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Initiatives to Effectively Help Reduce Traffic Congestion in the Tri-Valley

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Initiatives to Effectively Help Reduce Traffic Congestion in the Tri-Valley

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Abstract. In this paper, we present a comprehensive analysis of the current transit systems in the Tri-Valley of the Eastern Region of the San Francisco Bay Area. Using the most recent data available from various sources and significant research we provide a close look into ridership trends, public surveys and transit reports. System maps, connections, routes and schedules are analyzed from all the mass transit systems available in the Tri-Valley region. Transit system infrastructure, resources and limitations are assessed and presented. Different performance metrics are also evaluated and compared against mass transit systems available in other parts of the San Francisco Bay Area. Throughout various data analysis techniques, the extend of societal, geographic, economic and environmental factors are studied and assessed. Demographics are closely studied and analyzed with an aim to understand commuting behaviors and needs for the residents of all cities, towns and unincorporated areas within the Tri-Valley. Predictions for the Tri-Valley region are also presented. We focus on unveiling knowledge from ridership trends, Public Transit Systems and their available routes and resources. We create and present data visualizations, perform data mining and use statistical techniques to identify patterns and opportunities. Our results indicate that a significant mobility function exists between the residents of Contra Costa and Alameda counties and the cities of San Francisco, Oakland and San Jose. With a commute volume of 66%, investing in mass transit, scaling current Public Transit Systems and leveraging the resources in the region are key initiatives to effectively help reduce traffic congestion in the Tri-Valley.

1 Introduction

Traffic in the Tri-Valley Region of the San Francisco Bay Area, is an everyday problem for thousands of people. It is also a problem affecting not only the environment, but the quality of life of the habitants of the region. This paper analyses the magnitude of the prevailing traffic conditions in the Tri-Valley region of the eastern San Francisco Bay Area, studies the current transit systems, its resources and limitations, and takes a closer look at ridership and commuter patterns, integrating a collection of prospect alternatives to effectively help reduce traffic congestion in the area.

Formed by the cities of Pleasanton, Livermore, Dublin, San Ramon, Danville and the unincorporated communities of Alamo and Blackhawk in Northern California, the Tri-Valley region is located approximately 28 miles east of San Francisco and 45 miles north of San Jose. It is considered a suburb of both main metropolitan areas and their surroundings, including those along Oakland to the north and the high-tech hub of Silicon Valley to the south. As estimated in the 2010 census, the region has over 360,000 habitants and includes one of fastest-growing cities in the state of California[3].

The Tri-Valley region is a home to many lakes, state and regional parks, mountains, trails and open space preserves. It is also home to numerous vineyards near the city of Livermore in the east, and golf courses in the north. Its cities are well known for their tree-lined streets, clean parks and Mediterranean-like weather. Its public schools are often ranked of the highest and the housing conditions remain overall more affordable than other cities within the rest of the Bay Area.

For the habitants of the Tri-Valley region, it is not uncommon to spot a lot of wildlife. Eagles, deer, coyotes, owls, squirrels and many different types of birds are seen often in people's backyards. A mix of desert, mountain and coastal species compose the biological community and ecosystem in the area.

Due to the fact that life in the Tri-Valley region is considered privileged and highly appraised within the Bay Area, a vast number of young families keep moving in looking for the excellent schools, larger homes with generous backyards and a well- balanced lifestyle suitable to raise children in a nurturing and safe environment. The problem with this however is the settlement of highly educated families in an area which is miles away from the main professional work centers but limited in Public Transit Services that would satisfy the ever-increasing need for mass transportation in the region.

The Tri-Valley is estimated to have a median household income of $140,000 with both parents working in most of the families, having to spend long commuting hours to Santa Clara, San Mateo and San Francisco Counties (commute volumes increasing 66% since 2007)[4]. In addition, manual labor in the region reportedly comes from even further away working class suburbs located in the farthest north and east ends of the Contra Costa and Alameda Counties, congesting the zone to some of the worst levels seen in the San Francisco Bay Area.

In recent years, pollution and heavy traffic in the Tri-Valley has become of the highest concern and a recurrent top story in the local news. Numerous articles of daily traffic incidents on Interstate 680 refer to recurrent notifications of traffic alerts and road closures causing major delays in this extremely important highway, which communicates north and south bypassing several cities on the east of the San Francisco Bay Area and Silicon Valley in Santa Clara County[5]. Even though some strategically placed infrastructure has been made available to connect the region to well-established Public Transit Systems such as BART through the stations at Walnut Creek and West Dublin/Pleasanton, connection to these end-points is not efficient within the cities that integrate the Tri-Valley region. This represents a major problem for the habitants in the

[3] https://visittrivalley.com/plan-your-trip/getting-here/
[4] http://www.bayareaeconomy.org/files/pdf/BACEI_Tri_Valley_report.pdf
[5] https://en.wikipedia.org/wiki/Interstate_680_(California)

region, who in many cases are forced to rely on their cars as a medium of transportation to and from their work centers.

Highways and boulevards in the Tri-Valley area as a consequence get highly congested at various times during the day. The problem is most severe during peak commuting hours especially in the evenings, when up to two hours of waiting in traffic has become the norm over distances that would otherwise only take 20 minutes. With traffic comes along hidden tolls such as pollution, long commuting hours and higher levels of stress that affect society, public health and the environment. The Tri-Valley region is at a serious risk of becoming yet another badly-congested area in the world comparable to the extent of cities like Los Angeles and New York City with all of the negative effects that come with it. Pollution, endangered species, several public health issues, and disrupted families are only a few of the understated traffic side effects in the Tri-Valley region. Immediate attention and a resolution that is effective, realistic and practical for the years to come is now long overdue and of the highest priority. In this paper we research and analyze the most recent data available from the US Census along with public and private ridership data. We investigate and visualize ridership trends, commute volumes. We analyze current Public Transit Systems in the Tri-Valley and their resources. We visualize routes, connections and research demographic data that allows us, through data mining techniques, to identify opportunities to effectively help reduce traffic in the Tri-Valley. We identify that connections between BART and ACE are needed and that investing in mass transit alternatives must be prioritized. Reliable mass transit to BART is key as parking in the Walnut Creek and Pleasanton BART stations is limited and does not meet the high demand. The addition of ACE southbound trains must also be prioritized.

In this paper we present detailed data about the Tri-Valley, its demographics and geography. We look closely at the Public Transportation Systems available in the region. Ridership trends, routes and resources are analyzed for BART, ACE, WHEELS and County Connection. Through data mining techniques and data visualizations we identify opportunities and initiatives to help reduce traffic congestion in the Tri-Valley. General ethical principles are also discussed.

2 Life in the Tri-Valley

In 2018, it is hard to imagine a place where unspoiled wildlife, city life and urban facilities coexist. Public and private services integrate into a well-maintained system of streets and highways, clean parks, excellent schools, and health agencies along with environmental institutions. With one of the lowest crime rates in the state of California[6], lowest average dollar per square foot in the San Francisco Bay Area, vast mix of wildlife, Mediterranean weather, and only 25 miles from San Francisco to the North and 45 miles from San Jose to the South, the Tri-Valley region offers high quality of

[6] https://www.paragon-re.com/trend/current-sf-home-value-tables-by-neighborhood

life in Northern California attracting not only the development of new businesses and young families but highly skilled talent[7] and entrepreneurs[8].

Table 1. Average dollar per square foot in the San Francisco Bay Area, Q4 2017 – Q1 2018

Region	Zone	Average dollar per square foot
Tri-Valley	San Ramon[9]	$493
Tri-Valley	Pleasanton[10]	$530
San Francisco	Potrero Hill[11]	$897
San Francisco	Mission Bay[12]	$1,113
San Mateo County	San Carlos[13][14]	$1,195
San Jose	Downtown[15]	$737
Santa Clara County	Lost Gatos[16][17]	$937
Santa Clara County	Palo Alto[18]	$1,708

[7] http://www.bayareaeconomy.org/files/pdf/BACEI_Tri_Valley_report.pdf
[8] https://www.paragon-re.com/trend/tri-valley-real-estate-market-report
[9] https://www.census.gov/quickfacts/fact/table/sanramoncitycalifornia/PST045217
[10] https://www.realtor.com/local/Pleasanton_CA
[11] https://www.realtor.com/local/Potrero-Hill_San-Francisco_CA
[12] https://www.trulia.com/real_estate/Mission_Bay-San_Francisco/1437/market-trends/
[13] https://www.trulia.com/real_estate/San_Carlos-California/
[14] https://en.wikipedia.org/wiki/San_Carlos,_California
[15] https://www.trulia.com/real_estate/San_Jose-California/
[16] https://www.zillow.com/los-gatos-ca/home-values/
[17] https://en.wikipedia.org/wiki/Los_Gatos,_California
[18] https://www.trulia.com/real_estate/Palo_Alto-California/

2.1 Geography

The Tri-Valley is located in the Eastern San Francisco Bay Area. It takes its name from the conjunction of the San Ramon Valley, the Livermore Valley and the Amador Valley, occupying a total area of about 120 square miles. It is home to many state and regional parks among which some of the most important are Las Trampas Regional Wilderness, Mt. Diablo State Park, The Livermore Valley Wine Country[19], Del Valle Regional Park, Pleasanton Ridge Regional Park, and Morgan Territory Regional Preserve. It also hosts several renowned golf courses like Crow Canyon Country Club, Diablo Country Club and The Castlewood Country Club. It is mainly accessible from San Francisco via Bay Bridge/I-80 and I-580, from Silicon Valley through I-680 North and from Oakland/Berkeley through I-880 South[20].

Table 2. List of important natural reserves and parks in the Tri-Valley[21].

Natural Preserve
Mount Diablo State Park
Las Trampas Regional Wilderness
Bishop Ranch Regional Preserve
Shadow Cliffs Regional Park
Pleasanton Ridge Regional Park
Arroyo Moncho
Arroyo Valle
Arroyo Seco
Las Positas
Brushy Peak Regional Preserve
Del Valle Regional Park

[19] https://www.winecountry.com/regions/livermore-tri-valley/
[20] https://en.wikipedia.org/wiki/Tri-Valley
[21] https://visittrivalley.com/things-to-do/outdoors/

Fig. 1. Tri-Valley location in the Bay Area[22].

2.2 Demographics

The population in the Tri-Valley region is estimated to be around 360,000 per the 2010 United Stated Census, representing close to five percent of the approximately 7.68 million people who live in the San Francisco Bay Area[23]. The Tri-Valley along with other cities in the East Bay mainly from Contra Costa and Alameda Counties constitute the densest region within the Bay Area outside of San Francisco and San Jose, with a race composition of mainly Caucasians followed by Asians. The Tri-Valley is integrated by the cities of Danville, San Ramon, Dublin, Pleasanton, Livermore and the unincorporated communities of Alamo and Blackhawk with the city of Livermore being the most populous within the Tri-Valley[24]. Cities in the Tri-Valley are considered some of the wealthiest suburbs in the San Francisco Bay Area[25]. Furthermore, the city of Pleasanton was reportedly ranked one of the wealthiest cities in the United States in 2013[26].

The sub-regions, are all well characterized by elements that define the charm and city lives of each one. San Ramon is host to several headquarters of major labs and companies while Alamo, a relatively small city located between the cities of Walnut creek and Danville, is established near a green belt with homes built on lots of 0.5

[22] California map source http://www.broadbandmap.ca.gov, edited with Adobe Spark
[23] https://en.wikipedia.org/wiki/San_Francisco_Bay_Area
[24] https://patch.com/california/livermore/tri-valley-ranked-among-100-safest-towns-california-latest-analysis-shows
[25] https://en.wikipedia.org/wiki/Danville,_California
[26] https://en.wikipedia.org/wiki/Pleasanton,_California

acres[27]. Blackhawk, located on the foothills of Mt. Diablo, is a master plan community with a country club, golf courses and its own shopping plaza. It comprises seven gated communities with a total of 3345 households. According to the 2010 Census, Dublin is the second fastest-growing city in California.

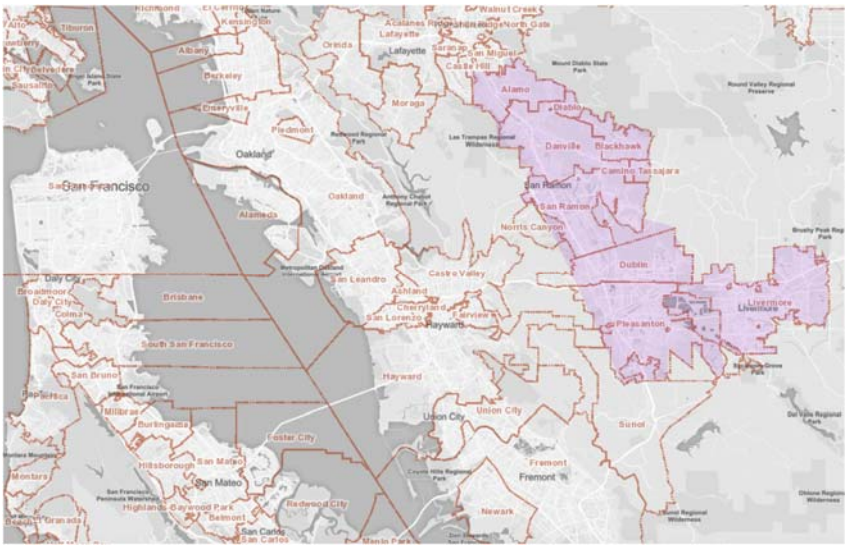

Fig. 2. Cities in the Tri-Valley region[28].

Table 3. Population Distribution by City in the Tri-Valley[29].

City	Estimated	Whites	Asians	Hispanics	Households with children	Adult Population	Median Household Income
Danville	44,631	83%	10%	6.8%	40%	60%	$129,515
San Ramon	79,000	53%	35.6%	8.7%	47.4%	62.6%	$119,297
Dublin	60,000	51.3%	26.8%	14.5%	39%	64.9%	$114,699
Livermore	90,000	64.7%	8.2%	20.9%	38.6%	65.1%	$96,632
Pleasanton	82,270	67%	23%	10.03%	42.7%	62.1%	$101,022
Alamo	14,750	86.9%	8.2%	5.8%	37.32%	56.7%	$140,561
Blackhawk	9,354	73.6%	19.3%	5.0%	37.1%	61.7%	$167,875

[27] https://en.wikipedia.org/wiki/Alamo,_California

[28] Bay Area Map Identified by Cities source http://www.broadbandmap.ca.gov, edited with Adobe Illustrator.

[29] https://www.census.gov

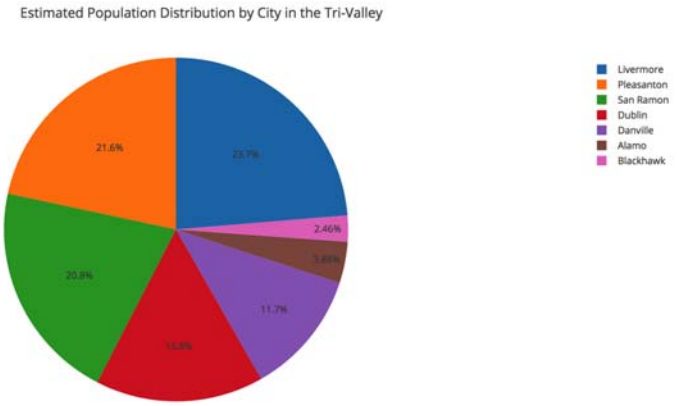

Fig. 3. Population Distribution by City in the Tri-Valley[30].

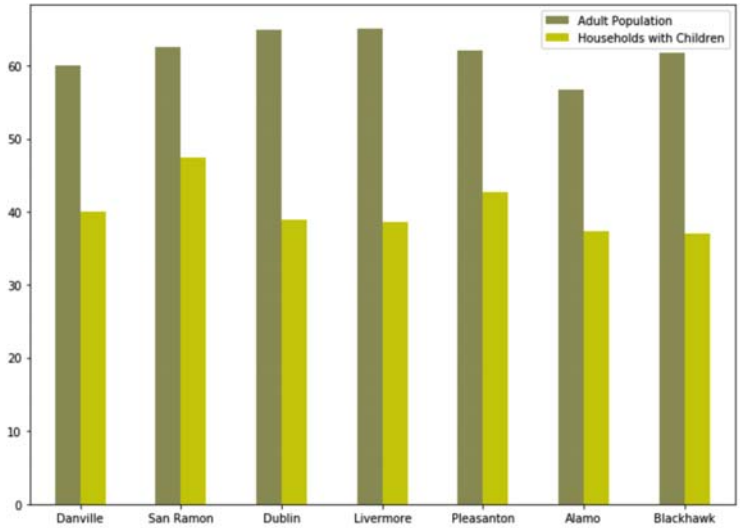

Fig. 4. Adult Population Distribution by City in the Tri-Valley[31].

Figure 3 shows that the cities of Livermore, Pleasanton and San Ramon have significantly larger estimated population numbers compared with other cities within the

[30] Data source https://www.census.gov Visualization done using Online Graph Maker - Plotly Charts https://plot.ly/create/#/

[31] Data source https://www.census.gov Visualization done using Pandas

Tri-Valley. However, Figure 4 shows that the ratio of adult population and households with children is similar across each of the different seven cities which compose the region, with San Ramon having the highest number of households with children followed by the city of Pleasanton.

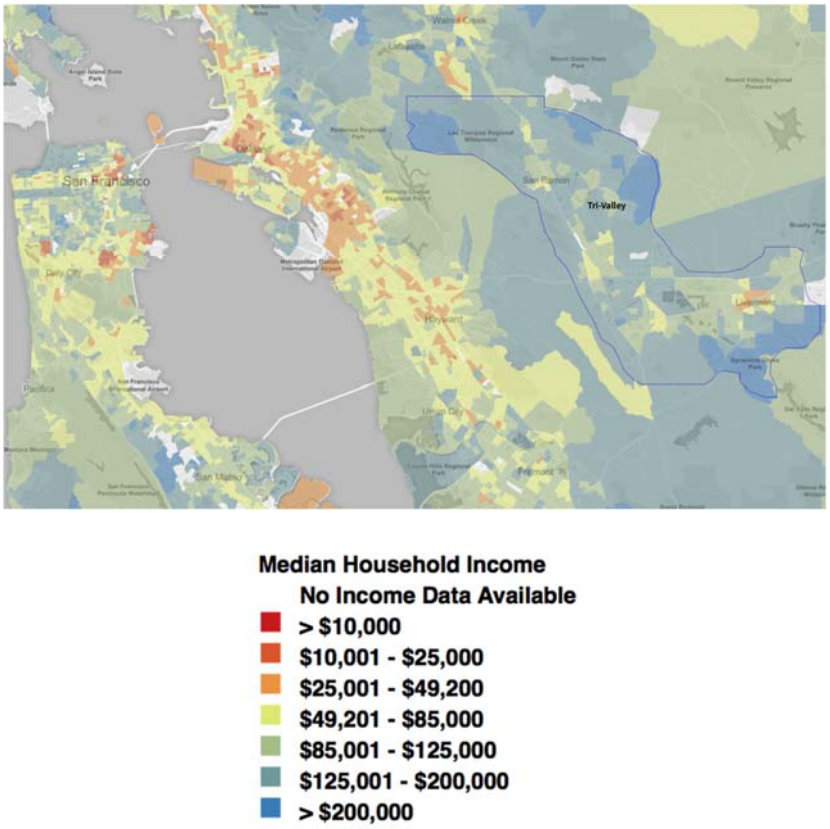

Fig. 5. Bay Area Median Household Income[32].

According to the Association of Bay Area Governments (ABAG) and the Metropolitan Transportation Commission, the population growth for the Tri-Valley region has been projected to be one of the highest in the San Francisco Bay Area along with Santa Clara and San Francisco Counties, exalting the need for the creation of initiatives that effectively address the traffic situation in those areas[33].

