking trips to and from Swanston station

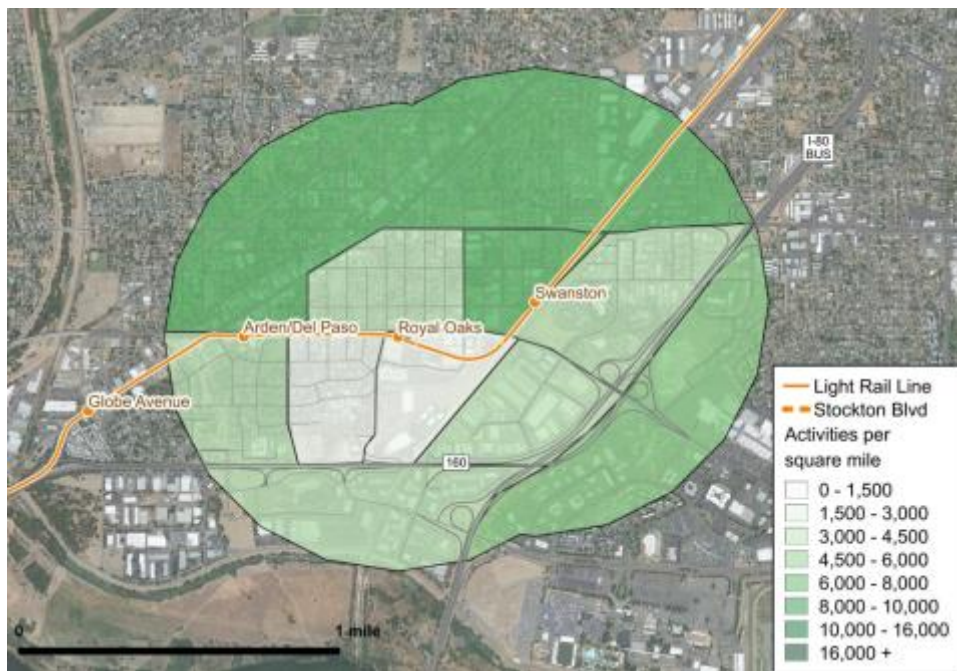


Figure 62. Activities (population + jobs) per square mile around Royal Oaks and Swanston stations



Figure 63. Station utility around Royal Oaks and Swanston stations

Automobile trips from LRT stations

Although it is somewhat outside the initial scope of this study, trip-making data provides useful information about the travel patterns of those accessing LRT stations by automobile. The following analyses show the destinations of trips beginning in some of the largest LRT parking lots. These data may provide insight into where shuttles, ridesharing services, and other last-mile alternatives might be most beneficial.

These analyses include TAZs outside of the transit corridors, which tend to be much larger, so the shading in the following figures represent trips per square mile. However, the total number of trips are labeled on each map.