[32] http://www.broadbandmap.ca.gov Identified by Median Household Income, edited with Adobe Illustrator CC

[33] https://mtc.ca.gov/sites/default/files/2-The_Bay_Area_In_2040.pdf

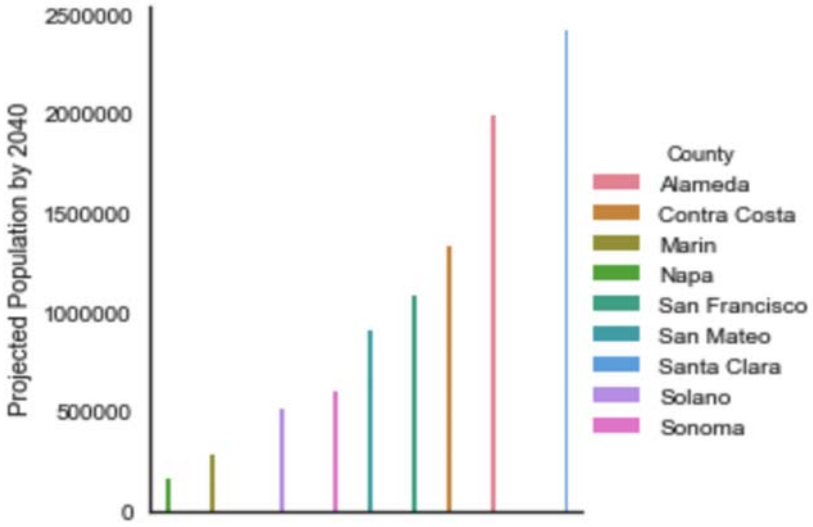

Fig. 6 Projected Population for 2040 in the San Francisco Bay Area by County[34].

A region of highly educated and skilled people, it was estimated per the Bay Area Economy Report, that the percent of adults with a master's degree increased from 16 to 21 percent between the years of 2000 and 2012. Moreover, about 30% of all foreign-born workers in the Tri-Valley are STEM (Science, Technology, Engineering and Math) workers. Approximately 62,185 foreign-born workers live in the Tri-Valley[35].

The Tri-Valley also greatly invests in educating their local youth population to be highly skilled and college prepared including all STEM areas. School Districts in the Tri-Valley have a rating of 9-10 in primary schools and middle schools which in consequence lead to high rates for high school graduation compared with the rest of the Bay Area[36].

Also measured by the Academic Performance Index in 2013, the schools in the Tri-Valley reported a superior Growth API compared to the rest of the Bay Area and California[37].

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[34] Data source https://mtc.ca.gov/sites/default/files/2-The_Bay_Area_In_2040.pdf, visualization using Seaborn

[35] http://www.bayareaeconomy.org/files/pdf/BACEI_Tri_Valley_report.pdf

[36] https://www.greatschools.org/gk/ratings/

[37] http://www.bayareaeconomy.org/files/pdf/BACEI_Tri_Valley_report.pdf

Table 4. Education Measures in Tri-Valley[38].

Measure	Region	Score
High School Graduation Rates	Tri-Valley	95%
High School Graduation Rates	Silicon Valley	80%
College readiness	Tri-Valley	60%
College readiness	Rest of Bay Area	40%
Average 2013 Growth API	Tri-Valley	908
Average 2013 Growth API	Silicon Valley	842
Average 2013 Growth API	Rest of California	790

2.3 Transportation

The Tri-Valley has three main mass public transportation systems: a local bus service (WHEELS39), Bay Area Rapid Transit (BART) and the Altamont Corridor Express (ACE). Also serving the Tri-Valley cities of Danville, San Ramon and unincorporated areas of central Contra Costa county is the Transit Agency County Connection. With a fleet of 184 buses and four electric trolleys it provides fixed routes and paratransit bus services[40]. Several transit resources have also been made successfully available across the entire San Francisco Bay Area, covering each of its nine counties from north to south, and west to east. Several commuter benefit programs and resources have been implemented. Clipper card, FastTrak, express lanes, discount incentives, web-based and mobile transit apps are few examples.

[38] http://www.bayareaeconomy.org/files/pdf/BACEI_Tri_Valley_report.pdf

[39] https://www.wheelsbus.com/about/

[40] https://countyconnection.com/about/electric-buses/

Table 5. Transit Systems and their available resources in the Tri-Valley

Agency	Promotions	Mobile App	Parking	Clipper Card	Express Routes	Service Animal	Bike Racks	Paratransit Service	Trip Planner
WHEELS	Yes[41]	Yes	No	Yes	Yes	Charge	X4	Yes	N/A[42]
BART	Yes[43]	Yes	Yes	Yes	Yes	Free	Yes	Yes	Yes
ACE	Yes[44]	Yes[45]	Free	No	NA	Yes[46]	Yes[47]	Yes	Limited[48]

Commute. Despite all of the many available resources and significant investments, traffic congestion has continued to grow. According to the 2012-2016 American Community Survey 5-year Estimates, hundreds of thousands of people drive alone from the Tri-Valley Counties of Alameda and Contra Costa[49] to their work centers. Moreover it is estimated that by 2040, the San Francisco Bay Area will grow from 7.7 million people to 9.1 million, similar to large metropolises like New York and Bangkok which face some of the worst traffic jams in the world[50].

[41] https://twitter.com/i/web/status/1007706843668467713

[42] https://tripplanner.transit.511.org/mtc/XSLT_TRIP_REQUEST2?language=en

[43] https://www.bart.gov/guide/customerservices

[44] https://www.acerail.com/Getting-You-There/Transfers-Shuttles/ACE-VTA-Better-Together

[45] https://511.org/transit/centers

[46] https://www.acerail.com/Getting-You-There/FAQ

[47] https://www.acerail.com/Getting-You-There/FAQ

[48] https://www.acerail.com/Getting-You-There/Trip-Planner

[49] https://www.census.gov/search-results.html?page=1&stateGeo=none&searchtype=web&cssp=&q=transportation&search.x=0&search.y=0&search=submit

[50] https://mtc.ca.gov/sites/default/files/2-The_Bay_Area_In_2040.pdf

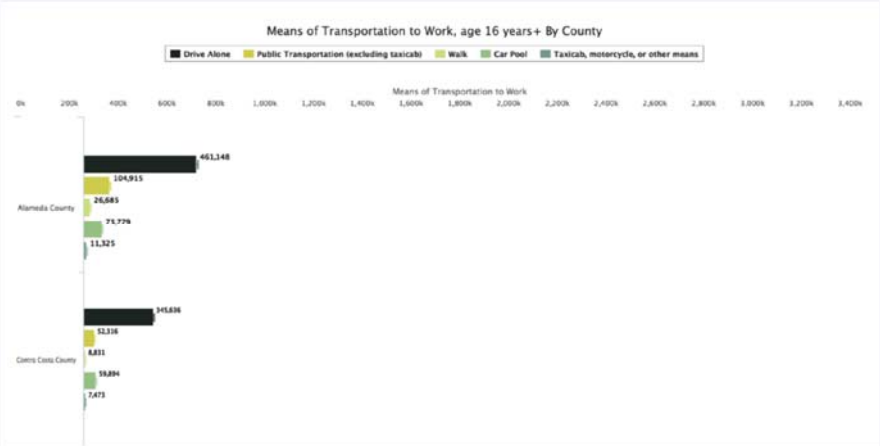

Fig. 7. Means of Transportation to Work by County[51].

Table 6. 5 year estimates commuting to work by County

	Alameda[52]	Contra Costa
Car, truck, van – drove alone	62.6%	
Car, truck or van – carpooled	10.0%	
Public Transportation (excluding taxicab)	14.2%	
Walked	3.6%	
Other Means	3.6%	
Worked at Home	6.0%	

While looking closer at the data, we perform clustering analysis over the 2016 ACS 5-Year Estimates Contra Costa County Means of Transportation by Selected Characteristics dataset. The results as expected show observations to be dense for people who decide to drive alone and to be more scattered for those who decide to use public transportation, meaning a large percentage of workers 16 years or older who reside in Contra Costa County, do prefer to rely on an automobile as their mean of transportation to their work centers, including carpooling options.

[51] https://www.census.gov/search-results.html?page=1&stateGeo=none&searchtype=web&cssp=&q=transportation&search.x=0&search.y=0&search=submit

[52] https://data.census.gov/cedsci/results/tables?q=Alameda%20County,%20California&g=0500000US06001&tab=ACSDP5Y2016.DP03&ps=app*page@1$table*currentPage@1

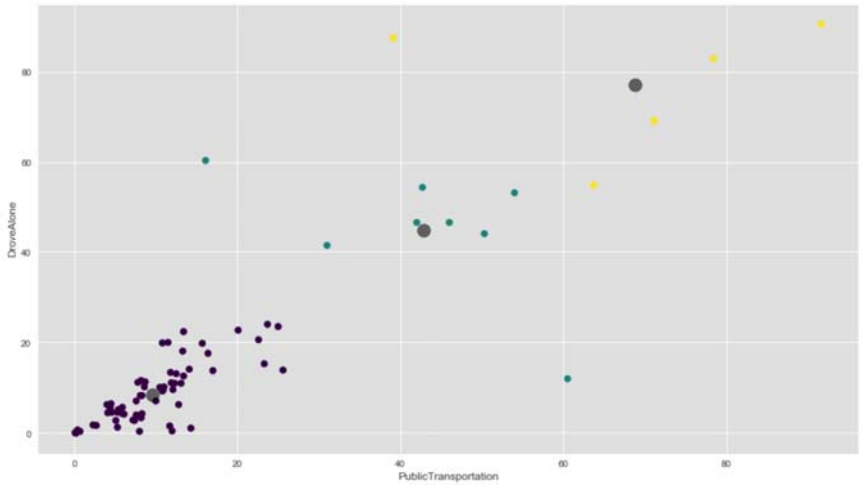

Fig. 8. Contra Costa County Means of Transportation - Clustering Data Analysis[53]**.**

In an attempt to understand more about the data, dimensions, trends and variations which determine the chosen means of transportation to work centers among the residents in Contra Costa County, we decide to mine the data even further . Since the Contra Costa County Means of Transportation dataset has multiple dimensions, a subspace is desired where much of the variation could be explained with a reduced number of dimensions. To do this, we rely on a Principal Component Analysis for the purpose of reducing dimensionality. The original Contra Costa County Means of Transportation dataset has 78 dimensions which are then projected into the top two dimensions (principal components) of variation. Per the obtained variance ratio, our analysis shows the first principal component explains 58.15% of the variance while the second principal component explains 41.84% of the variance, representing together 99.99% of the information.

[53] Appendix: Contra Costa County Means of Transportation - Clustering Data Analysis

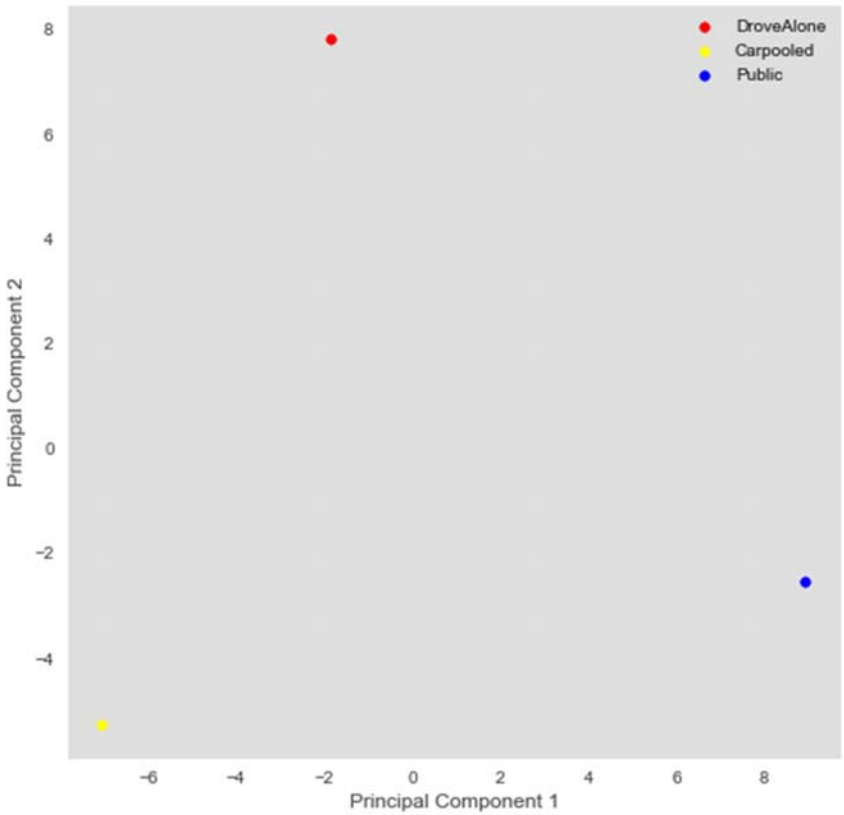

Fig. 9. Contra Costa County Means of Transportation –Top Two Components[54].

Next, we decide to rely on parallel coordinates[55] to visualize (in the simplest form) how distinct data points explain the means of transportation to work chosen by the residents of Contra Costa County based on their specific demographic data.

The results show that people in Contra Costa County between the ages of 25 and 44 years old rely upon public transportation as their means to commute to their work centers, however there is a shift in preferences for people 40 years old and older. People in this age range choose to drive alone during their commute. This has a significant impact on the traffic in the region, especially in relation to the 61.87% average estimated adult population who reside in the Tri-Valley. Also, among the different races which comprise the population in the Tri-Valley, Hispanics are shown to be more prone to carpool when compared to people of different racial background. Hispanics account for an estimated average of 10.24% of the population in the Tri-Valley. Results show that people with the highest earnings are less likely to opt for carpooling and use public

[54] Appendix B: Contra Costa County Means of Transportation –Principal Component Analysis.

[55] Appendix C: Contra Costa County Means of Transportation –Parallel Coordinates Analysis

transportation instead, particularly those who work on the finance, insurance and scientific sectors.

In regard to travel distance and time, the results reveal that people who leave their homes before 7:30AM rely more on public transportation; however, a large percentage of people in Contra Costa County leave their homes after 8:30AM in which case the preferred means of transportation to work is to drive alone or carpool. In the Tri-Valley it is estimated that an average of 58.44% households are families who need to arrange for children to attend their school centers, usually by 9:00AM.

Alternatively, we believe more data insights might be gained from performing association rules data analysis, however such a task would require the collection and storage of transactional-level data.

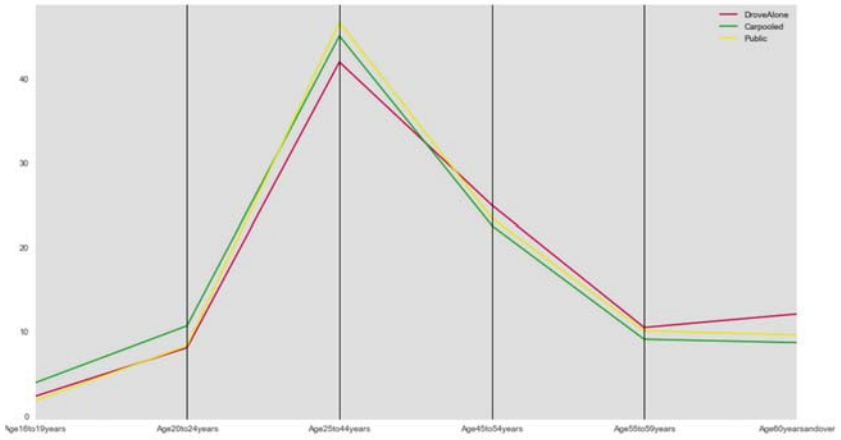

Fig. 10. Contra Costa County Means of Transportation – By Age

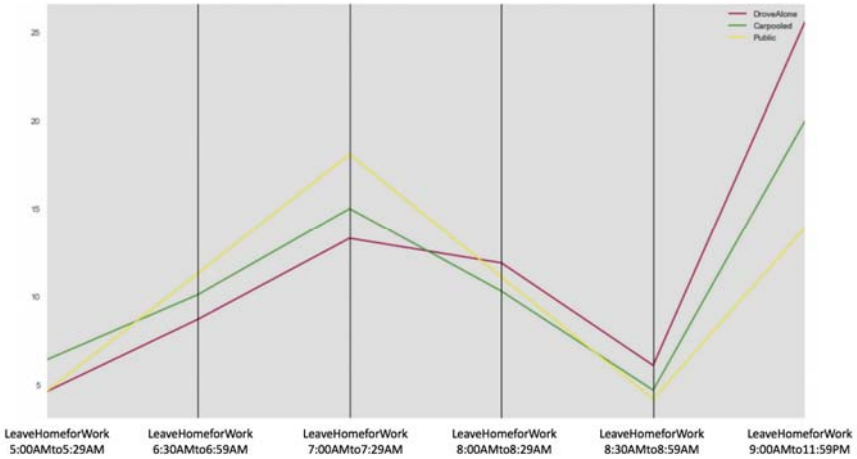

Fig. 11. Contra Costa County Means of Transportation – By Leave Home for Work

Figures 9, 10, 11 and 12, also reveal that thousands of people from the Tri-Valley commute to San Francisco, Santa Clara and San Mateo Counties aggravating traffic congestion in all the main Tri-Valley highways including I-580 (primary east-west route) and I-680 (primary north-south route). According to the 2009-2013 5-Year American Community Survey Commuting, a significant number of people also commute from Contra Costa County to Alameda County and vice versa, where a large number of employers have settled across business parks and work centers. In the cities of Pleasanton and San Ramon alone, some of the largest employers are Workday Incorporated, Oracle, Safeway, and Kaiser Permanente[56].

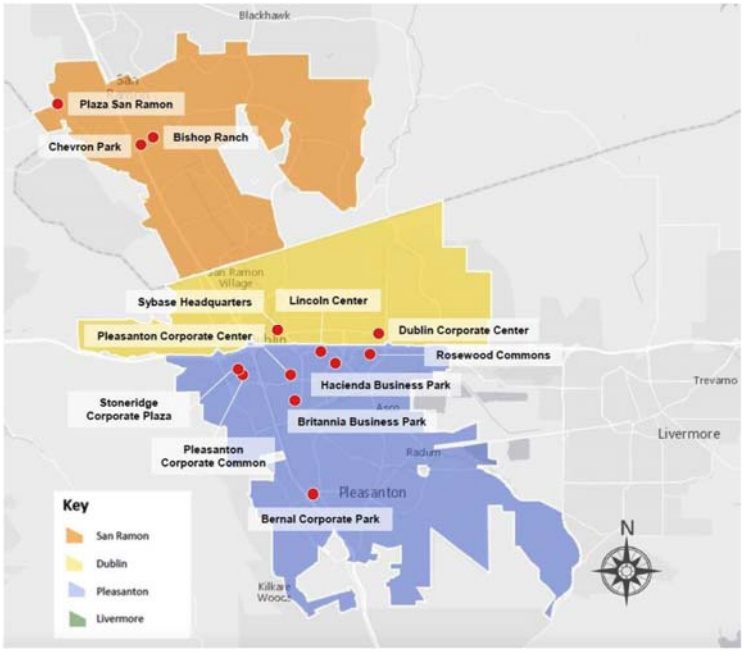

Fig. 12. Pleasanton Regional Business Park Inventory, 2017[57].

As noted by the Bay Area Economic Council Institute, a mobility function exists with a correlation between the level of education attainment and the length of commute, meaning workers with a lower level of education work closer to home while workers with a higher education attainment have longer commutes from the Tri-Valley region to the Santa Clara, San Mateo and San Francisco Counties[58].

[56] http://www.cityofpleasantonca.gov/civicax/filebank/blobdload.aspx?BlobID=30084

[57] http://www.cityofpleasantonca.gov/civicax/filebank/blobdload.aspx?BlobID=30084

[58] http://www.bayareaeconomy.org/files/pdf/BACEI_Tri_Valley_report.pdf

Figure 12 below shows heavy traffic during commute hours on a Thursday around 5:00PM in the Tri-Valley specific areas of Livermore and the Walnut Creek-Alamo-Danville along highway I-680.

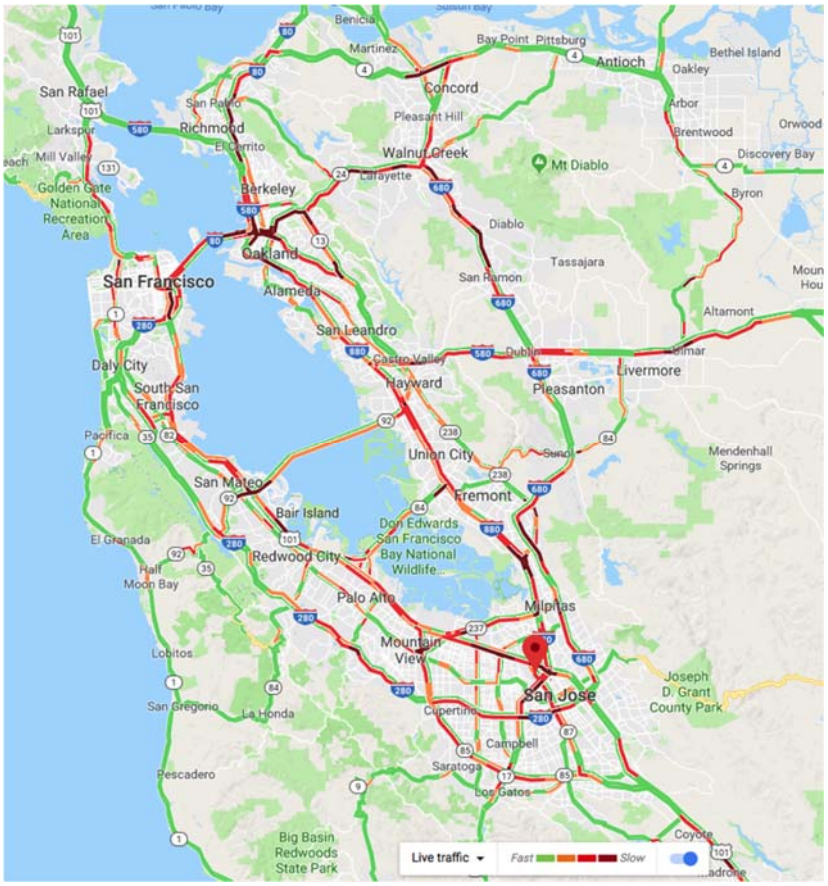

Fig. 13. San Francisco Bay Area Traffic, Thursday 14-Jun-2018 17:31:41 (PDT)[59].

[59] Map data ©2018 Google, United States

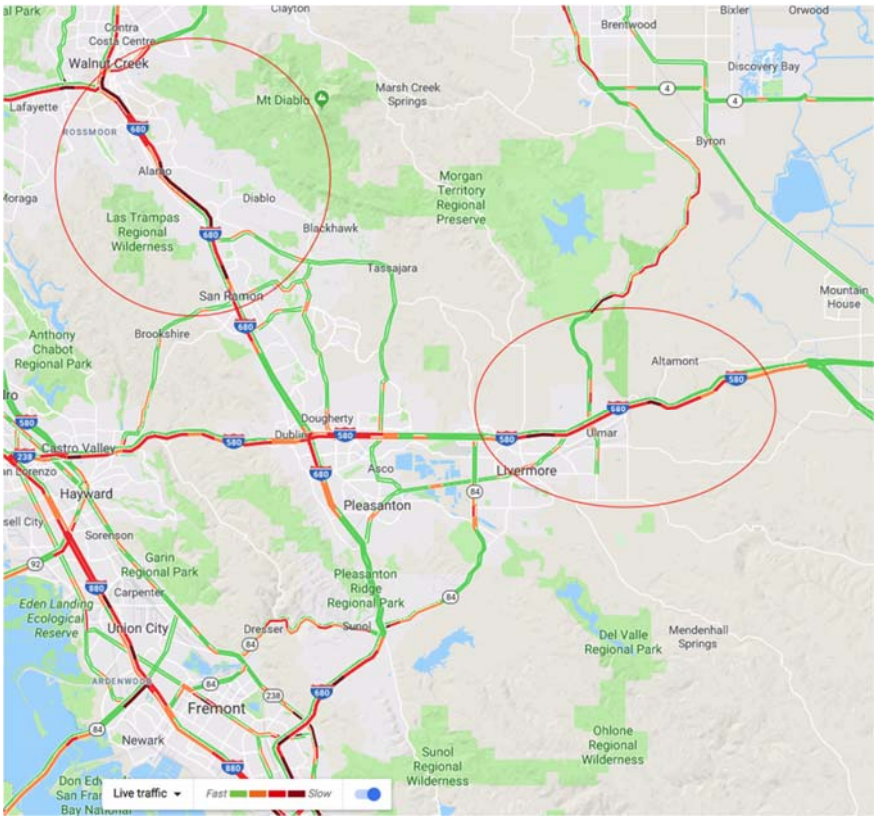

Fig. 14. Tri-Valley Traffic, Thursday 14-Jun-2018 17:31:41 (PDT)[60].

Commuting flows and volumes between the Tri-Valley and the rest of the Bay Area are explained by the high population growth experienced during the last two decades in the region (+20% for the Tri-Valley compared to +8% for the Bay Area)[61]. High quality of life, relatively lower prices per square foot than the rest of the Bay Area, relatively short distances to Silicon Valley and San Francisco major work centers, and excellent schools have all contributed to the influx of talented and skilled people choosing the Tri-Valley as their preferred place to settle, regardless of the longer commute hours from their work centers.

[60] Map data ©2018 Google, United States
[61] http://www.bayareaeconomy.org/files/pdf/BACEI_Tri_Valley_report.pdf

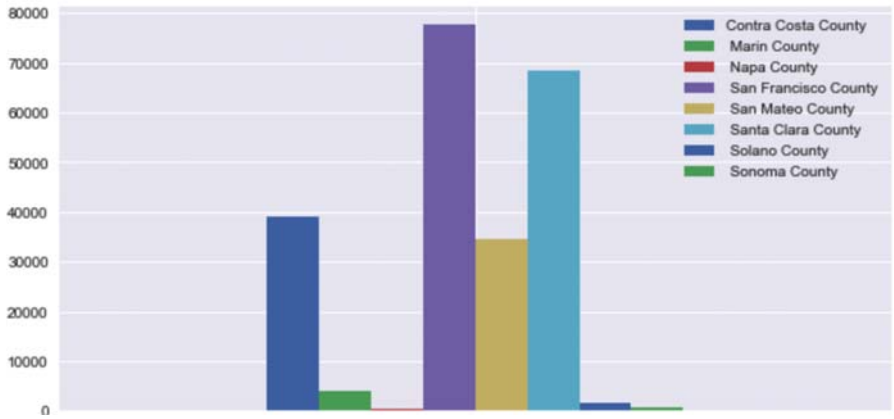

Fig. 15. Alameda County to other Counties Commuting Flow[62].

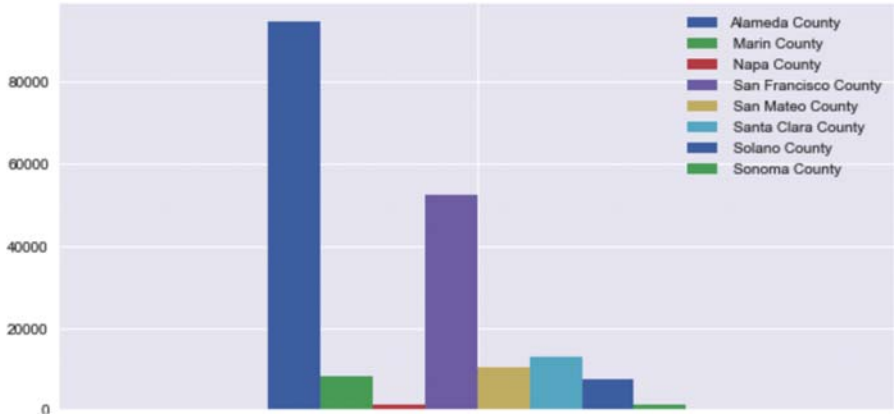

Fig. 16. Contra Costa County to other Counties Commuting Flow[63].

3 WHEELS

Started in 1986, WHEELS is a local bus agency that provides service among different cities within the Tri-Valley, providing connections with other important public transportation systems such as the Walnut Creek and the Dublin/Pleasanton BART

[62] https://www.census.gov/library/publications/2015/acs/acs-32.html, source Table 1. County to County Commuting Flows for the United States and Puerto Rico: 2009-2013, visualized with pandas

[63] https://www.census.gov/library/publications/2015/acs/acs-32.html, source Table 1. County to County Commuting Flows for the United States and Puerto Rico: 2009-2013, visualized with pandas

stations as well as the Pleasanton ACE Station, the Livermore Transit Center (ACE) and the Central Contra County Transportation Authority (County Connection). WHEELS is operated by the Livermore Amador Valley Transit Authority (LAVTA), and according to the 2016 Comprehensive Annual Financial Report (CAFR), it transported over 1.64 million passengers between 2015 and 2016. Recent significant improvements are the implementation of Clipper and the purchase of twenty electric-hybrid buses. Also reported in 2016 CAFR, WHEELS was estimated to provide 139,313 fixed route service hours and 58,848 paratransit trips in FY 2017[64].

Table 7. Transportation Services provided by WHEELS in 2016

Service	Region	Passengers
Fixed Route	Local and sub-regional bus	5,751 (avg. daily)
Rapid Transit[65]	Local and sub-regional bus rapid transit	NA
Shuttles	Servicing the ACE Rail and BART stations.	NA
Dial-A-Ride	Servicing Senior and Disable Persons.	58,798

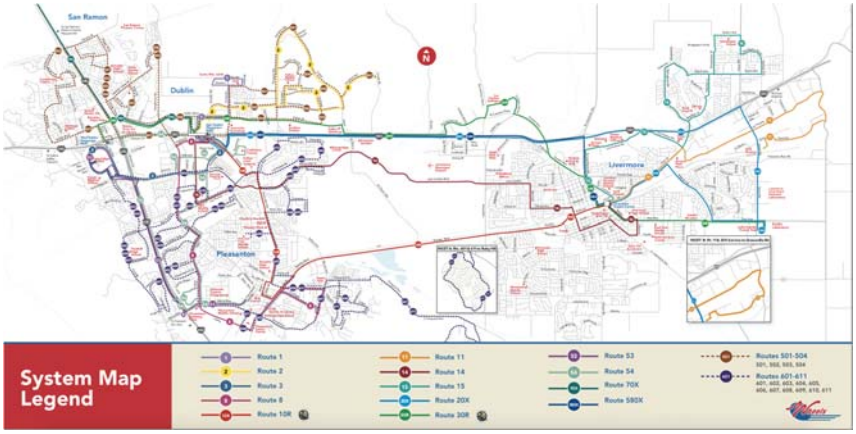

Fig. 17. WHEELS System Map[66].

For the Tri-Valley region in particular, WHEELS often implements coupons and promotions on different holidays and events, such as Father's Day and the Try Transit to School Promotion in which students in middle school and high school are able to ride fixed routes for free[67]. Also beginning November 1, WHEELS added support for

[64] https://en.wikipedia.org/wiki/WHEELS_(California)
[65] https://www.wheelsbus.com/services/rapid/
[66] https://www.wheelsbus.com/wp-content/uploads/2018/02/93025_SystemMap_1000_proofLR.pdf

[67] https://www.wheelsbus.com/news/news-1/

Clipper Card along with other bus services in the East Bay extending the convenience of this highly-valued service to the region[68]. Like many other transit services in the Bay Area, WHEELS is available on all major social networks including the rapidly growing Nextdoor.com[69]; however, it is not available as a Transit Center in 511.org, one of the most popular Bay Area web sources which provides real-time traffic information[70].

On August 2016, WHEELS redesigned its fixed-route system to decrease its service in low-ridership areas in favor of service with a higher frequency on all major arterials.

The main goal of this change was to improve ridership performance, however the shift also naturally imposed an impact on the traffic congestion in the region adding more vehicles per square foot at a given point in time. Although the number of passengers has increased more than double from 1990, it has decreased in recent years.

According to the, 2017 CAFR, there was a 6.8% reduction in ridership in FY2017 compared to that of FY2016. 1,536,084 passengers were served by WHEELS in 2017.

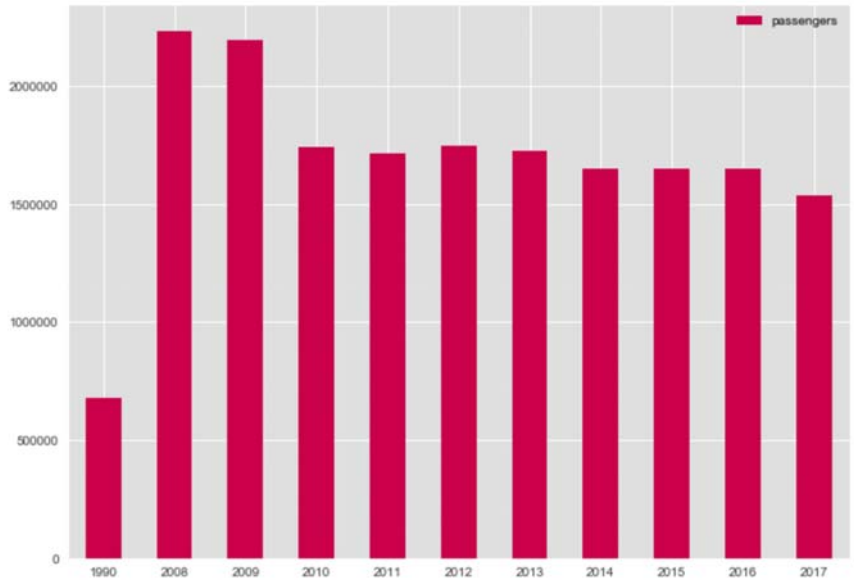

Fig. 18. WHEELS annual ridership[71].

[68] https://www.wheelsbus.com/news/clipper-accepted-on-wheels-beginning-november-1st/

[69] https://www.forbes.com/sites/markgibbs/2012/09/21/nextdoor-the-first-mile-of-social-networking/#3e46d7aa3b12

[70] https://511.org/about/about511/overview

[71] Data source: https://www.wheelsbus.com/wp-content/uploads/2017/12/LAVTA-2017-CAFR-Final-Draft-121917_Website.pdf, Data visualization using pandas.DataFrame.plot.bar

Currently two new funds are available to improve passenger experience and increase ridership. WHEELS on Demand, which aims to provide coverage in low density areas through a partnership with private transportation companies, and the Tri-Valley-San Joaquin Valley Regional Rail Group whose goal is to support the project of BART at Livermore and facilitate for better connections between BART and ACE.

In 2007, two surveys were conducted with the goal of gaining more knowledge on the ridership trends, current and potential user demographics, habits and interests. For the purpose of this paper, we chose to take a closer look at the 2007 Telephone Survey Report which includes data of potential users that could help alleviate traffic in the Tri-Valley if they would eventually decide to use WHEELS as a means of transportation to their work centers and/or schools[72]. "Potential riders are those who say they would be very likely or somewhat likely to use WHEELS at least once a month if service came within a block or two of your home and ran directly to within a block or two of where you need to go anywhere in the Tri- Valley area"[73]. The sample data was taken in March of 2007 across 700 households. It was obtained by random-digit-dial selection and stratification resulting in a total sub-sample of 400 potential riders in the cities of Livermore, Pleasanton and Dublin. It is important to note that per the current WHEELS System Map[74] the WHEELS service in the Tri-Valley is limited to only these three cities. WHEELS is available to 66.1% of the estimated population that resides in the Tri-Valley. The remaining 33.9% of the population belonging to the cities of San Ramon, Danville, Alamo and Blackhawk are mostly left to methods of public transportation other than WHEELS. It is estimated that 147,735 people live in areas where WHEELS Service is not available.

More than eleven years have passed since the survey was conducted and published in March 2007. At the time, about 38% of the identified WHEELS Potential Riders strongly expressed their perception of traffic congestion in the Tri-Valley to be intolerable. Up to 77% of Potential Riders also expressed an interest in using a Direct Service on I580 between Livermore and the Dublin/Pleasanton BART station and about 65% said they would probably use a Rapid Bus Service between Livermore and the Dublin/Pleasanton via Stanly Boulevard which could help alleviate freeway congestion. 57% expressed the importance of having good tax-supported public transportation in the Tri-Valley despite their high income.

As it is possible to observe in Figure 19, even though a large percentage of WHEELS Potential Riders are well aware of WHEELS and its different services available, including express connections to BART, 24-hour service to BART and Rapid Bus Services within the cities of Livermore, Dublin and Pleasanton; still approximately 84% choose to drive alone while 16% use different public transit systems or different means to get to work. Important facts to consider are the estimated bus:car ratio (length of time spent on the trip) for local and out-of-county trips which are approximately 2.3:1 and

[72] https://www.wheelsbus.com/about/reports/#tab-id-2

[73] https://www.wheelsbus.com/wp-content/uploads/2015/09/Telephone_Survey_Report_2007.pdf

[74] https://www.wheelsbus.com/services/route-map/

2.2:1 respectively. The difference for both types of trips is more than double using WHEELS than what it would usually take if using a car. This without considering the comfort and reliability scores to which people rate the use of their own automobiles.

From the 13% percent of Potential Riders who use different Public Transit Systems other than WHEELS, it is reasonable to think they partially rely in their own vehicles as a mean to connect to other public transit systems. As Figures 16 and 17 show, a significant population of the Tri-Valley commute to other counties within the San Francisco Bay Area primarily to the counties of San Francisco, San Clara and San Mateo, however, roughly 4.4% use ACE and 8% use BART as a mean of transportation to their work centers. Surprisingly a large percentage of non-commuters do use BART, about 70% however roughly 8.5% of them rely on WHEELS as a mean to get to BART. This is a very small portion in comparison to the 75% of people who ride to BART. More research would be recommended on this specific rubric that would consider timetables, bus service frequency, parking fees and ridership trends among others.

As can be observed, commuters within the Tri-Valley are less likely to rely on Public Transit Systems, a large 88% of Potential Riders expressed to drive alone in the area imposing a huge overload to the region's freeways and contributing to traffic congestion. A key thing to notice are the barriers to use public transportation with the need to use a car for personal errands being the most significant in addition to the need to drop off and pick up someone young. As stated previously, an average of 42% of households within the Tri-Valley region have children 18 years and younger which also attend several enrichment programs during the week at a different location within the Tri-Valley. It is not uncommon for residents of the Tri-Valley to travel to one or more cities within the Tri-Valley multiple times per week, however only 1% of Potential Riders rely on Public Transit Systems to do so. More research is recommended on this specific rubric that would consider timetables, bus stations, bus service frequency and ridership trends.

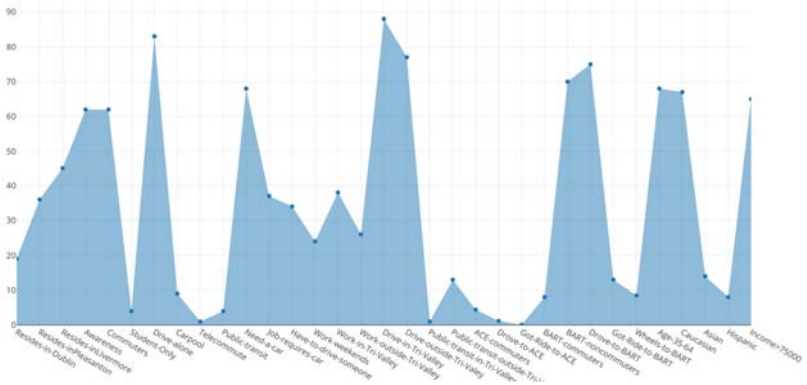

Fig. 19. Percent of WHEELS Potential riders and their demographic data[75].

[75] Appendix D: Percent of Wheels Potential riders and their demographic data.

4 County Connection

In 1980 County Connection was created to provide fixed-route and paratransit service to Central Contra Costa. Among the different areas that are served by County Connection, three local routes and four express routes serve communities in Tri-Valley including the cities of Danville, San Ramon and unincorporated Alamo. There is also a pilot Shuttle Bus Service in the Alamo Creek Area and different school routes under the 600 route category. All routes connect to other important transportation hubs such as BART, ACE Train or Drive-and-Park Transit Centers.

Today County Connection has a fleet of over 120 busses including some electric ones. It offers passengers the ability to pay with Clipper Card, Cash, and monthly passes. It provides bike racks, wheelchair access, passenger lifts and ramps, and various tools for the visual and hearing impairments. County Connection also offers several promotions and discounts through the year such as the Regional Transit Connection Card Discount Program, the Senior Fare and the BOGO special offer[76].

In terms of real time bus tracking, County Connection is available as part of the Transit App[77] and the web based system Bus Tracker.