I-80 stations



Figure 64. I-80 stations parking area

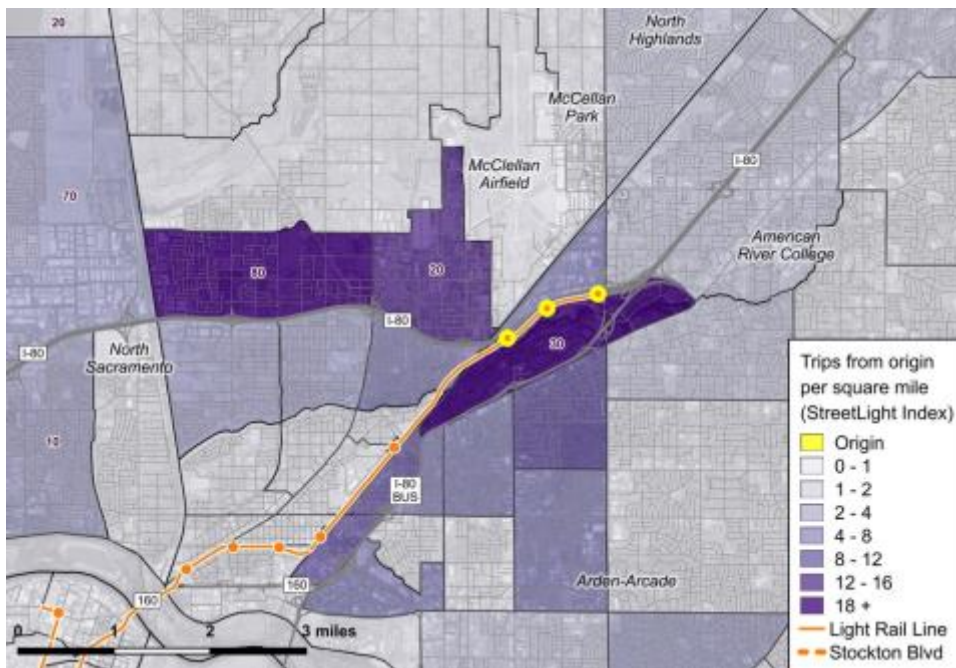


Figure 65. Vehicle trip destinations (StreetLight Data) – I-80 stations

Historic Folsom station



Figure 66. Historic Folsom station parking area

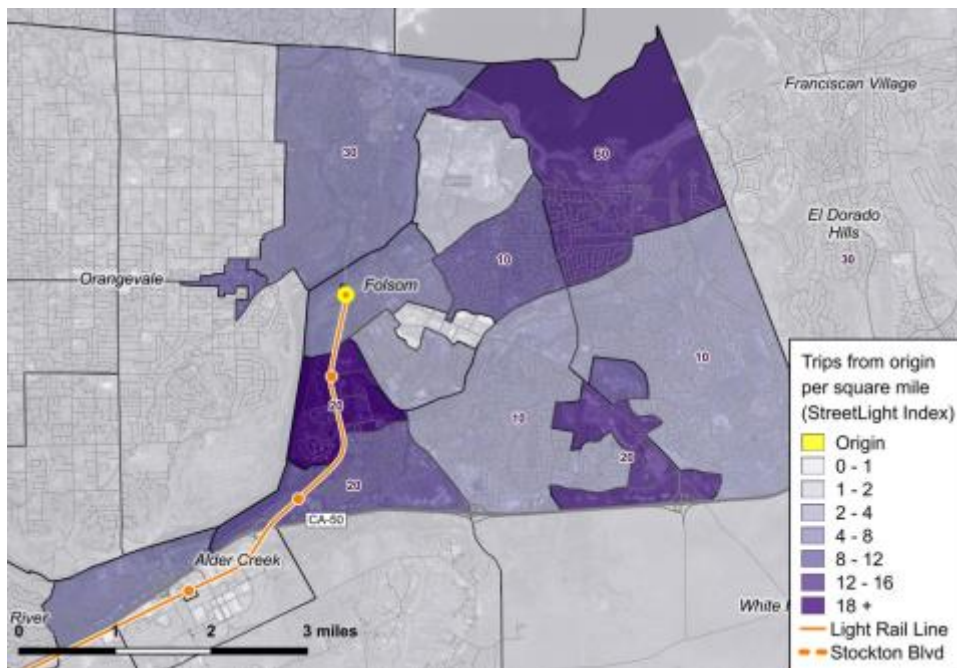


Figure 67. Vehicle trip destinations (StreetLight Data) – Historic Folsom station