Table 8. Local and Express Routes provided by County Connection serving the Tri-Valley[78]

Route	Schedule	Frequency
21-BART Walnut Creek/San Ramon	5:30am to 11:20pm	Every 30 min peak / 60 min off-peak
35-BART Dublin/San Ramon	6:00am to 8:17pm	Every 30 min peak / 60 min off-peak
36-San Ramon/BART Dublin	6:20am to 9:00pm	Every 60 min
92X-ACE Express	5:35am to 7:31pm	Every 60 min peak / none off-peak
95X-San Ramon Express	6:30am to 9:04am & 4:00pm to 7:15pm	Every 40 min peak / none off-peak
96X-Bishop Ranch North Express	5:37am to 7:39pm	Every 10-20 min peak / 1 trip off-peak
97X-Bishop Ranch South Express	6:30am to 6:14pm	Every 30 min peak / none off-peak

[76] https://countyconnection.com/fares/bogo/

[77] https://countyconnection.com/about/real-time-bus-tracker/

[78] Data Source: https://countyconnection.com/maps-schedules/

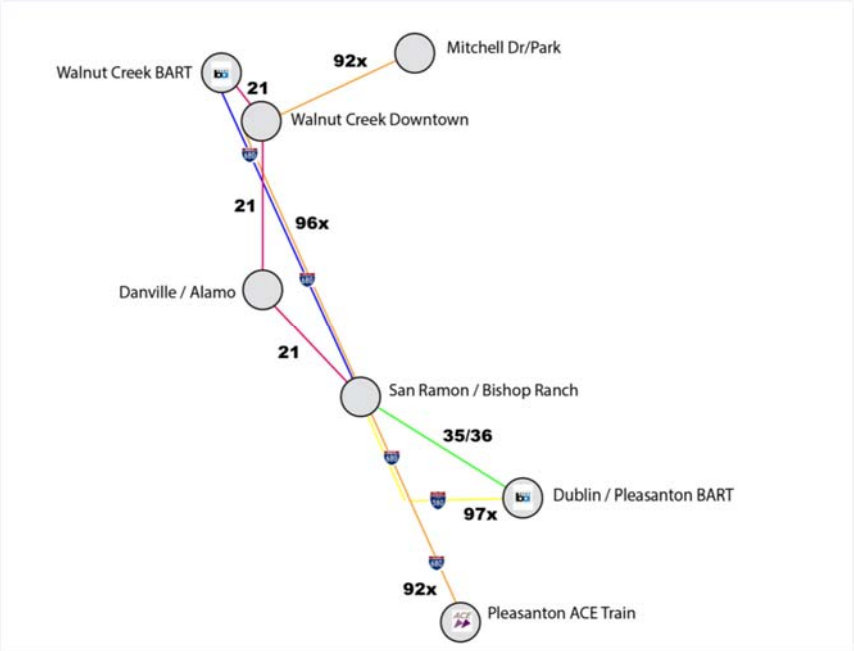

Fig. 20. County Connection System Map of Routes that service in the Tri-Valley[79].

Per the Central Contra Costa County Transit Authority FY2016/17[80], Local Routes 21, 35 and 36 were created in 2009 to provide service to residential, medical and shopping areas along main avenues such as South Main Street, Danville Avenue, San Ramon Valley Boulevard, Bollinger Canyon and Bishop Drive. They also provide connections to several other express lines and the BART stations at Walnut Creek and Dublin.

Figure 21 shows a clear trend of County Connection users mainly exiting at terminus with an access to a BART Station possibly seeking connections to BART to further continue their commute to their work centers at cities out of the Tri-Valley. For instance, 72% of users who rode Route 21 exited at terminus Walnut Creek BART Station, 72% of users who rode Route 35, also exited at terminus Dublin BART station per the Southbound Alighting metric as stated in the Route 35 Segment Map, Average Ridership % and Load by Segment and Direction of the Comprehensive Operations Analysis FY 2016/17[81]. Similarly 65% of users who rode Route 36 exited at terminus Dublin BART.

[79] Data source https://countyconnection.com/maps-schedules/ , System Map done using Adobe Illustrator CC2018

[80] https://countyconnection.com/wp-content/uploads/2018/06/COA-5-17-18-web-test.pdf

[81] https://countyconnection.com/wp-content/uploads/2018/06/COA-5-17-18-web-test.pdf

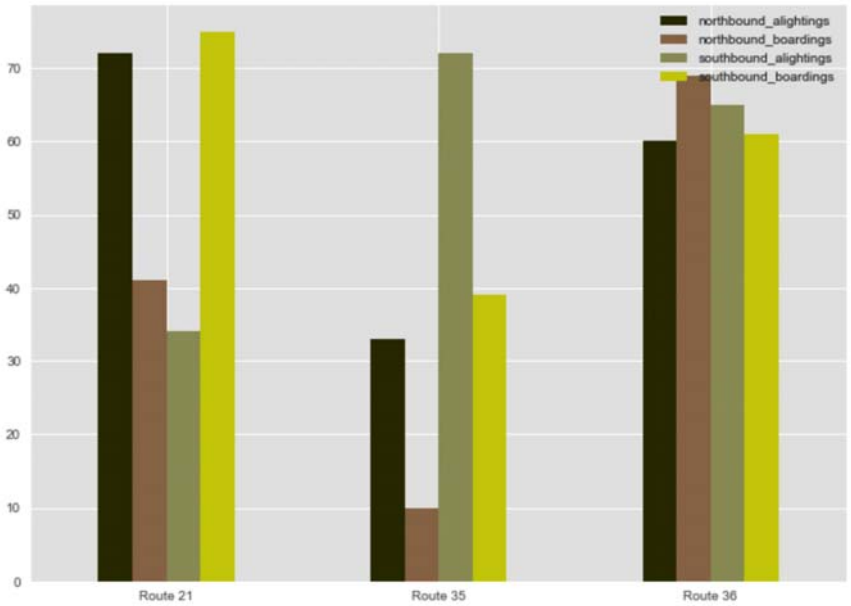

Fig. 21. County Connection Ridership of Local Routes that service in the Tri-Valley[82].

Express Routes 92X, 96X and 97X were also created in 2009. Route 92X is the Express Route from the Walnut Creek northern terminus at Mitchell Drive P&R to the ACE Train Station at Pleasanton. "This route is a partnership with the Altamont Corridor Express (ACE Train) to provide a regional connection to the ACE Train station in Pleasanton"[83].

The route mainly travels via I-680 with a middle stop at the Danville P&R. It offers three trips in the morning and three trips in the afternoon.

[82] See Appendix E
[83] https://countyconnection.com/wp-content/uploads/2018/06/COA-5-17-18-web-test.pdf

Table 9. Route 92X - Mitchell Dr/Park And Ride to Ace Train Station | Mon-Fri[84]

Mitchell Drive/Park And Ride	Danville Park & Ride	Ace Train Station
5:35am (departs)	5:56am (departs)	6:34am (arrives)
6:35am (departs)	6:57am (departs)	7:39am (arrives)
6:58am (departs)	7:20am (departs)	8:03am (arrives)
No service	3:24pm (departs)	4:14pm (arrives)
No service	4:24pm (departs)	5:14pm (arrives)
No service	5:24pm (departs)	6:14pm (arrives)
No service	7:30am (arrives)	6:55am (departs)
No service	8:30am (arrives)	7:55am (departs)
No service	9:00am (arrives)	8:25am (departs)
5:51pm (arrives)	5:06pm (arrives)	4:33pm (departs)
6:41pm (arrives)	6:06pm (arrives)	5:33pm (departs)
7:31pm (arrives)	7:05pm (arrives)	6:33pm (departs)

Express Route 96X is in service every 10-20 minutes between 5:37am to 10:00am and 3:00pm to 7:39. Its northern terminus is at the Walnut Creek BART Station and it mainly travels via I-680 with middle stops at Danville. This Express Route was mainly created to serve the Bishop Ranch Business Park and the San Ramon Transit Center.

Express Route 97X was also mainly created to serve the Bishop Ranch Business Park and the San Ramon Transit Center but with a south terminus at the Dublin/Pleasanton BART Station. The route connects with many other lines and travels mainly through Highways I-580 and I-680.

The School Bus 600 Routes servicing County Connection in the Tri-Valley are Route 622 with 1 PM trip, Route 623 with 1 PM trip, Route 635 with 1 PM trip and Route 636 with 2 PM trips. Route 623 is the most popular.

Figures 14 and 15 reveal the area between Walnut Creek and south of San Ramon as one of the most congested in the Tri-Valley and the Bay Area in general. This same area is serviced by transit agency County Connection which busses routes follow mainstream highways I-680 and I-580 along with other different important arterials in the region contributing to the severe traffic congestion that can be observed specially during peak hours. Figures 16 and 21 also demonstrate an imminent function of mobility from this area to other counties within the Bay Area, the most popular being San Francisco, San Mateo and Santa Clara making access to other hubs of Mass Transit such as BART and ACE Train of significant importance. When taking a closer look at Table 9 for instance, we note Route 92X - Mitchell Dr/Park And Ride to Ace Train Station offers three morning southbound trips covered in the time range from 5:35AM to 7:20AM. This is not ideal however when we consider the geographical characteristics of the area where according to Figure 4 more than 40 percent of

[84] https://countyconnection.com/routes/92X/

households have children younger than 18 years old who most likely need to be dropped at their schools usually by 8:30AM. Moreover, Figure 11 shows that the majority of people who live in Contra Costa County leave home for work after 9:00AM where more than 62% of the commuters either opt or have to drive alone to their work centers.

According to the 2018 County Connection Fixed Route Onboard Survey, more than fifty percent of respondents said they would opt for another vehicle-based form of backup transportation in the event County Connection was not available to them, with Taxi/Uber/Lyft/Drive-own-vehicle the preferred options[85]. All of which would contribute to traffic congestion in the area. Similarly this hypothetical scenario could be assumed by non-users and potential users of County Connection Transit System. Along the same lines, respondents of the survey noted that areas for improvement were the frequency of the service and the time when the service ends. Relatively specifically to Route 21 within the Tri-Valley a survey respondent commented out "very poor we have to wait 45 minutes if we miss the bus[86]."

Another important indicator of this mobility function is the fact that Route 21-BART Walnut Creek/San Ramon is the highest in the Tri-Valley accounting for transfers collected to County Connection from BART and Routes 35 and 36 to County Connection from LAVTA[87]. No Paper Transfers were recorded to County Connection from ACE. Follow up investigation is recommended[88].

Also since it is the area between Walnut Creek and San Ramon cities serviced by County Connection Public Transit Agency, and since it is the same area a region highly notorious for its constant and extensive traffic congestion it is recommended that all cities within the Tri-Valley serviced area routes are appropriately represented in the County Connection's Advisory Committee Membership List and that Public Participation reaches stronger presence in the form of diverse Community-Based Organizations (CBOs). Per Title VI Program Report, adopted in March 2018 no cities in the Tri-Valley serviced area by County Connection were represented by CBOs that the agency would utilize for outreach. Only the non-Tri-Valley neighbour cities of Concord, Walnut Creek, Martinez and Pleasant Hill have presence through various CBOs mainly of lower income and minority population sectors[89].

Conversely most of the routes serviced in the Tri-Valley cities by County Connection Transit Agency were self-denominated as minority. And while County Connection was

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[85] https://countyconnection.com/wp-content/uploads/2018/07/2018-County-Connection-Onboard-Survey.pdf

[86] https://countyconnection.com/wp-content/uploads/2018/07/2018-County-Connection-Onboard-Survey.pdf Additional Improvements people would like to see.

[87] https://countyconnection.com/wp-content/uploads/2018/07/2018-County-Connection-Onboard-Survey.pdf Figures 4.4 and 4.7

[88] https://countyconnection.com/wp-content/uploads/2018/07/2018-County-Connection-Onboard-Survey.pdf Figure 4.8

[89] https://countyconnection.com/wp-content/uploads/2018/05/CCCTA-Title-VI-Program-Report-Update-2018-for-FTA.pdf

able to improve the on-time route performance since 2015 to be higher than 85% this was not the case for Minority Routes[90].

5 BART

The Tri-Valley region is also serviced by the Bay Area Rapid Transit (BART) at the stations in Walnut Creek, West Dublin/Pleasanton, and East Dublin/Pleasanton constructed in 1997. All three BART stations are key infrastructure for the Tri-Valley region as they allow connecting the area with the western major cities of San Francisco, Oakland, South San Francisco and Daily City in the peninsula. They also connect the region with populous eastern cities of the Contra Costa County and Alameda Counties.

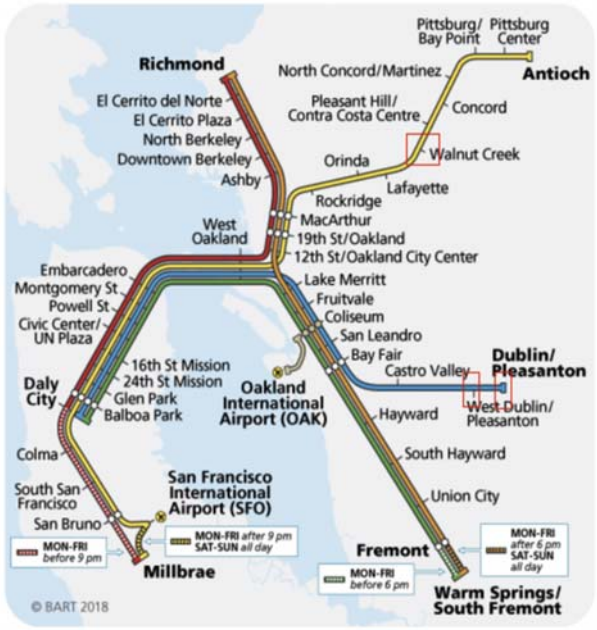

Fig. 22. BART System Map[91].

The East Dublin/Pleasanton station was constructed in 1997 and it has become now a major transit hub in the region. Future plans at this station include connecting with the Iron Horse Regional Trail providing cyclist access to the station, and the

[90] https://countyconnection.com/wp-content/uploads/2018/05/CCCTA-Title-VI-Program-Report-Update-2018-for-FTA.pdf

[91] Picture https://www.bart.gov/stations edited using SnapNDrag Pro

construction of The Dublin Transit Center which is a major proposed project to build multi-story parking building along with a new stations to service the city of Livermore.

According to the BART Planning Department 2002, 80% of the users at the East Dublin Station used the service to commute to work at the time[92].

Table 5. Most Recent BART Ridership in the Tri-Valley by weekday, 2017 Data (Entries)[93]

Station	Month	Weekday Ridership
Walnut Creek	June 2017	7,079
East Dublin Pleasanton	June 2017	8,523
West Dublin Pleasanton	June 2017	3,586
Walnut Creek	April 2017	6,686
East Dublin Pleasanton	April 2017	8,210
West Dublin Pleasanton	April 2017	3,434
Walnut Creek	March 2017	6,840
East Dublin Pleasanton	March 2017	8,041
West Dublin Pleasanton	March 2017	3,418

Per the most recent BART ridership data, the station of East Dublin/Pleasanton has the highest number of users out of the BART stations that service the Tri-Valley, with an average of 8,258 passengers per weekday, followed by Walnut Creek with an average of 6,868 passengers.

[92] https://www.bart.gov/stations

[93] https://www.bart.gov/about/reports/ridership, https://www.bart.gov/sites/default/files/docs/ridership_2017.zip

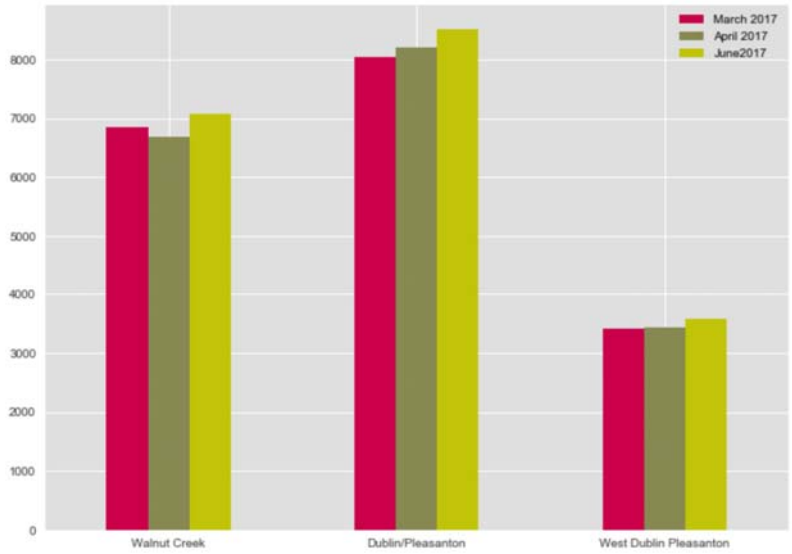

Fig. 22. BART ridership by weekday by month. March, April and June of 2017. Tri-Valley

Also while taking a closer look at ridership trends based on the Ridership_June2017.xlsx file available at https://www.bart.gov/about/reports/ridership website, both Entries and Exits were analyzed for all three BART stations that service the Tri-Valley. On the same lines the East Dublin/Pleasanton station reportedly had the largest number of passengers exiting at major work-center BART stations within Counties out of the Tri-Valley. 5,260 Tri-Valley BART users combined exited at Embarcadero Station (EM), and 3,999 Tri-Valley BART users combined exited at Montgomery Station (MT). Both stations are located in the city of San Francisco at the boundaries of its Financial District. Figure 23 shows other areas within the county of San Francisco with significant Exit rate such as the stations of Powell, Civic Center, 16th Street Mission and 24th Street Mission.

Notably is also the high Exit rate at the BART stations located in the vicinities of the cities of Oakland, and Emeryville where approximately 2,525 Tri-Valley BART users combined exited at the stations of MacArthur (MA), 19th Street Oakland (19), 12th Street / Oakland City Center (12) and Lake Merritt (LM) in June of 2017.

Conversely, the BART ridership trend noted in Figure 25 show a much lower than expected Exit rate at the BART station of Oakland International Airport (OA) in comparison with the amount of Tri-Valley BART users combined who exited at the San Francisco International Airport (SO) in the month of June 2017. This could be possibly assumed as 1) a function of convenience/proximity where Tri-Valley residents opt for BART as a mean of transportation for the airport located at the greatest distance from home and 2) the number of flights and connections available at SFO.

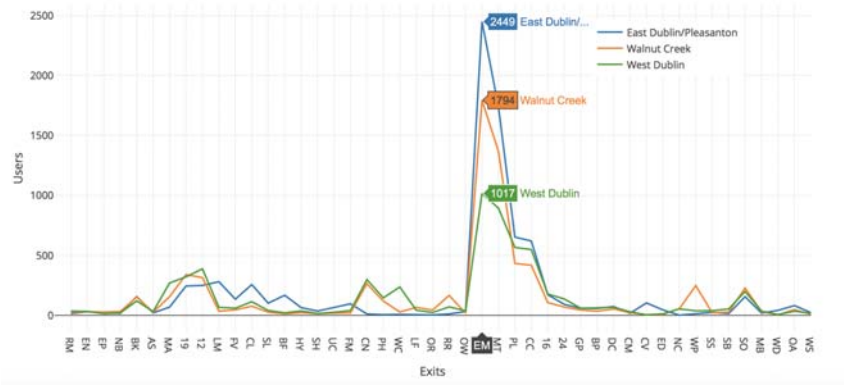

Fig. 23. BART Exit trend by origin Station (San Francisco analysis). Tri-Valley Stations[94].

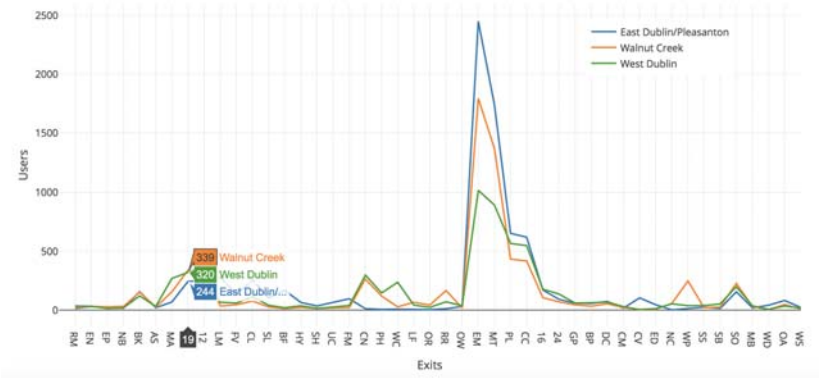

Fig. 24. BART Exit trend by origin Station (Oakland analysis). Tri-Valley Stations[95].

[94] See Appendix F

[95] See Appendix F

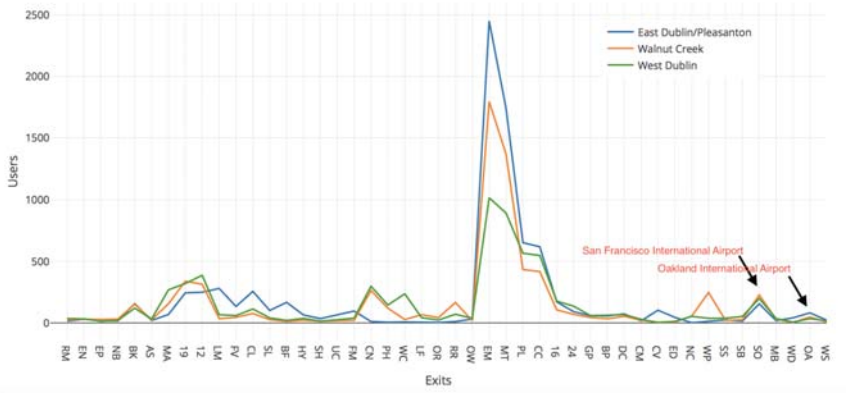

Fig. 25. BART Exit trend by origin Station (Airport analysis). Tri-Valley Stations[96].

BART in the Tri-Valley extends most of its core resources as in the rest of the Bay Area. Support for Clipper Card and Commuter Tax Benefits are highlights among proprietary mobile site m.bart.gov and several third party web-based advertisements which provide near real-time traffic data including 511.org. For quite some time now

BART has also offered discounts to seniors and people with disabilities, a youth discount for people between ages 5 and 18 and most recently BART has introduced a new discount for higher-education students with San Francisco State University being the first college to participate in this program[97]. In the Tri-Valley, the Walnut Creek station is equipped with 48 keyed bike lockers, and bike racks; the parking lot at this station also supports several programs such as the Carpool Permit Program, the Scoop to BART Carpool Program and the Reserved Permit Programs. Parking costs $3 for a day. Parking at the Walnut Creek Station is estimated to be filled by 7:00AM[98].

The other two stations which serve BART at the Tri-Valley, East Dublin/Pleasanton and West Dublin/Pleasanton also offer different carpool programs, bike racks, bike lockers and both have parking lots with a daily fee of $3. Parking fill time is 7:30AM at the Dublin/Pleasanton Station and no data is yet available for the West Dublin/Pleasanton station[99].

"Today, the Millbrae BART station is the largest intermodal terminal west of the Mississippi, featuring a cross-platform connection to Caltrain[100]." Caltrain is the

[96] See Appendix F

[97] https://www.bart.gov/guide/faq?new

[98] https://www.bart.gov/stations/wcrk

[99] https://www.bart.gov/stations/dubl

[100] https://www.bart.gov/stations/mlbr

commuter passenger rail service that runs from San Francisco, along the San Francisco Peninsula all the way to the cities of Gilroy and San Jose[101]. Among other regional commuter rail trains that service the Bay area are Amtrak (California Zephyr, Capital Corridor, Coast Starlight, and San Joaquin) and the Altamont Corridor Express (ACE) as its counterpart in the Tri-Valley Region[102].

Since the BART Station at Millbrae serves as an essential intermodal terminal of mass transportation allowing for connections between BART, Caltrain and Bus Transit Systems, we decided to take a closer look at performance metrics of this station to understand the demand that it meets. This will serve as a basis when comparing against the current demand at the East Dublin/Pleasanton BART station in the Tri-Valley.

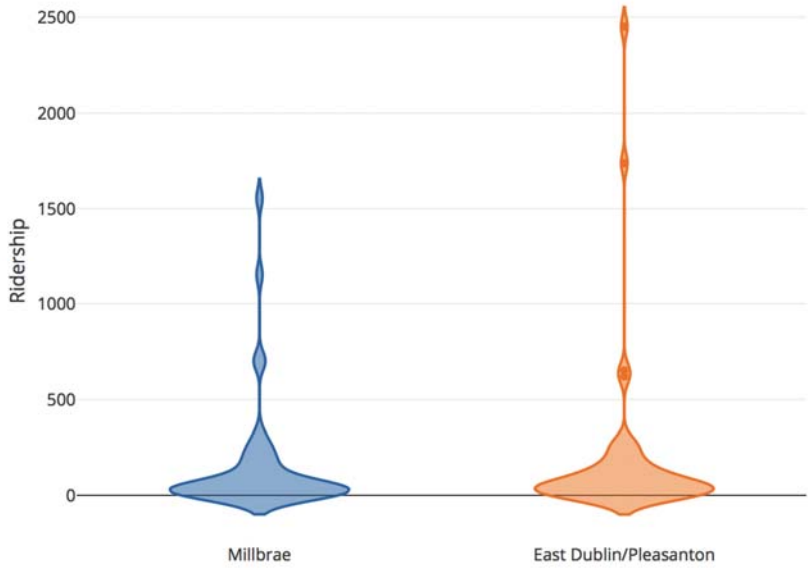

Fig. 26. BART ridership Millbrae and East Dublin/Pleasanton stations. Average Weekday June 2017[103].

Our Violin Plot shows a comparison of ridership distribution between the two stations that serve as major transit hubs in each side of the bay. On the West the station of Millbrae served approximately 6,994 average weekday users with 2,709 exiting at the San Francisco Stations of Embarcadero and Montgomery while on the Tri-Valley the station of East Dublin/Pleasanton served approximately 8,523 average weekday users

[101] http://www.caltrain.com/about.html

[102] https://en.wikipedia.org/wiki/List_of_San_Francisco_Bay_Area_trains

[103] See Appendix G

in the month of June 2017 with 4,188 exiting at the San Francisco Stations of Embarcadero and Montgomery.

Although the demand at the East Dublin/Pleasanton is proximately 9.8% more than the one observed in Millbrae, the station in the Tri-Valley does not offer the intermodal facilities of its counterpart in the San Francisco Peninsula. For instance, while many alternatives to parking are available at the East Dublin/Pleasanton station and its surroundings, the Estimated Parking Fill Time is 7:30 AM and while "the station features a number of local and regional bus connections" it does not provide a cross-platform connection to the Altamont Corridor Express which is the nearest commuter rail train located south and at 4.8 miles away[104].

Table 6. Estimated Travel Time from the East Dublin/Pleasanton BART Station to the Fairgrounds-East/ACE Pleasanton by Means of Transportation[105].

Means of Transportation	Travel Time
Driving	10 - 24 min
Walking	1h 10 min – 1h 37 min
Transit	24 - 48 min

[104] https://www.bart.gov/stations/dubl

[105] Map data ©2018 Google, United States

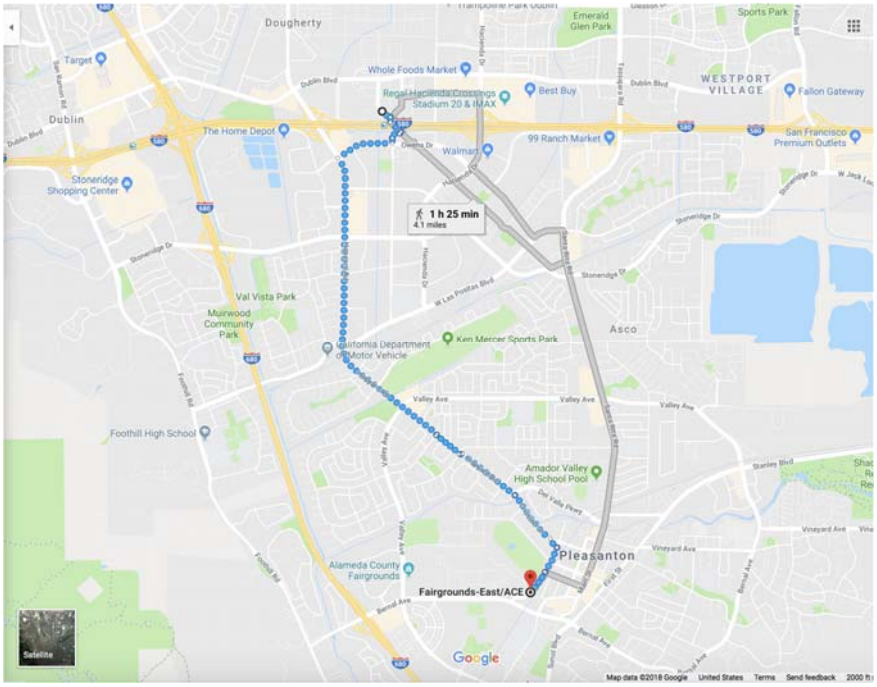

Fig. 27. Walking directions from the East Dublin/Pleasanton BART to the Fairgrounds-East/ACE Pleasanton[106].

[106] https://www.google.com/maps/dir/East+Dublin+Bart+Station,+Dublin,+CA/Fairgrounds-East%2FACE,+Pleasanton,+CA+94566/@37.6770247,-121.9060921,14z/data=!4m18!4m17!1m5!1m1!1s0x808feeaafb3157cb:0xd58801a1aec98ba3!2m2!1d-121.899419!2d37.702923!1m5!1m1!1s0x808fe999cfa3c32b:0x53a11dc5c9d6ea3!2m2!1d-121.8823527!2d37.6590643!2m3!6e0!7e2!8j1540195560!3e2

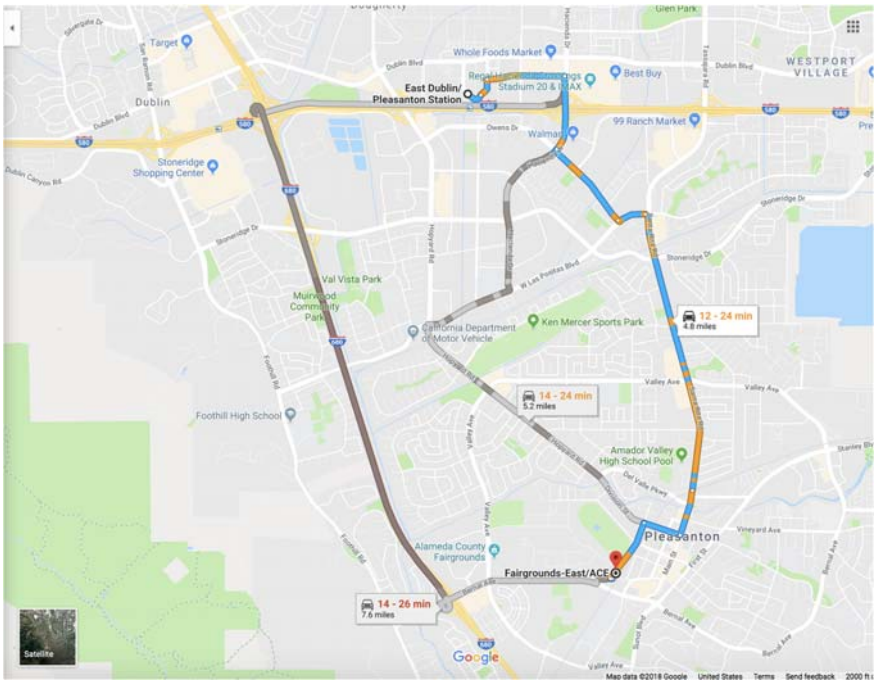

Fig. 28. Driving directions from the East Dublin/Pleasanton BART to the Fairgrounds-East/ACE Pleasanton[107].

[107] https://www.google.com/maps/dir/East+Dublin+Bart+Station,+Dublin,+CA/Fairgrounds-East%2FACE,+Pleasanton,+CA+94566/@37.6770247,-121.9060921,14z/data=!4m18!4m17!1m5!1m1!1s0x808feeaafb3157cb:0xd58801a1aec98ba3!2m2!1d-121.899419!2d37.702923!1m5!1m1!1s0x808fe999cfa3c32b:0x53a11dc5c9d6ea3!2m2!1d-121.8823527!2d37.6590643!2m3!6e0!7e2!8j1540195560!3e2

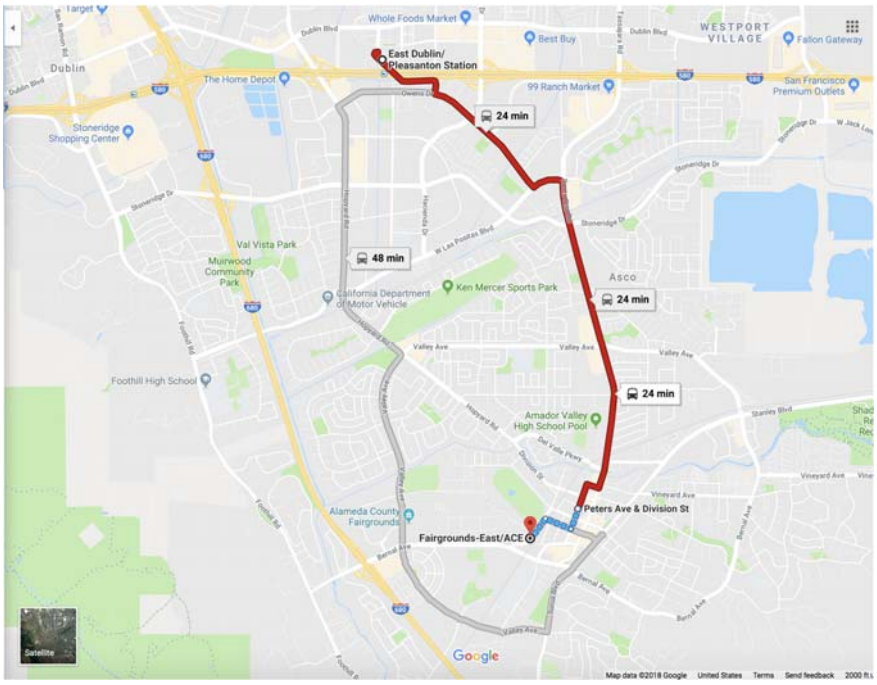

Fig. 29. Transit directions from the East Dublin/Pleasanton BART to the Fairgrounds-East/ACE Pleasanton[108].

Other recent indicators of the growing demand for mass transit system in the Tri-Valley is the top score in the Home-Based Ridership Changes reported for the West Dublin/Pleasanton in the BART 2015 Station Profile Survey Preliminary Results[109].

Also across all BART lines, the shift in percentages for the means of transportation to BART suggest a critical need for parking and effective bus/transit systems that connect to BART. In the Tri-Valley, parking in all three BART stations is limited and filled by 7:30AM and only approximately ten percent of BART users reportedly use transit to get to BART.

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[108] https://www.google.com/maps/dir/East+Dublin+Bart+Station,+Dublin,+CA/Fairgrounds-East%2FACE,+Pleasanton,+CA+94566/@37.6770247,-121.9060921,14z/data=!4m18!4m17!1m5!1m1!1s0x808feeaafb3157cb:0xd58801a1aec98ba3!2m2!1d-121.899419!2d37.702923!1m5!1m1!1s0x808fe999cfa3c32b:0x53a11dc5c9d6ea3!2m2!1d-121.8823527!2d37.6590643!2m3!6e0!7e2!8j1540195560!3e2

[109] https://www.bart.gov/sites/default/files/docs/BART%202016%20Wksp%204.D%202015%20Station%20Profile.pdf

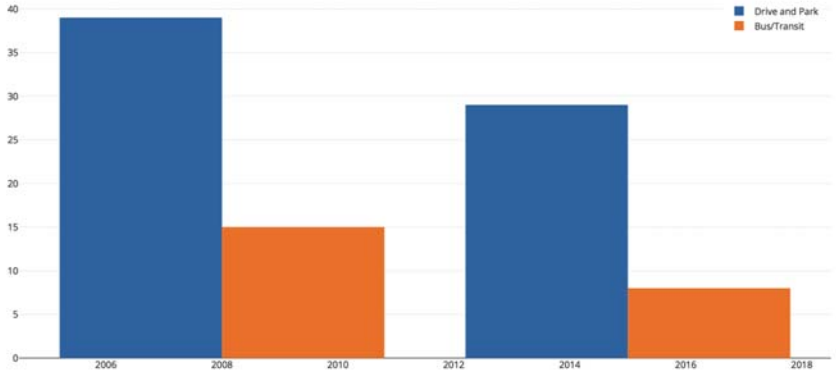

Fig. 29. Means of transportation to get to BART expressed in percentages[110].

On the other hand, Table 7 shows that two out of the three BART stations that serve the Tri-Valley occupied top ranks for stations where users were dropped off to get to BART, implying the users could not or decided not to use public transit systems nor were they either able to drive and park. Possibly a correlation to this trend exists to having no guaranteed parking or an inefficiently perceived transit system with a ratio bus:car (length spent on the trip) of 2.3:1 which does not satisfy the user requirements in terms of performance. More statistical analysis is recommended regarding the correlation between variables. Depending on the availability and distribution of the data, different methodologies can be used to determine the strength of the relationship that would explain the ridership trends shown in Figure 29 and Table 7. Some of the most widely used are Pearson r correlation, Kendall rank correlation and Spearman rank correlation[111]. Also notable is the top ranked station of Bay Fair which, although not considered part of the BART stations to service the Tri-Valley, its proximity to the region and lines serving this station provides an outlet for the Tri-Valley residents to the North and South via Richmond-Warm Springs/South Fremont and to the West via Dublin/Pleasanton - Daly City and Daly City -Warm Springs/South Fremont[112].

[110] See Appendix H

[111] http://www.statisticssolutions.com/correlation-pearson-kendall-spearman/

[112] https://www.bart.gov/stations/bayf

Table 7. Top 10 Stations where users were dropped off to get to BART[113].

Top 10 Stations	% Drop off/taxi/other
Fremont	33%
Pittsburg/Bay Point	31%
Dublin Pleasanton	**30%**
Coliseum	29%
Walnut Creek	**28%**
Bay Fair	**28%**
Lafayette	26%
Daly City	26%
Glen Park	26%
El Cerrito del Norte	26%

Notably in Table 8, not a single BART station which services the Tri-Valley was ranked among the top 10 stations where users opted for riding a Bus/Transit to get to BART regardless of the different transit alternatives available for connecting to BART via Bus/Transit or Express Routes and despite the high demand at the stations in the region (approximately 8,000 average weekday users for the East Dublin/Pleasanton Station and 7,000 average weekday users for the Walnut Creek Station) less than 5% of users reportedly relied on Bus/Transit to get to BART according to the 2015 BART Station Profile Study[114].

Table 8. Top 10 Stations where users use Bus/Transit to get to BART[115].

Top 10 Stations	% Bus / Transit
Embarcadero	28%
Powell St.	21%
Montgomery St.	21%
Civic Center/UN Plaza	20%
Daly City	16%
Glenn Park	16%
Millbrae	16%
12th St. Oakland City Center	15%
El Cerrito del Norte	13%
Balboa Park	13%

113 https://www.bart.gov/sites/default/files/docs/BART%202016%20Wksp%204.D%202015%20Station%20Profile.pdf

114 https://www.bart.gov/sites/default/files/docs/StationProfile2015_HomeOriginOnePagers_rev0629.pdf

115 https://www.bart.gov/sites/default/files/docs/BART%202016%20Wksp%204.D%202015%20Station%20Profile.pdf

Table 9 however reveals that the most popular means of transportation to get to BART is arguably Drive and Park. Higher percentages account for all top 10 Stations were users drove and were able to park compared to those users who were dropped off or used Transit to get to BART. Notably, all three BART stations that service the Tri-Valley were ranked among the top 10. For the Walnut Creek and East

Dublin/Pleasanton stations about 51% and 52% of users respectively drove and parked, while approximately 60% of users at the West Dublin Pleasanton station reportedly chose (or were able) to drive and park. It is important to note that Park does not necessarily mean a single drive-alone automobile but rather includes motorcycle/motorized scooter and carpool which explained the higher percentages when compared to the average users per weekday per station.

Table 9. Top 10 Stations where users chose to or could drive and park to get to BART[116].

Top 10 Stations	% Drive and park
North Concord/Martinez	70%
West Dublin/Pleasanton	60%
Orinda	54%
Dublin/Pleasanton	52%
Walnut Creek	51%
Concord	48%
Millbrae	48%
South Hayward	47%
Lafayette	45%
Fremont	44%

In Figure 30, a relatively small percentage of users is shown who relied on Public Transportation to connect to all BART Stations that service the Tri-Valley.

The low percentages explain why data from the same BART stations is missing in Table 8. For instance for the East Dublin/Pleasanton station which is the most populous station in the Tri-Valley with an average 8,000 users per weekday only four percent of users relied on public transportation to get to BART, approximately 320 users per weekday. On the same lines, only three and one percent of users relied in public transit to get to the stations at Walnut Creek and West Dublin/Pleasanton despite the various routes and transit alternatives available from both WHEELS and County Connection Transit Agencies that aim to provide connections to BART.