Glenn station



Figure 68. Glenn station parking area

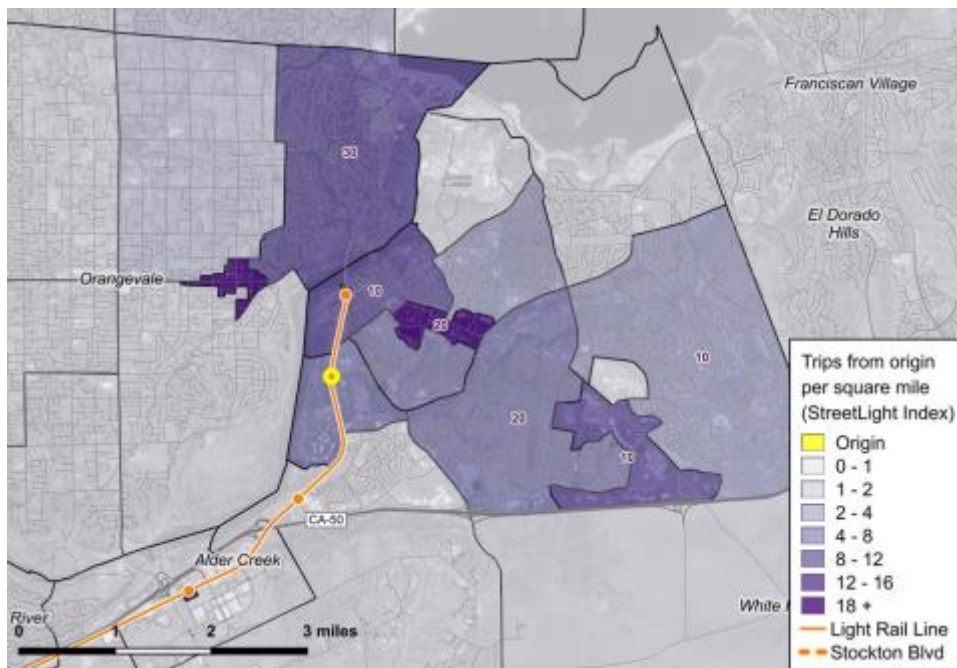


Figure 69. Vehicle trip destinations (StreetLight Data) – Glenn station

Iron Point station



Figure 70. Iron Point station parking area

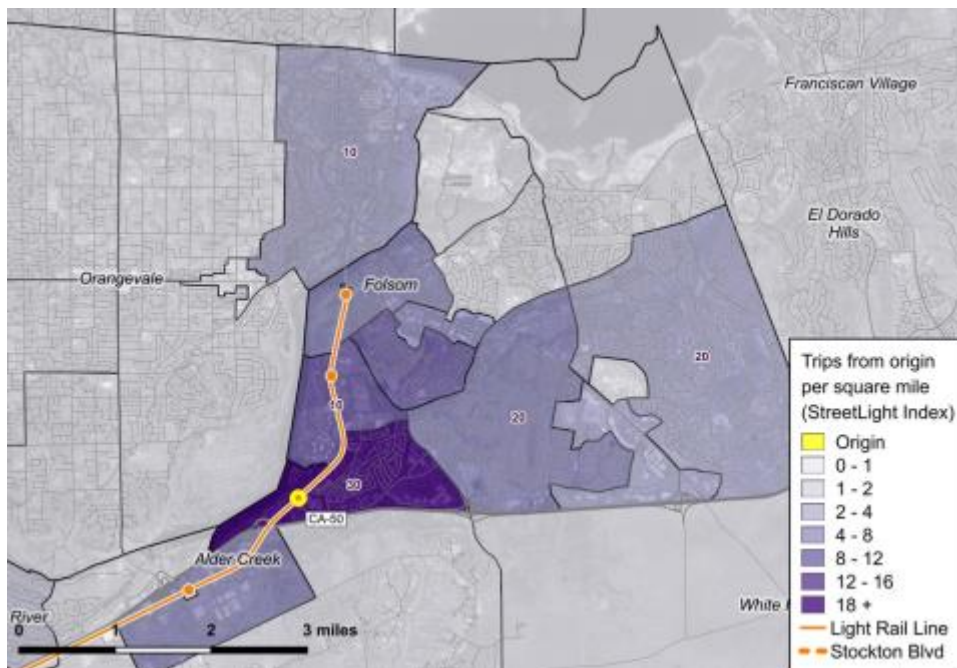


Figure 71. Vehicle trip destinations (StreetLight Data) – Iron Point station

Florin station



Figure 72. Florin station parking area

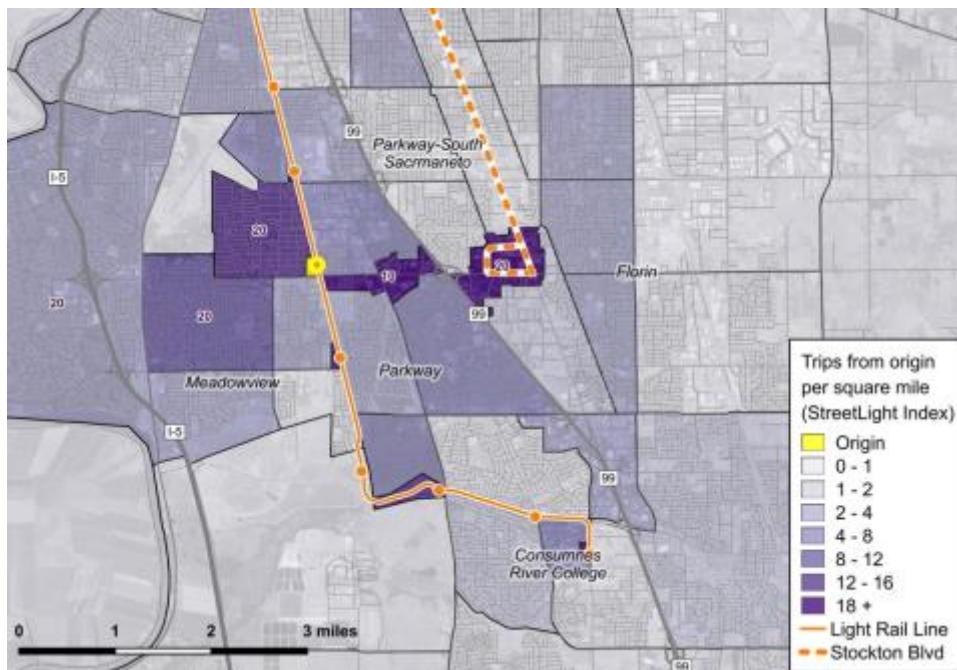
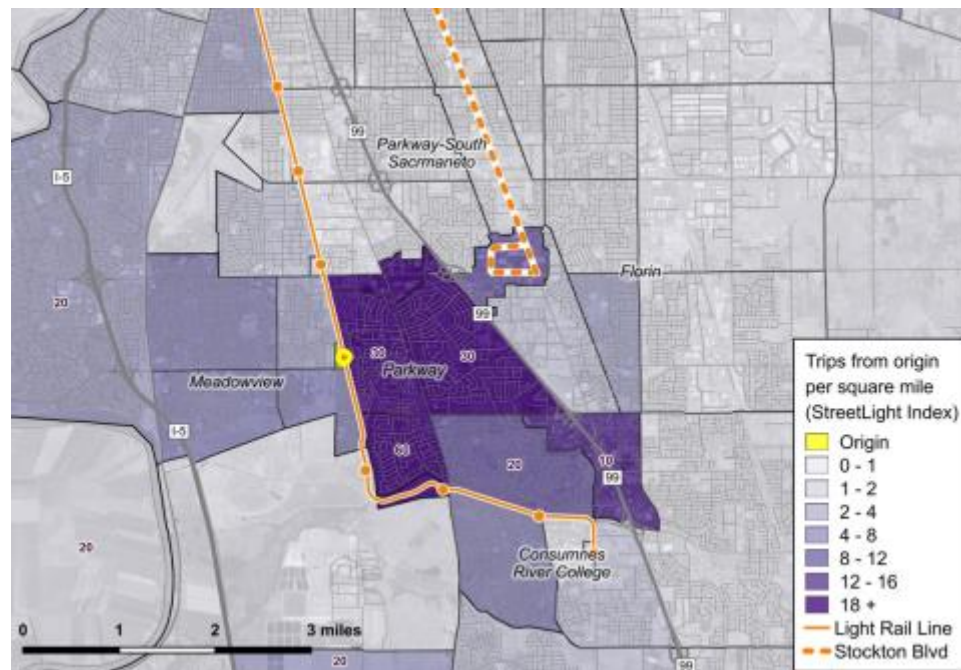


Figure 73. Vehicle trip destinations (StreetLight Data) – Florin station



Equity analysis

An important application of accessibility metrics is in conducting equity analyses. The purpose of these analyses is to ensure that transportation-related decisions benefit disadvantaged populations – e.g., low-income households, minorities, children, and the elderly – or at the least, do not disproportionately burden them. Figure 76 shows accessibility overlaid with poverty. In this case, accessibility is represented as access to low-income jobs by transit. The figure can be interpreted as follows:

- The bluest areas have the highest accessibility (and lowest poverty).
- The reddest areas have the highest poverty (and lowest accessibility).
- The green areas have high accessibility and high poverty (combined blue and red).

The reddest areas – those with poverty and poor accessibility – are those that need the most attention in addressing inequities.

This information has several important policy implications. First, it suggests that greater attention could be paid to providing equitable access in certain areas – e.g., Meadowview, the southern end of Stockton Boulevard near route 99, the North Highlands, and parts of North Sacramento – wherever transit improvements are reasonable. Second, it highlights areas that currently serve low-income households with good transit accessibility and ideal areas for future affordable housing.