On the contrary it is reasonable to attribute percentages of users who drove and park in addition to those who were dropped off to get to BART to traffic congestion in the area. Adding the two metrics results in 82% of users at the East Dublin/Pleasanton station relying on a vehicle to get to BART which equals approximately 6,560 average users/vehicles per weekday one way only. And for the Walnut Creek station 78% of

116 https://www.bart.gov/sites/default/files/docs/BART%202016%20Wksp%204.D%202015%20Station%20Profile.pdf

users relied on a vehicle to get to BART which equals approximately 5,460 users/vehicles per weekday one way only. It is imperative that the use of Public Transit to get to BART as the chosen mode of travel increases in future years for the Tri-Valley Region. Percentages are considered to be extremely low when compared with the high demand on all three BART stations that service the area putting a huge load on traffic congestion mainly in highway I-680 and along alternative arteries parallel to it.

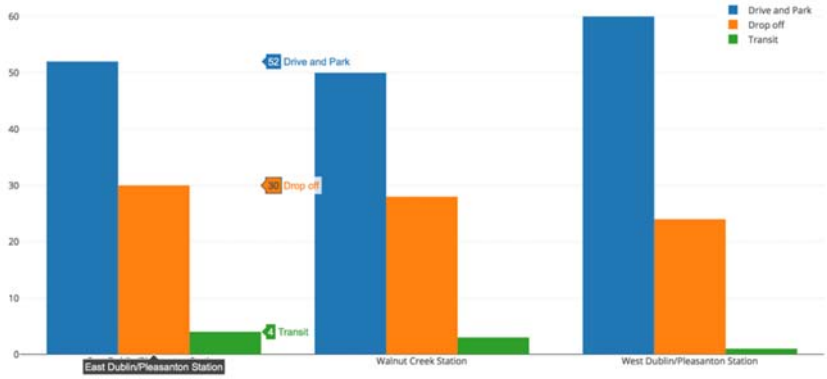

Fig. 30 Travel Mode to BART Stations that service the Tri-Valley (from home origins)[117].

Reported in the 2015 BART Station Profile Study, the City of Home Origin to the BART Stations which serve the Tri-Valley could be assumed to have a strong correlation coefficient between the BART Station and the distance to the City of Home Origin. More statistical analysis is recommended to further explain the percentages in Table 10 below, however for the South-North equidistant cities of San Ramon, Danville, Alamo and Blackhawk, additional data collection and analysis is also recommended. A simplistic trend can be assumed however for these cities according to Table 10, where the BART users in the city of San Ramon connect to BART at the South Stations of West Dublin and East Dublin/Pleasanton, and the BART users who reside in the cities of Alamo and Danville connect to BART at the Northern Station in Walnut Creek.

Table 10 City of Home Origin by Station. Tri-Valley[118].

City of Home Origin	East Dublin/Pleasanton	Walnut Creek	West Dublin/Pleasanton
Pleasanton	31%	N/A	22%
Dublin	27%	N/A	39%
Livermore	17%	N/A	4%
San Ramon	12%	4%	26%
Danville	3%	13%	4%

[117] See Appendix I

[118] https://www.bart.gov/sites/default/files/docs/StationProfile2015_HomeOriginOnePagers_rev0629.pdf

Alamo	N/A	3%	N/A

6 ACE

The Altamont Corridor Express (ACE) became operational in 1998 servicing passengers in San Joaquin, Santa Clara and part of the Alameda County in The Tri-Valley[119]. It initially offered two west bound and two east bound trains, later a third and fourth were added. The train is a key infrastructure for Public Transportation as it connects passengers from Stockton to San Jose, having two important station in the Tri-Valley: Livermore and Pleasanton stations.

WiFi is available for all passengers in each trainset for up to 1GB of data usage per day. Currently ACE rail operates only Monday to Friday but service for weekends are included in future plans. According to ACE FAQ, The Altamont Corridor Express is enduring discussions with Alameda County in regard to parking needs and the growth in the Tri-Valley region.

The station at Pleasanton is one of the busiest in the route. It is near the East Dublin/Pleasanton BART station and it is serviced by multiple shuttles and private (corporate sponsored) busses. The latest ACE westbound train to depart from Pleasanton to San Jose is at 8:18 AM. The San Joaquin Regional Rail Commission (SJRRC) was appointed to manage The Altamont Corridor Express (ACE) until September of 2019[120].

As it was reported in the SJJPA 2018 Business Plan, currently a grant application exists called the Transit and Intercity Rail Capital Pro-gram (TIRCP) which if funded, it will be applied towards improvements in the Stockton-Sacramento corridor including additional round-trips in the ACE Route.

Table 11. Schedule for Westbound Trains for the ACE Station that service the Tri-Valley[121].

Station	Train1	Train2	Train3	Train4
Livermore	5:25AM	6:40AM	7:45AM	8:10AM
Pleasanton	5:33AM	6:48AM	7:53AM	8:18AM

[119] http://www.acerail.com/About/AskACE
[120] http://www.acerail.com/Getting-You-There/FAQ#faq-id-521

[121] https://www.acerail.com/Getting-You-There/Transfers-Shuttles

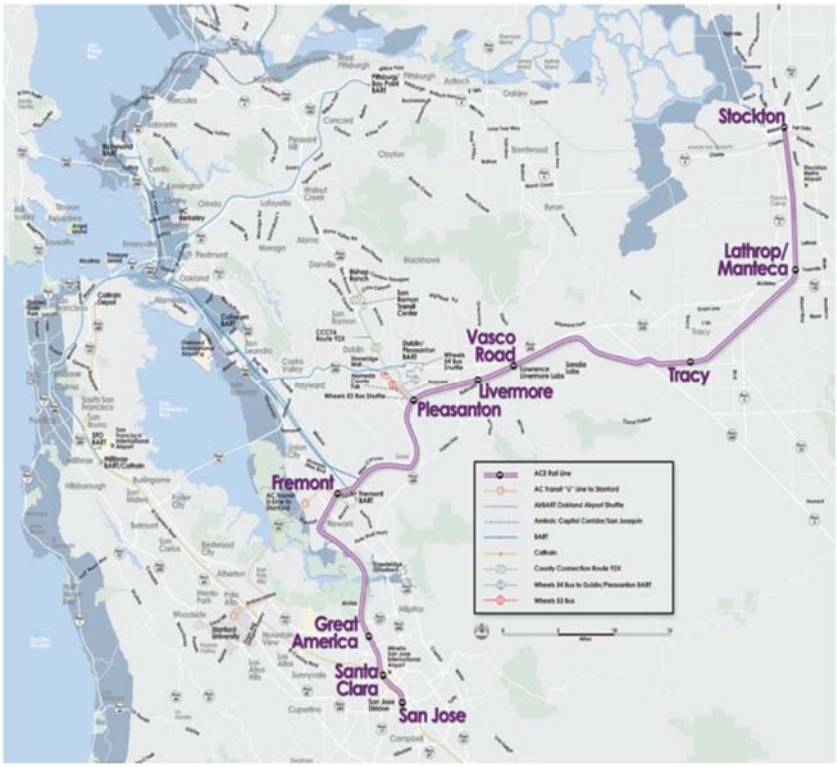

Fig. 31. ACE System Map[122].

As far as the Altamont Corridor Express is concerned, the trains are well equipped with world-class amenities providing a pleasant experience to all riders. From bike racks and charging stations, to free WiFi and even dim-lit cars for relaxation. ACE trains are focused on providing the highest quality in service and safety to all users. Although ACE does not currently support Clipper Card, tickets can be purchased online, at specific stations and by mail. ACE also supports numerous programs and promotions such as rewards for loyal passengers by providing the 12 consecutive ride for free[123], a test drive for prospect riders, and several discounts during specific holidays and events.

In the Tri-Valley ACE is served by two stations: Livermore and Pleasanton, both offering free parking and a network of connections to shuttles, employer-ran buses to near-by business parks and bus services connections to WHEELS and BART[124]. ACE does not yet have its own mobile app however it provides text alerts as well as news

[122] http://www.acerail.com/Getting-You-There/Transit-Map/ACE_Transit_Map-1

[123] https://www.acerail.com/Getting-You-There/FAQ

[124] https://www.acerail.com/Getting-You-There/Maps-Stations/Pleasanton

via email and a mobile-friendly interactive tracking train page. ACE is also available on several popular social networks.

According to the Environmental Impact Analysis by the San Joaquin Regional Rail Commission, the daily ridership for the ACE stations that service the Tri-Valley was 543 users at the Livermore Station and 1,719 users at the Pleasanton station. Correspondingly the estimated daily ridership for the same stations by the year 2020 is 672 and 1,976 users daily. Ridership at both Tri-Valley stations accounting only for an approximately 6% as noted previously in Figure 19, a very low number when compared to commuters that travel from the Tri-Valley to the cities of Santa Clara, and San Jose which are also served by the Altamont Corridor Express.

Table 12. ACE Daily Ridership at the Tri-Valley Stations for 2015[125].

Station	2015	Estimated by 2020
Livermore	543	672
Pleasanton	1,719	1,976

"Daily ACE passenger volumes are projected to grow by approximately 11.7 percent from 2015 to 2020, increasing from 11,022 in 2015 (existing) to 12,316 (Daily Ons + Offs) in 2020 in San Joaquin, Alameda, and Santa Clara Counties"[126].

In regards to this mobility function from the residents of the Tri-Valley to other counties along the Altamont Corridor Express, we looked at the daily origin-destination estimated ridership trend for 2013 as reported in the ACE Extension Lathrop to Ceres/Merced Ridership, Revenue, and Benefits Report March 30, 2018. Notably were the westbound ridership trips coming from the Tri-Valley station of Pleasanton into the Silicon Valley ACE stations of San Jose and Fremont[127].

[125] https://www.acerail.com/About/Projects-Initiatives/Current/ACE-Extension-Lathrop-to-Ceres-Merced/Draft-Environmental-Impact-Report/4_17_Trans.pdf

[126] https://www.acerail.com/About/Projects-Initiatives/Current/ACE-Extension-Lathrop-to-Ceres-Merced/Draft-Environmental-Impact-Report/4_17_Trans.pdf

[127] See Appendix J

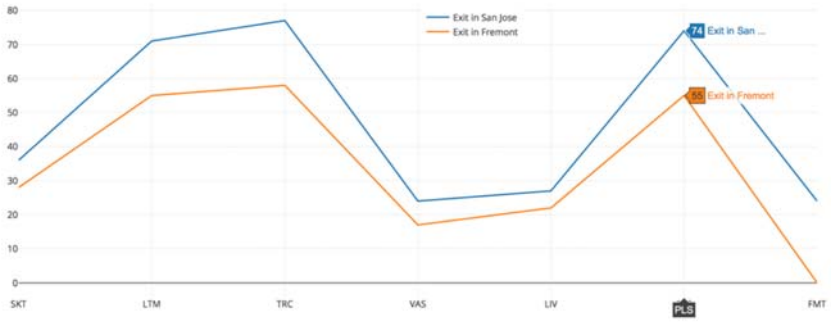

Fig. 32. Estimated ACE daily ridership trend by origin-destination for 2013[128].

Figure 32 shows that the majority of people detraining at the San Jose ACE station board at the ACE stations of Tracy and the Tri-Valley station of Pleasanton. "the majority of ACE riders are employed in the South Bay, particularly Silicon Valley. Other areas of high employment concentration include the Tri-Valley and around Fremont. Some ACE passengers reported working as far away as Oakland, San Francisco, and the Peninsula (e.g., Mountain View, Palo Alto, and Redwood City)[129]."

On the other hand "A substantial movement between the Central Valley and the Tri-Valley (16 percent of trips originating in the Central Valley are destined for the Tri-Valley)[130]."

[128] See Appendix J

[129] https://www.acerail.com/About/Projects-Initiatives/Current/ACE-Extension-Lathrop-to-Ceres-Merced/Draft-Environmental-Impact-Report/Appendix-D-2-Ridership,-Revenue-and-Benefits-Repor.pdf

[130] https://www.acerail.com/About/Projects-Initiatives/Current/ACE-Extension-Lathrop-to-Ceres-Merced/Draft-Environmental-Impact-Report/Appendix-D-2-Ridership,-Revenue-and-Benefits-Repor.pdf

7 General Ethical Principles

This paper is written to our best professional competence and aiming to present a high-quality research with the purpose of raising awareness and understanding of a public problem, and its alternative solutions. Using the best of our data mining, reproducible research and computing skills we aim to contribute to society by presenting hereby a comprehensive investigation of a problem that affects thousands on a daily basis, the quality of their lives, and their environment. Our research efforts, data collection and data visualizations presented in this paper, respect and honor at all times the diversity, privacy, racial background and economic status of all habitants of the Tri-Valley. Our efforts in analyzing and presenting a series of initiatives to effectively help reduce traffic congestion in the Tri-Valley are expected to be used in benefit of all residents of the Tri-Valley and the people interacting within the Tri-Valley region for a better quality of life, reduction in gas emissions and traffic congestion, ultimately contributing to a human well-being for a better, healthier, cleaner, happier society.

We confirm the data gathered during our research efforts was collected from official sources all listed in the References section. We strived to be as transparent, and updated as it was possible, presenting the most recent data available for both past and future predictions. We thoroughly respect copyrights from external sources, patents and projects. Our efforts are limited to raising awareness and emphasizing areas that need attention with the ultimate goal of helping society. We understand this paper represents a work of trust, because of this, we confirm our efforts relied in presenting objective results and evaluations aligned to general ethical principles at all times and with an aim to procure public good in the benefit of the people. On the same lines we expect this paper to be used by external organizations and groups in a way that is responsible, ethical and in the benefit of society. Any decisions influenced by the analysis and evaluations presented in this paper, are also expected to be transparent, of the highest quality and aiming to procure the welfare of society at all times.

We acknowledge that although some data attributes from the data collected resulted in most value for the purpose of this paper, they reveal private individual characteristics and behavioral patterns that could potentially be used in an unethical manner. Commuters income, time to leave home for work, occupation and racial background are all examples of data attributes that expose residents of the Tri-Valley up to a certain degree. And although it is true that even further analysis could benefit from the collection of transactional-level data, this would urge transit authorities, government agencies, employers, developers and all people who would to gain access to the data to use it a most ethical way. Misuse of the information can occur at any level and to all sorts of data so it is very important that future data collection through transit surveys complies with data protection regulations at all times.

8 Conclusions

Mass Transit. With more than 360,000 habitants, both parents in most of the families working in STEM related fields, an inter-City inter-County mobility function with a commute volume of 66% increase rate since 2007, an estimate population grow of 22% and being one of the worst congested regions in the San Francisco Bay Area, mass transit in the Tri-Valley needs to be prioritized. Connections to BART and ACE are key and need further be evaluated. Both transit systems provide service to thousands of users per weekday as a mode of transportation to their work centers mostly in San Francisco, Oakland, Santa Clara, San Mateo and San Jose, however less than five percent use Bus/Transit to get to BART and ACE. Faster, direct, and more frequent busses are needed to cover the high demand for Mass Transit Systems at all three ends of the Tri-Valley region. Specifically, effective and efficient connections to the East Dublin/Pleasanton and the Walnut Creek BART stations which reportedly serve 8,000 and 7,000 users average per weekday is of the highest importance. Evaluating and investing in alternative Mass Transit Systems such as Light Rail in the region is also highly recommended. A loop-style route vertically connecting the Walnut Creek BART station in the North, with the East Dublin/Pleasanton BART station and the ACE Pleasanton station in the South is much needed and recommended to help alleviate traffic congestion in Highway I-680 and to meet the demand of thousands of commuters that rely on BART and ACE to get to their work centers every day.

Scaling. With 360,000 habitants in the Tri-Valley, approximately 40% of households with children younger than 18 years old, 35% of WHEELS potentials riders claiming a need to having to drive someone young, no parking available at the Walnut Creek nor the East Dublin/Pleasanton BART stations after 7:30AM and no Westbound ACE trains available after 8:18AM, the high rate of commuters driving alone and leaving home for work after 9:00AM is explained. School entrance in the Tri-Valley is at about 8:30AM for all education levels, so a parent that has to drop off a child to school is thereafter left with no alternatives for using mass transit systems BART and ACE as a mode of transportation to his/her work center if commuting out of the Tri-Valley. About 80% of commuters reportedly drive-alone and approximately 75% of WHEELS potential riders claimed to also commute out of the Tri-Valley. Current Mass Transit Systems need to scale to suffice the high demand and estimated growth of 22%. Specifically, parking options at BART need to be increased to allow for commuters in the 8:30-9:30AM range. It is also highly recommended that an additional Westbound ACE train be evaluated by the Altamont Corridor Express to provide service to the thousands of commuters that travel from the Tri-Valley to the Silicon Valley region in the high peak hours of 8:30-9:30AM after dropping off a child . User surveys and potential ACE riders data collection are also highly recommended. Further analysis of demographics is encouraged since the growth in the region has constantly increased and since ridership data reported for 2013 demonstrated a strong mobility function of STEM commuters travelling from the Tri-Valley ACE station at Pleasanton to the Silicon Valley station of San Jose.

Scaling both service and infrastructure is key to effectively help alleviate the traffic congestion in the Tri-Valley. With the BART station at East Dublin/Pleasanton being one of the most populous among the entire BART System having 8,000 average users

per weekday it is highly recommended that resources to this station are prioritized with the goal to transform it into a world class intermodal station serving Bus/Transit, BART and ACE Transit Agencies similar to its counterpart in Millbrae. The demand in East Dublin/Pleasanton station is however much more as reported in the most recent BART ridership trends. Awareness of the critical needs at this station need to be raised and understood among the various communities and authorities in the Tri-Valley. Further investing is highly recommended to connect BART and ACE stations at Pleasanton. The current ratio bus:car (length of time spent on the trip) for the connection BART-to-ACE can be 4:1 at its worst. On top of a bus:car ratio for the connection of bus/transit to BART of 2.3:1. So assuming a person uses transit to travel from the Walnut Creek BART station to the ACE Pleasanton Station, the trip, just to get to ACE, will take approximately 2 hours and several transit transfers instead of just an average of 26 minutes driving via I-1680 in no peak hours. The total commuter time however will still need to include ridership on ACE commuter rail train to the city of destination.

Assuming it is San Jose the total commuter time using transit would take more than 2.5 hours compared to approximately 1 hour driving in non-peak time. Driving times can however vary largely during peak hours.

Leverage. With several Park & Ride stations servicing the cities of Alamo, Danville, San Ramon and Pleasanton it is highly recommended that Single Routes and Express Routes are further evaluated to effectively leverage existing local infrastructure. Park & Ride could represent feasible and effective solutions to connect people to transit. We strongly recommend routes be evaluated to consider this community alternatives. Evaluating further investments in the Iron Horse Trail is recommended specifically those related to green modes of transportation such as the use of bikes, e-bikes, green trains and electric vehicles. Cities around the world are moving towards heavily investing in bicycling companies and better bicycling and walking infrastructure. The Tri-Valley has a tremendous resource in the Iron Horse Trail and its potential to help alleviate traffic congestion in the area and in a way that is environmentally friendly.