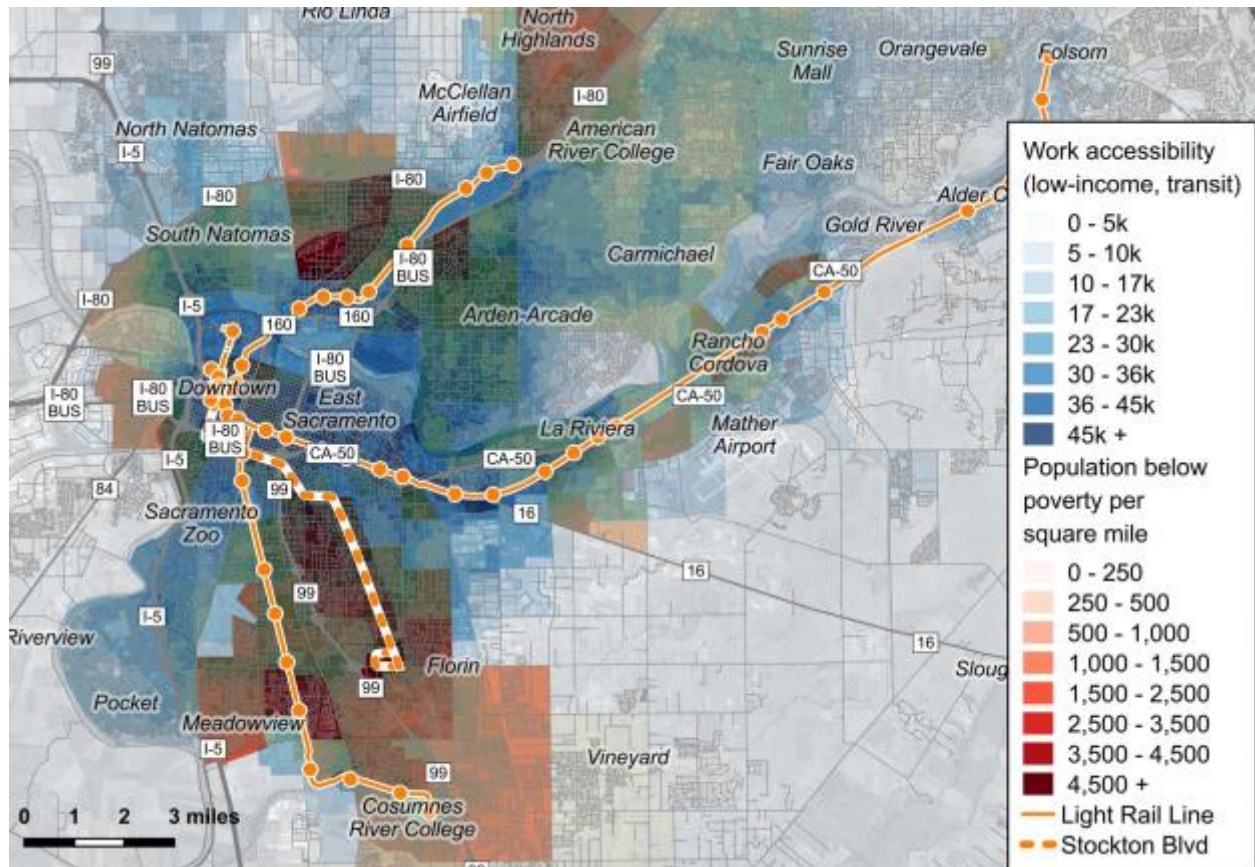


Figure 76. Access to low-income jobs by transit, overlaid with poverty

Visualizing these patterns can be challenging and there are many options for doing so, but the underlying data is essential for making informed decisions that improve equity and tracking progress towards advancing equity over time. For example, the City of Sacramento and related agencies may set goals related to the percentage of low-income households that should meet a minimum acceptable level of transit accessibility, then work towards meeting those goals.

Appendix A. Geographic relationships

Census data (e.g., households, jobs, incomes, and automobile ownership) are reallocated to TAZs based on the percentage of overlapping areas. The intersection between TAZs and census block groups is calculated in QGIS. For block groups that intersect with more than one TAZ, the percent of its area in each TAZ is calculated. Population, households, and vehicles are then allocated to each TAZ accordingly. To simplify these calculations, this method does not account for how the population is distributed within a block group, but future work may incorporate these more advanced techniques.

Certain values, such as medians, cannot be assigned proportionally using the approach described above. Therefore, estimates are developed using the available categorical data. To calculate median age, for example, the total population within each age group are first reallocated based on the methods above. Age groups include the following: 0-4, 5-9, 10-14, 15-17, 18-19, 20, 21, 22-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-61, 62-64, 65-66, 67-69, 70-74, 75-79, 80-84, and 85 or older. To estimate the median age for a particular zone, the bin corresponding with the median individual is identified and the midpoint is selected. Therefore, if the median individual falls in the 55-59 bin, the median is estimated as 57. If the median individual falls in the 60-61 bin, the median is estimated as 60.5. The same method is used to estimate median incomes.

Appendix B. Teralytics validation

Since Teralytics data is only provided as aggregate flows among zones, the same validation procedure as with StreetLight Data (see Appendix 3) is not possible. However, because Teralytics relies on a single data source with a considerably large penetration rate, the same level of validation is not entirely necessary. Using information about the market penetration of devices, Teralytics interpolates its data to the entire population and reports absolute trip numbers.

For this study, Teralytics trips are reported as LRT trips and non-LRT trips. To validate these reported values, we compare the aggregate number of LRT trips reported by Teralytics to the actual number of LRT boardings reported by Sacramento Regional Transit.

The Teralytics data represents approximately 43,100 LRT trips during a typical weekday in March 2015. This compares well to data from Sacramento Regional Transit, which reports 43,001 average daily trips during the same quarter.

Shown below is the distribution of Teralytics LRT trips by time of day during a typical weekday and weekend, which are consistent with our general understanding of transit trip-making patterns and with the LRT's hours of operation.

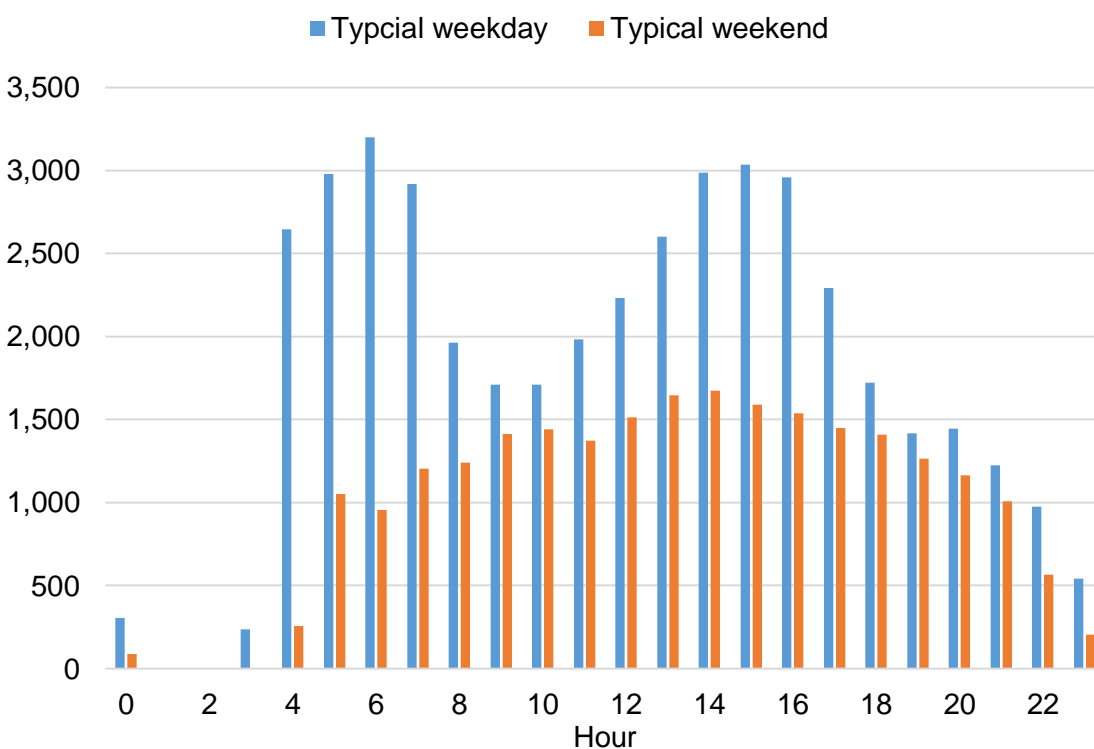


Figure 77. LRT trips by time of day for a typical week in March 2015 (Teralytics)

Appendix C. StreetLight Data validation

StreetLight Data reports traffic flows as a StreetLight Index. This number is based on observed GPS traces, but the data is first cleaned, analyzed, and aggregated before being reported. This value is meant to be consistent across different geographies and over time but does not represent actual trip numbers.