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Appendix A: Contra Costa County Means of Transportation - Clustering Data Analysis

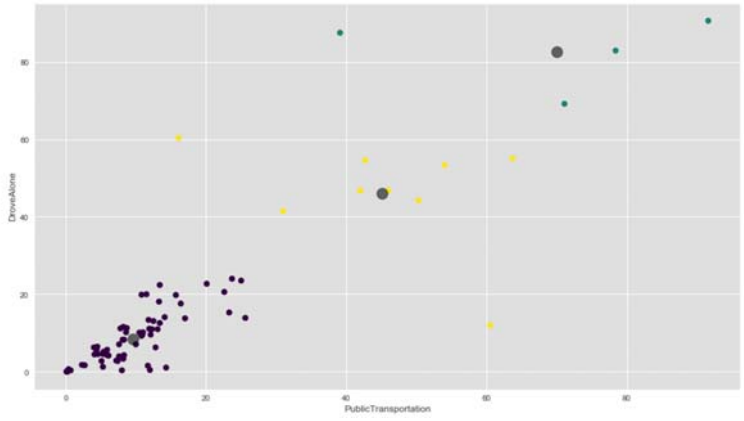
Data Analysis: Clustering
Algorithm: K-means clustering
Implementation: sklearn.cluster.KMeans
Platform: Anaconda Python Distribution
Data Source:
https://data.census.gov/cedsci/results/tables?q=Contra%20Costa%20means%20of%20transportation&g=0500000US06013&tab=ACSST5Y2016.S0802&ps=app*page@1$app*from@RESULTS_ALL$table*currentPage@1$map*classification@Natural%20Breaks$map*breaks@5$map*vintage@2016$map*layer@county$map*palette@Blues$map*zoom@3.819$results*page@1
Data Set: ContraCostaMeansofTransportation.csv
Programming Language: Python
Libraries: Pandas, NumPy, Matplotlib and SciKit-Learn

```
In [11]: ########Cluster Analysis#########
         # CSV file
         csv_file = '/Users/pleon/Desktop/CapstoneA/ContraCostaMeansofTransportation.csv'
         # read cvs with pandas read_csv
         df = pd.read_csv(csv_file, skiprows=1, names=['Characteristic', 'DroveAlone', 'Carpooled', 'PublicTransportation', 'ID'
         df.head()
```

Out[11]:

	Characteristic	DroveAlone	Carpooled	PublicTransportation	ID
0	16to19years	2.3	3.9	1.8	1
1	20to24years	8.1	10.7	8.3	2
2	25to44years	42.0	45.1	46.7	3
3	45to54years	25.0	22.6	23.5	4
4	55to59years	10.5	9.1	10.1	5

```
In [12]: import numpy as np
         from sklearn.cluster import KMeans
         f1 = pd.to_numeric(df['DroveAlone'].values)
         f2 = pd.to_numeric(df['PublicTransportation'].values)
         X = np.array(list(zip(f1, f2)))

In [13]: kmeans = KMeans(n_clusters=3)
         kmeans = kmeans.fit(X)
         labels = kmeans.predict(X)
         centroids = kmeans.cluster_centers_
         print(centroids)

         [[ 9.53538462  8.54      ]
          [70.05       82.65      ]
          [45.14444444 46.03333333]]

In [14]: plt.scatter(X[:, 0], X[:, 1], c=labels, s=50, cmap='viridis')

         centers = kmeans.cluster_centers_
         plt.scatter(centroids[:, 0], centroids[:, 1], c='black', s=200, alpha=0.5);
         plt.xlabel('PublicTransportation'), plt.ylabel('DroveAlone')

Out[14]: (Text(0.5,0,'PublicTransportation'), Text(0,0.5,'DroveAlone'))
```



Appendix B: Contra Costa County Means of Transportation – Principal Components analysis.

Data Analysis: PCA

Algorithms: 1)Standardize Data, 2)Fit Transform
Implementation: sklearn.decomposition
Platform: Anaconda Python Distribution
Data Source:
https://data.census.gov/cedsci/results/tables?q=Contra%20Costa%20means%20of%20transportation&g=0500000US06013&tab=ACSST5Y2016.S0802&ps=app*page@1$app*from@RESULTS_ALL$table*currentPage@1$map*classification@Natural%20Breaks$map*breaks@5$map*vintage@2016$map*layer@county$map*palette@Blues$map*zoom@3.819$results*page@1
Data Set: CC2.csv [3 rows x 78 columns]
Programming Language: Python
Libraries: Pandas, NumPy, SciKit-Learn : StandardScaler, PCA

```
In [16]: ########## PCA ##########
         # PCA: split data table into X: Characteristic and Y:PublicTransportation
         csv_file = '/Users/pleon/Desktop/CapstoneA/CC2.csv'
         df = pd.read_csv(csv_file, skiprows=1, names=['Age16to19years', 'Age20to24years', 'Age25to44years', 'Age45to54years', '
         df.head()
```

Out[16]:

	Age16to19years	Age20to24years	Age25to44years	Age45to54years	Age55to59years	Age60yearsandover	male	female	white	black	...	TraveltimetoWorkLes
0	2.3	8.1	42.0	25.0	10.5	12.1	54.0	46.0	63.7	7.8	...	
1	3.9	10.7	45.1	22.6	9.1	8.7	54.1	45.9	47.9	7.5	...	
2	1.8	8.3	46.7	23.5	10.1	9.6	53.3	46.7	55.0	11.2	...	

3 rows × 78 columns

```
In [38]: X = df.iloc[:,0:77].values
         X
```

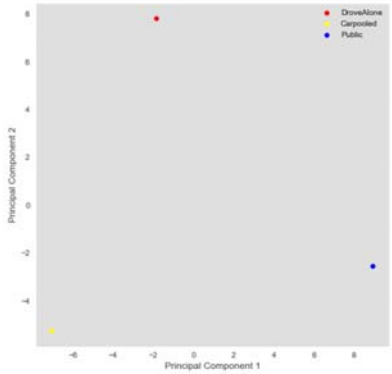
```
Out[38]: array([[ 2.3,  8.1, 42. , 25. , 10.5, 12.1, 54. , 46. , 63.7,  7.8,  0.4,
                  15.7,  0.4,  7.6,  4.4, 22.6, 50.3, 71.1, 16.4, 12.5, 20.1, 13.4,
                  11. ,  5.9, 10.8, 10. , 13.1, 12.3,  5.9, 31. ,  4.3,  4.1, 91.6,
                  42.7, 17. ,  8.2,  8.3,  0.1,  0.7,  7.2,  7.6,  2.7, 10.9,  5.3,
                  10.8, 13.4, 23.3,  8.6,  4. ,  0.2,  5.1, 78.4, 14.1,  7.4,  0.2,
                  60.5, 39.1,  0.3,  5.4,  4.6,  4.5,  8.2,  8.7, 13.3, 11.8, 11.9,
                   6.1, 25.6,  8. , 12. , 14.3, 11.7,  5.3, 12.8,  8.3, 11.5, 16.1],
                 [ 3.9, 10.7, 45.1, 22.6,  9.1,  8.7, 54.1, 45.9, 47.9,  7.5,  0.7,
                  20.4,  0.9, 17.5,  5.1, 38.4, 29.3, 53.6, 21. , 25.4, 26.6, 27.7,
                  15.3,  7.2, 16. , 11.4, 13.8, 11.1,  5. , 20.3,  7.2,  8. , 84.8,
                  33.3, 23.9, 12.9,  8.6,  0.1,  0.8, 10.2,  7. ,  2. , 10.5,  4.5,
                   9. , 16.7, 20.2,  9.9,  3.2,  0.1,  5.9, 78.2, 12.7,  8.9,  0.2,
                  51.1, 48.4,  0.5,  5.6,  6.4,  6.7, 10.7, 10.1, 15. , 10.6, 10.3,
                   4.7, 20. ,  6.1,  8.4,  9. ,  8.6,  4.4, 14.4,  8.6, 13. , 27.4],
                 [ 1.8,  8.3, 46.7, 23.5, 10.1,  9.6, 53.3, 46.7, 55. , 11.2,  0.5,
                  19.8,  0.7,  7.1,  5.7, 20.6, 44.2, 69.3, 17.6, 13.1, 22.7, 12.6,
                  10.2,  4.3,  9.3,  7.1, 11. , 11. ,  5.7, 41.4,  4.8,  4.5, 90.7,
                  54.5, 13.8,  3.4,  4.3,  0.1,  0.4,  2.9,  4. ,  1.7,  9.5,  4.6,
                  19.9, 22.4, 15.3, 10.2,  6.3,  0.1,  2.8, 83. , 14.1,  2.8,  0. ,
                  12. , 87.6,  0.3,  5.2,  4.6,  6.5, 11.6, 11.3, 18.1, 13.4, 11.1,
                   4.2, 13.9,  0.4,  0.5,  1.1,  1.6,  1.3,  6.3,  8.3, 20. , 60.5]])
```

```
In [39]: y = df.iloc[[0,1,2],[77]].values
         y

Out[39]: array([['DroveAlone'],
                ['Carpooled'],
                ['Public']], dtype=object)

In [40]: #Standarisation
         from sklearn.preprocessing import StandardScaler
         XS = StandardScaler().fit_transform(X)

In [75]: import numpy as np
         from sklearn.decomposition import PCA
         pca = PCA(n_components=2)
         principalComponents = pca.fit_transform(XS)

In [76]: print(pca.explained_variance_ratio_)

         [0.58154937 0.41845063]

In [77]: print(pca.explained_variance_)

         [66.29662818 47.70337182]

In [82]: # Plotting Principal Components
         PCAdf = pd.DataFrame(data = principalComponents, columns = ['Principal Component 1', 'Principal Component 2'])
         PCAdf = pd.concat([PCAdf, df[['Transportation']]], axis = 1)
         PCAdf
```

Out[82]:

	Principal Component 1	Principal Component 2	Transportation
0	-1.849785	7.819362	DroveAlone
1	-7.058236	-5.268560	Carpooled
2	8.908022	-2.550802	Public

```
In [106]: fig = plt.figure(figsize = (8,8))
          ax = fig.add_subplot(1,1,1)
          ax.set_xlabel('Principal Component 1', fontsize = 12)
          ax.set_ylabel('Principal Component 2', fontsize = 12)
          transportations = ['DroveAlone', 'Carpooled', 'Public']
          colors = ['red', 'yellow', 'blue']
          for transportation, color in zip(transportations,colors):
              indicesToKeep = PCAdf['Transportation'] == transportation
              ax.scatter(PCAdf.loc[indicesToKeep, 'Principal Component 1']
                         , PCAdf.loc[indicesToKeep, 'Principal Component 2']
                         , c = color
                         , s = 30)
          ax.legend(transportations)
          ax.grid()
```



Appendix C: Contra Costa County Means of Transportation – Parallel Coordinates.

Implementation: Parallel Coordinates Data Visualization

Platform: Anaconda Python Distribution
Data Source:
https://data.census.gov/cedsci/results/tables?q=Contra%20Costa%20means%20of%20transportation&g=0500000US06013&tab=ACSST5Y2016.S0802&ps=app*page@1$app*from@RESULTS_ALL$table*currentPage@1$map*classification@Natural%20Breaks$map*breaks@5$map*vintage@2016$map*layer@county$map*palette@Blues$map*zoom@3.819$results*page@1
Data Set: CC2.csv [3 rows x 78 columns]
Programming Language: Python
Libraries: parallel_coordinates, pyplot

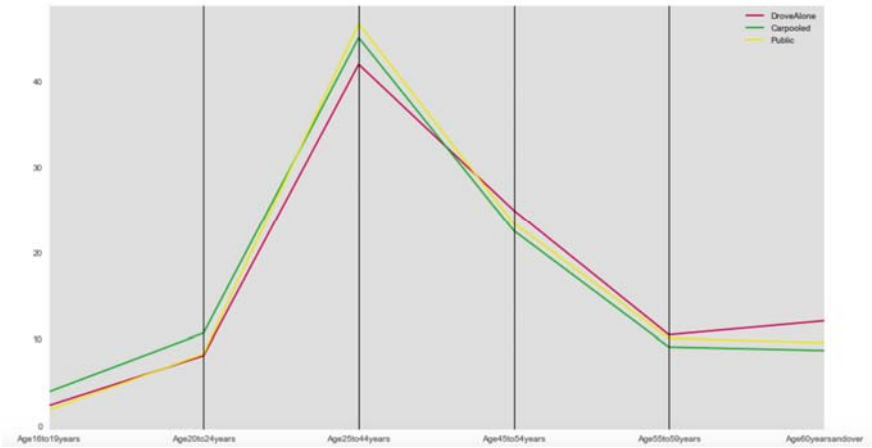
```
In [112]: ###### Parallel Coordinates #######
          from pandas import read_csv
          from pandas.tools.plotting import parallel_coordinates
          from matplotlib import pyplot as plt
          csv_file = '/Users/pleon/Desktop/CapstoneA/CC2.csv'
          df = pd.read_csv(csv_file, skiprows=1, names=['Age16to19years', 'Age20to24years', 'Age25to44years', 'Age45to54years', '
          df.head()

Out[112]:
```

	Age16to19years	Age20to24years	Age25to44years	Age45to54years	Age55to59years	Age60yearsandover	male	female	white	black	...	TravelTimetoWorkLes
0	2.3	8.1	42.0	25.0	10.5	12.1	54.0	46.0	63.7	7.8	...	
1	3.9	10.7	45.1	22.6	9.1	8.7	54.1	45.9	47.9	7.5	...	
2	1.8	8.3	46.7	23.5	10.1	9.6	53.3	46.7	55.0	11.2	...	

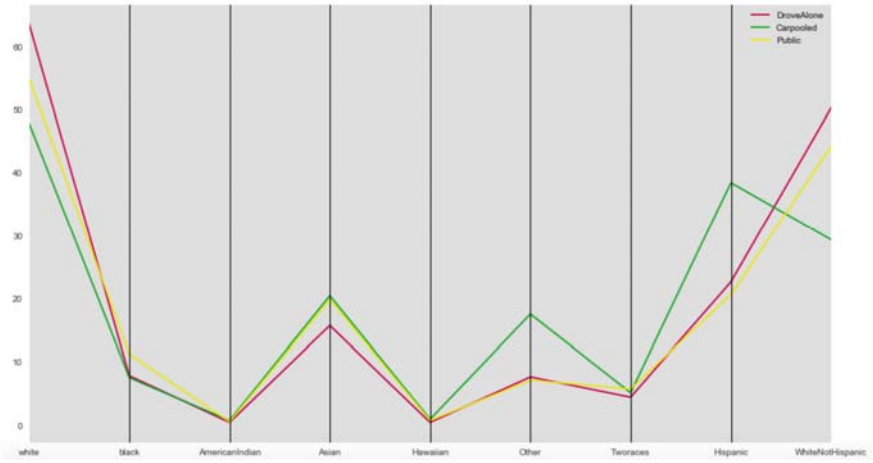
3 rows × 78 columns

dfByRace = df[['white', 'black', 'AmericanIndian', 'Asian', 'Hawaiian', 'Other', 'Tworaces', 'Hispanic', 'WhiteNotHispanic', 'Transportation']]
parallel_coordinates(dfByAge, 'Transportation', color=('#d6175c','#1caf37', '#efeb10'))
parallel_coordinates(dfByRace, 'Transportation', color=('#d6175c','#1caf37', '#efeb10'))
dfByEarnings = df[['1to9999earnings', '10000to14999earnings', '15000to24999earnings', '25000to34999earnings', '35000to49999earnings', '50000to64999earnings', '65000to74999earnings', '75000ormoreearnings', 'Transportation']]
parallel_coordinates(dfByEarnings, 'Transportation', color=('#d6175c','#1caf37', '#efeb10'))
dfByIndustry = df[['industryAgriculture', 'industryConstruction', 'industryManufacturing', 'industryWholesaletrade', 'industryRetail', 'industryTransportation', 'industryFinanceInsurance', 'industryScientific', 'industryEducational', 'industryEntertainment', 'Transportation']]
parallel_coordinates(dfByIndustry, 'Transportation', color=('#d6175c','#1caf37', '#efeb10'))

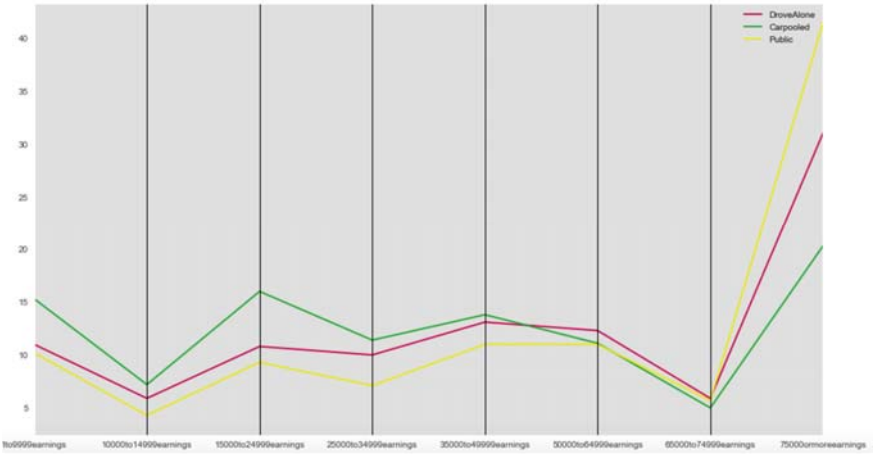
```
dfByWorkPlace = df[['WorkedinCounty', 'WorkedoutsideCounty',
'WorkedoutsideState', 'Transportation']]
parallel_coordinates(dfByWorkPlace, 'Transportation',
color=('#d6175c','#1caf37', '#efeb10'))
dfByDistance = df[['TravelTimetoWorkLessthan10minutes',
'TravelTimetoWork20to24minutes',
'TravelTimetoWork30to34minutes',
'TravelTimetoWork45to59minutes',
'TravelTimetoWork60orMoreminutes', 'Transportation']]
parallel_coordinates(dfByDistance, 'Transportation',
color=('#d6175c','#1caf37', '#efeb10'))
dfByLeaveHome = df[['LeaveHomeforWork500AMto529AM',
'LeaveHomeforWork630AMto659AM',
'LeaveHomeforWork700AMto729AM',
'LeaveHomeforWork800AMto829AM',
'LeaveHomeforWork830AMto859AM',
'LeaveHomeforWork900AMto1159PM', 'Transportation']]
parallel_coordinates(dfByLeaveHome, 'Transportation',
color=('#d6175c','#1caf37', '#efeb10'))
plt.show()
```



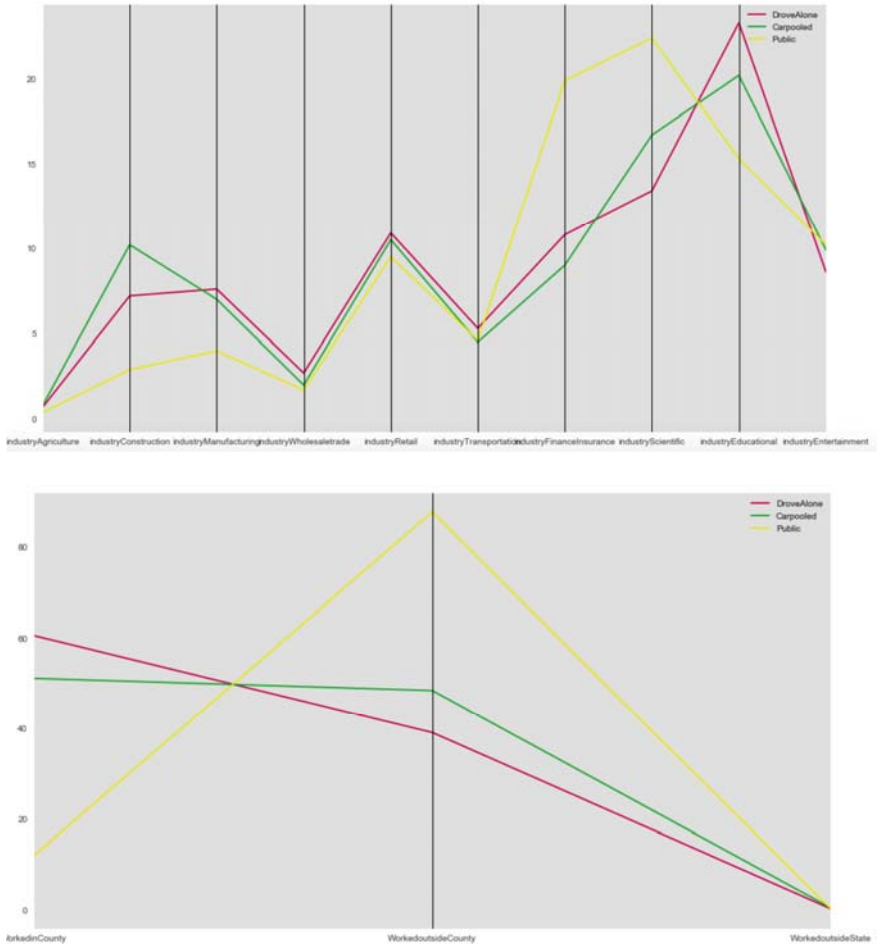
Contra Costa County Means of Transportation – By Age



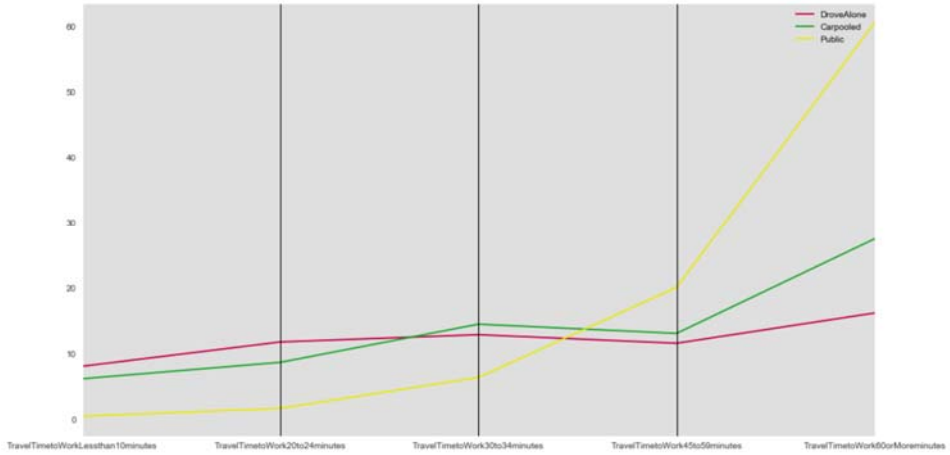
Contra Costa County Means of Transportation – By Race



Contra Costa County Means of Transportation – By Earnings



Contra Costa County Means of Transportation – By Work in County



Contra Costa County Means of Transportation – By Travel Time to Work

Appendix D: Percentage of WHEELS Potential Riders and their demographic data.