To validate and interpret the reported StreetLight Index values, we compared those values to annual average daily traffic (ADT) counts on specific highways throughout the Sacramento study area. These data, provided by Caltrans, represent actual observed traffic on 30 highway segments between 2004 and 2014 (two outlying observations, each with traffic counts below 4,000, are omitted). Truck traffic is subtracted from each total ADT for comparison to personal vehicle data from StreetLight Data. The relationship between ADT from non-trucks and the corresponding StreetLight Index for personal vehicles are shown below.

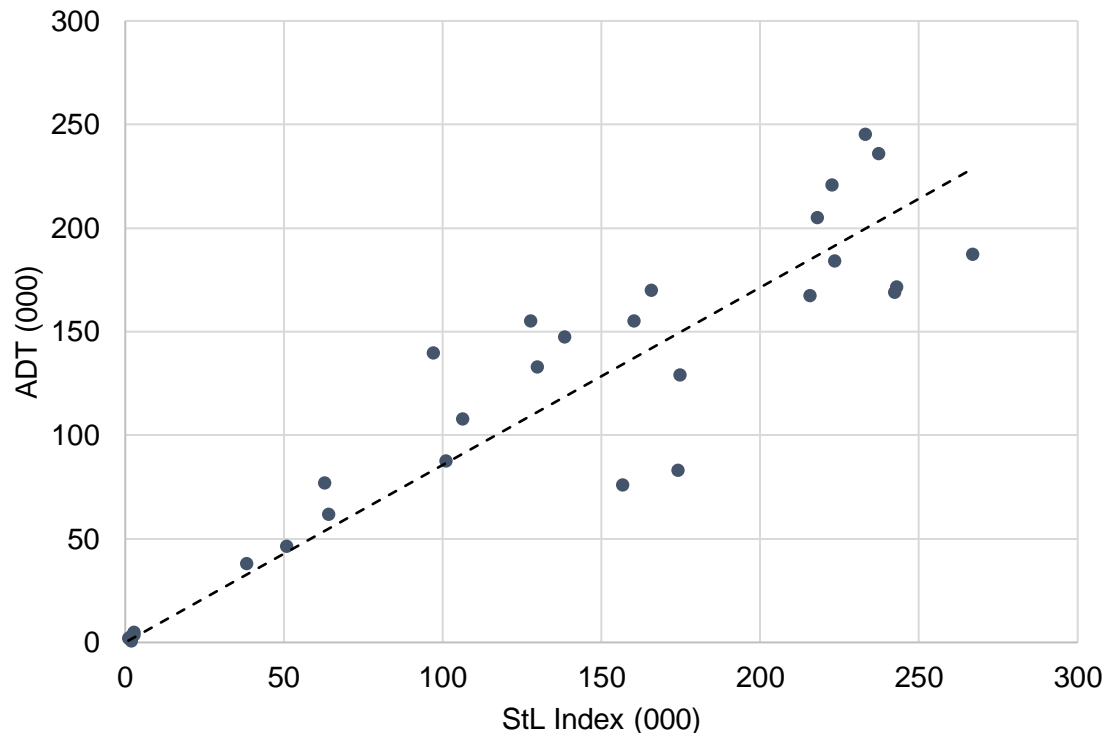


Figure 78. Relationship between observed traffic counts (ADT) and reported trip index values from StreetLight Data (StL Index) on 30 highway segments

The relationship between ADT and StreetLight Index values is strong. The fitted regression equation has an R-squared value of 0.95 and the relationship is significant with greater than 99 percent confidence. Treating ADT as the dependent variable and assuming a zero-intercept, the coefficient on StreetLight Index is 0.85.

Therefore, to approximate actual trips, we recommend multiplying reported Streetlight Index values by 0.85.