Data Source: https://www.wheelsbus.com/wp-content/uploads/2015/09/Telephone_Survey_Report_2007.pdf

Data Collection: Manual collection of percentages reported for the WHEELS Potential riders and their demographic data in the March 2007, Community Survey of Wheels Service Area Households prepared by CJI Research Corporation.

Dataset: 33 rows x 2 columns
Columns: Demographic attribute | Percentage

Data:
Resides-in-Dublin 19
Resides-in-Pleasanton 36
Resides-in-Livermore 45

Awareness	62
Commuters	62
Students-Only	4
Drive-alone	83
Carpool	9
Telecommute	1
Public-transit	4
Need-a-car	68
Job-requires-car	37
Have-to-drive-someone	34
Work-weekends	24
Work-in-Tri-Valley	38
Work-outside-Tri-Valley	26
Drive-in-Tri-Valley	88
Drive-outside-Tri-Valley	77
Public-transit-in-Tri-Valley	1
Public-transit-outside-Tri-Valley	13
ACE-commuters	4.4
Drove-to-ACE	1.2
Got-Ride-to-ACE	.08
BART-commuters	8
BART-noncommuters	70
Drove-to-BART	75
Got-Ride-to-BART	13
Wheels-to-BART	8.5
Age-35-64	68
Caucasian	67
Asian	14
Hispanic	8
Income>75000	65

Calculations:
Awareness: calculated as the average percentage of all Potential riders respondent as being Really familiar with the following Wheels Services: Awareness of Livermore-Dublin-Pleasanton service [55%], Awareness of 24 hour Bayfair service [15%] and Awareness of service to BART [57%].

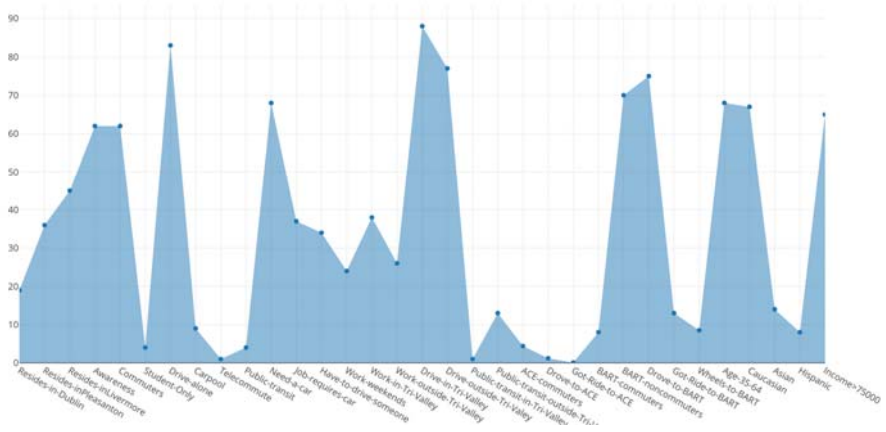
Commuters: Calculated as the sum of all Potential riders respondent as being either Employed [55%] only or Employed and a Student [7%].

Barriers to using transit to commute: Calculated for all Potential riders who are employed or students. Barrier noted as Have-to-drop-off-someone refers to a Potential rider who has to drop off someone who is too young to drive.

Mode to BART: Calculated as the average of all BART user respondents not only Potential Wheels Riders

Demographics: Age-35-64 was calculated as the sum of Potential Riders Age 35-44 [18%], Age 45-54 [29%], Age 55-64 [21%] and Income>75000 was calculated as the sum of Potential riders with an income $75,000 to $99,000 [22%], $100,000 to $124,999 [16%], $125,000 to $149,000 [7%] and $150,000 or more [20%]

Visualization:
Area chart implemented using Traces X[Demographic attribute], Y[Percentage]. Platform: Online Graph Maker - Plotly Char Studio https://plot.ly/#/



Percent of WHEELS Potential riders and their demographic data

Appendix E: County Connection Average Ridership % and Load by Direction by Local Routes by Service provided in the Tri-Valley.

Data Source: County Connection, Comprehensive Operation Analysis FY 2016/17, Central Contra Costa County Transit Authority, https://countyconnection.com/wp-content/uploads/2018/06/COA-5-17-18-web-test.pdf

Metrics:

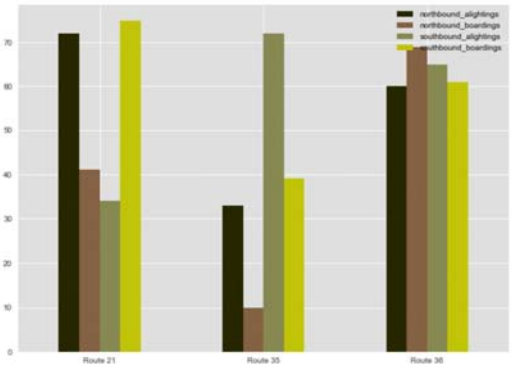
Route 21
Southbound_boarding: Walnut Creek BART Station
Southbound_alightings: San Ramon Transit Center
Northboud_boardins: San Ramon Transit Center
Northbound_alightings: Walnut Creek BART Station

Route 35
Southbound_boarding: San Ramon Transit Center
Southbound_alightings: Dublin BART station
Northboud_boardins: Dublin BART station
Northbound_alightings: San Ramon Transit Center

Route 36
Southbound_boarding: San Ramon Transit Center
Southbound_alightings: Dublin BART station
Northboud_boardins: Dublin BART station
Northbound_alightings: San Ramon Transit Center

Visualization: stacked plot bar using Pandas
Platform: Anaconda Python Distribution
Programming Language: Python

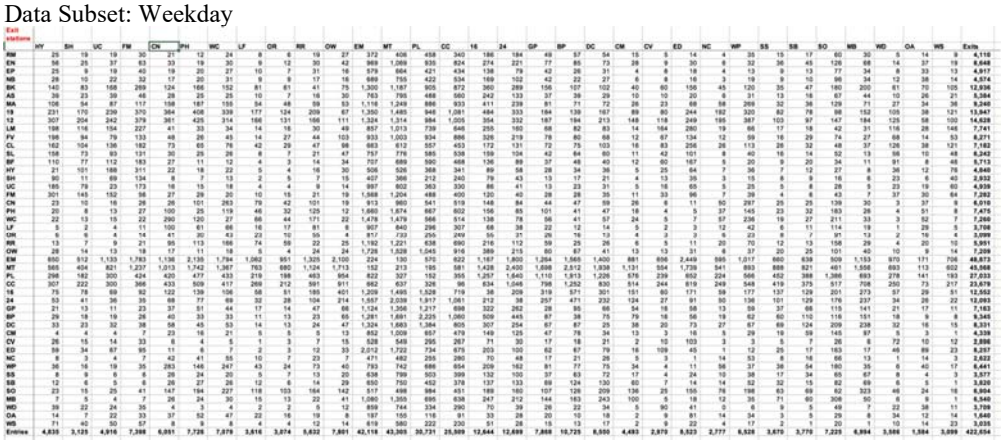
```
In [64]: ####### Ridership by routes ####
         southbound_boardings = [75,39,61]
         southbound_alightings = [34,72,65]
         northbound_boardings = [41, 10, 69]
         northbound_alightings = [72, 33, 60]
         income = ['Route 21', 'Route 35', 'Route 36']
         df = pd.DataFrame({'northbound_alightings': northbound_alightings,'northbound_boardings': northbound_boardings,'southbo
         df.plot.bar(rot=0, figsize=(11,8), color=('#333300','#977555', '#999966', '#cccc00'))

Out[64]: <matplotlib.axes._subplots.AxesSubplot at 0x1a25ef40b8>
```



Appendix F: BART Exit analysis by station. June of 2017. Tri-Valley Stations

Data Source: Ridership_June2017.xlsx
https://www.bart.gov/sites/default/files/docs/ridership_2017.zip

Data Subset: Weekday



Data source: Station_Names.xlsx
https://www.bart.gov/sites/default/files/docs/Station_Names.xls

Data:

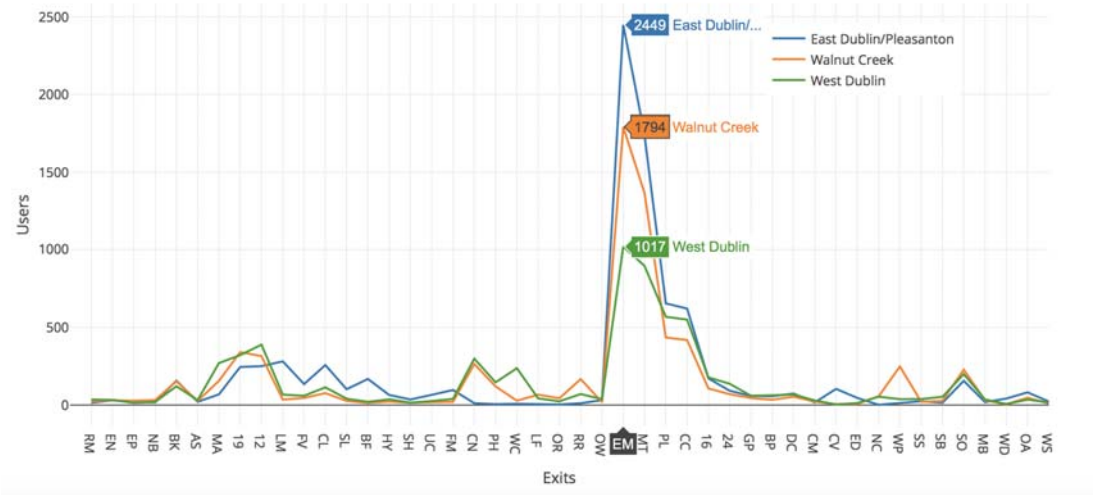
Two-Letter Station Code	Station Name
RM	Richmond
EN	El Cerrito Del Norte
EP	El Cerrito Plaza
NB	North Berkeley
BK	Berkeley
AS	Ashby
MA	MacArthur
19	19th Street Oakland
12	12th Street / Oakland City Center
LM	Lake Merritt
FV	Fruitvale
CL	Coliseum
SL	San Leandro
BF	Bayfair
HY	Hayward
SH	South Hayward
UC	Union City
FM	Fremont
CN	Concord
PH	Pleasant Hill
WC	Walnut Creek
LF	Lafayette
OR	Orinda
RR	Rockridge
OW	West Oakland
EM	Embarcadero
MT	Montgomery Street
PL	Powell Street
CC	Civic Center
16	16th Street Mission
24	24th Street Mission
GP	Glen Park
BP	Balboa Park
DC	Daly City
CM	Colma
CV	Castro Valley
ED	Dublin/Pleasanton
NC	North Concord
WP	Pittsburg/Bay Point

SS	South San Francisco
SB	San Bruno
SO	San Francisco International Airport
MB	Millbrae
WD	West Dublin/Pleasanton
OA	Oakland International Airport
WS	Warm Springs

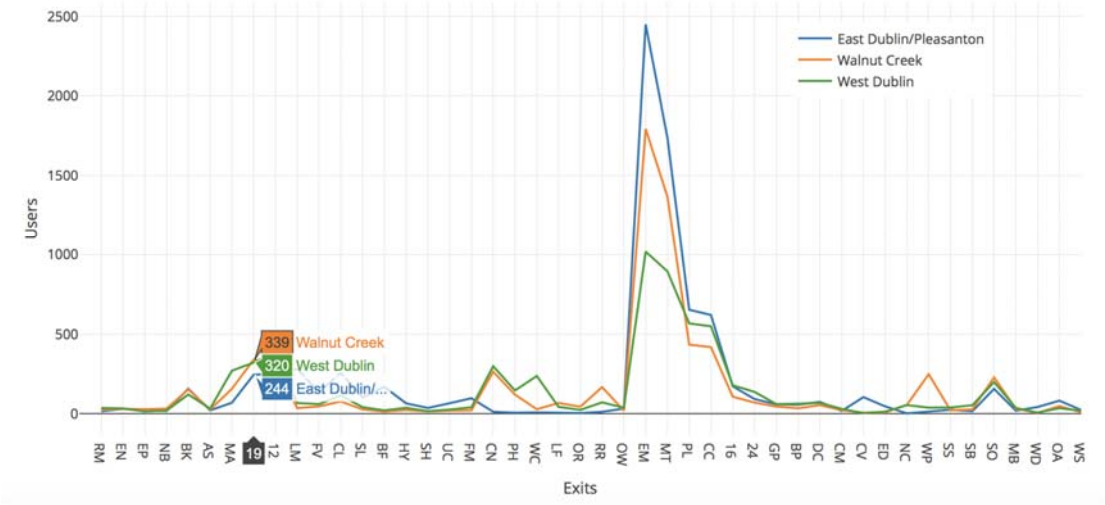
Visualization:
Line Chart implemented using Traces East Dublin/Pleasanton[X:Column0 Exits], [Y:Column37 ED], Walnut Creek[X:Column0 Exits][Y:Column21 WC], West Dublin[X:Column0 Exits][Y:Column39 WD]. Platform: Online Graph Maker - Plotly Char Studio https://plot.ly/#/

Line Chart #1: Exit trend by Station (San Francisco analysis). Tri-Valley stations
Line Chart #2: Exit trend by Station (Oakland analysis). Tri-Valley stations
Line Chart #3: Exit trend by Station (Airport analysis). Tri-Valley stations

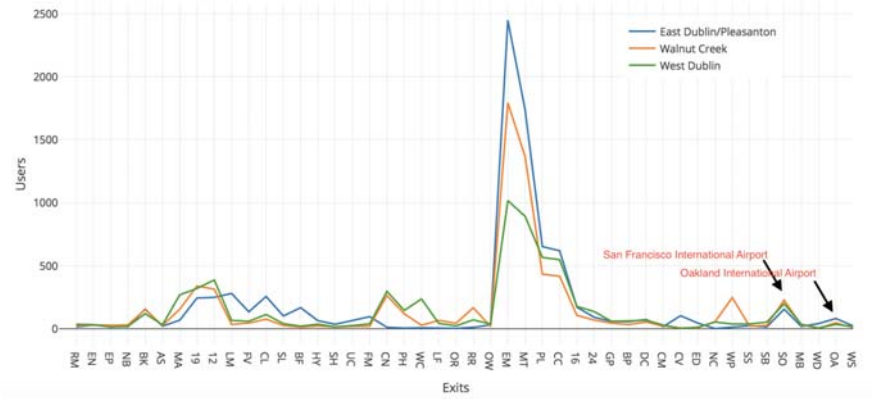
Line Chart #1



Line Chart #2



Line Chart #3



Appendix G: BART ridership Millbrae and East Dublin/Stations. June 2017

Data Source: Ridership_June2017.xlsx
https://www.bart.gov/sites/default/files/docs/ridership_2017.zip

Data Subset: Grid: Weekday. Stations East Dublin/Pleasanton [ED] and Millbrae [MB]

	ED	MB
RM	14	30
EN	30	68
EP	18	34
NB	16	34
BK	156	200
AS	20	44
MA	68	71
19	244	152
12	249	184
LM	280	31
FV	134	27
CL	256	37

SL	101	13
BF	167	11
HY	64	8
SH	35	6
UC	65	5
FM	96	7
CN	11	30
PH	5	26
WC	7	33
LF	3	19
OR	3	13
RR	11	29
OW	31	40
EM	2,449	1,153
MT	1,739	1,556
PL	652	693
CC	619	708
16	171	273
24	91	237
GP	58	141
BP	56	151
DC	73	238
CM	16	97
CV	103	6
ED	45	17
NC	1	13
WP	11	35
SS	24	67

SB	14	69
SO	155	323
MB	18	50
WD	41	7
OA	81	8
WS	22	1

Data source: Station_Names.xlsx
https://www.bart.gov/sites/default/files/docs/Station_Names.xls

Visualization:
Violin Chart implemented using Traces East Dublin/Pleasanton[X:Column0 Exits], [Y:Column37 ED], Millbrae[X:Column0 Exits][Y:Column43 MB]. Platform: Online Graph Maker - Plotly Char Studio https://plot.ly/#/

Appendix H: Access from home to BART (A comparison between Drive and Park against Bus/Transit for the years 2008 and 2015)

Data Source:
https://www.bart.gov/sites/default/files/docs/BART%202016%20Wksp%204.D%202015%20Station%20Profile.pdf

Data:

Year	Drive and Park	Bus/Transit
2008	39	15
2015	29	8

Visualization:
Bar Chart implemented using Traces 2008 and 2015.
Platform: Online Graph Maker - Plotly Char Studio https://plot.ly/#/

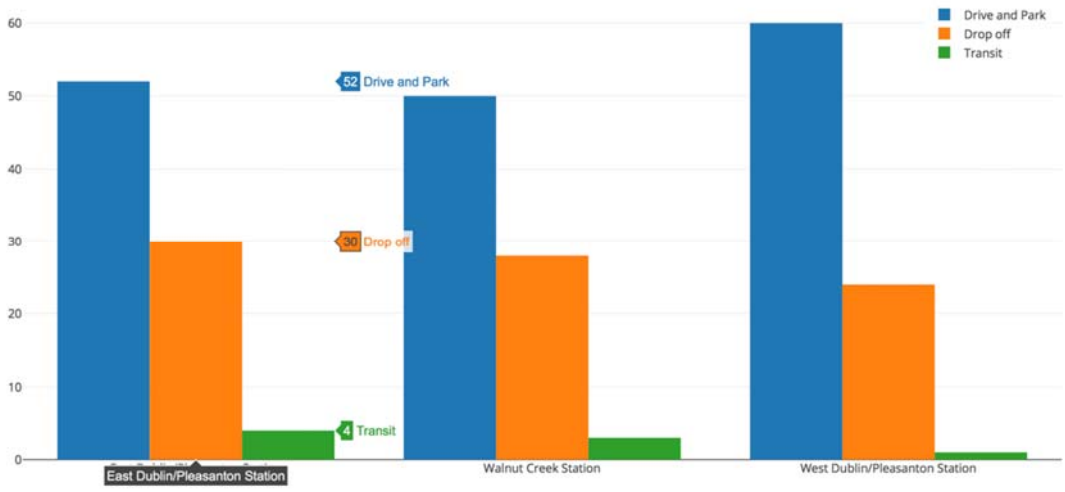
Appendix I: Travel Mode to BART Stations that service the Tri-Valley (from home origins).

Data Source:
https://www.bart.gov/sites/default/files/docs/StationProfile2015_HomeOriginOnePagers_rev0629.pdf

Data:

	Drive and Park	Drop Off	Transit
East Dublin/Pleasanton Station	52	30	4
Walnut Creek Station	50	28	3
West Dublin/Pleasanton	60	24	1

Visualization:
Bar Chart implemented using Traces Drive and Park, Drop Off and Transit. Platform: Online Graph Maker - Plotly Char Studio
https://plot.ly/#/



Appendix J: Estimated ACE daily ridership trend by origin-destination for 2013

Data Source:
https://www.acerail.com/About/Projects-Initiatives/Current/ACE-Extension-Lathrop-to-Ceres-Merced/Draft-Environmental-Impact-Report/Appendix-D-2-Ridership,-Revenue-and-Benefits-Repor.pdf

Data:

Origin Station	Exit in San Jose	Exit in Fremont
SKT	36	28
LTM	71	55
TRC	77	58
VAS	24	17
LIV	27	22
PLS	74	55
FMT	24	0

Visualization:
Line Chart implemented using Traces Exit in San Jose and Exist in Fremont. Platform: Online Graph Maker - Plotly Char Studio
https://plot.ly/#/