

**Urban Form and Travel Behavior:  
Case Study of Avalon Walnut Creek Transit Village**

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**ABSTRACT**

The coordination of land use and transportation can supplement climate change mitigation strategies by promoting policies that decrease sprawl and associated automobile use. Transit Oriented Developments (TODs) try to achieve this with high-density housing, lower parking requirements and mixed land uses close to transit. Convenient access to transit has been shown to significantly reduce vehicle-miles traveled (VMT) and increase transit ridership. While the benefits of TOD are well understood, more can be learned about existing TODs and progressive parking implementation. In this study, I explored whether 1) travel mode choice changed since residents moved to Avalon Transit Village and if 2) lower parking development standards adequately meet demand. I surveyed 418 households about their demographics, means of transportation, work and non-work travel relative to their previous residence, and obtained feedback on transit and Avalon. My results indicated that Avalon is successful in increasing BART ridership and decreasing car usage to work. Respondents with employer-provided free parking drove rather than using BART. Non-work trips shifted favorably for recreational trip purpose most likely due to the site infrastructure. Residents noted convenience to transit, work, and freeway as the primary reasons for moving there. While this demonstrates self-selection bias, it also shows a growing demand to live in accessible locations. Avalon provides a successful example of reducing work trips, however, further development, especially at vacant retail spaces, is needed to reduce vehicular non-work trips. Avalon additionally exemplifies a successful implementation of progressive parking requirements, which BART can reference as they implement more TODs.

**KEYWORDS**

Transit oriented development (TOD), Contra Costa Center Transit Village, mode choice, parking development standards, greenhouse gas emissions

## **INTRODUCTION**

American cities emit high levels of greenhouse gas (GHG) emissions to the atmosphere due to their high land consumption and resulting transportation preferences. Especially since the 1950's, development patterns have trended towards lower density housing and low intensity of uses on large areas of land (Beatley and Manning 1997 in Beatley 2000). In areas of low density, residents tend to rely on cars (Beatley 2000). This exacerbates climate change because cars are the greatest contributor to transportation emissions, and transportation is responsible for the largest share of greenhouse gas (GHG) emissions in California (Bartholomy et al. 2007, Norman et al. 2006). Re-envisioning cities has the potential to significantly reduce emissions and mitigate effects of climate change, while meeting residents' daily travel needs.

City planners can contribute to climate change mitigation and improved quality of life through coordination of urban form (physical layout) and transportation planning. Academics suggest that the coordination of land use and transportation planning can decrease vehicle miles traveled (VMT), improve livability characteristics of the community, increase accessibility, and alter mode choice for travel (Polzin 2004, Ewing et. al 2003, Cal Air Resources Board). The ratification of Senate Bill 375 (SB 375) by the California Legislature in 2008, which aims to address Assembly Bill 32 GHG emission reduction goals through better coordination of transportation, land use and community planning, demonstrates the legal incorporation of these findings (Cal. Air Resource Board 2008). Transit Oriented Development (TOD) is an emerging tool to realize SB 375 goals of decreasing sprawl and auto dependence, revitalizing areas, and expanding lifestyle choices (Cervero 2004). TODs consist of mixed land use, higher density housing, and reduced parking placed around alternative transit options (Ewing and Cervero 2010). Awareness of the connection between urban form and travel behavior, in addition to other factors, can help planners promote certain behaviors through the manipulation of the built environment.

Several physical factors can influence travel behavior. The manipulation of such factors to influence behavior is supported by the ideas of environmental possibilism and probalism. They respectively posit that people will choose among the available opportunities, and that in a given environment some options are more likely than others (MacDonald 2012). The 5D's – density, diversity, design, destination accessibility, and distance to transit – are likely to affect

travel behavior. TODs strive to increase the likelihood of using transit and non-vehicular modes by controlling these factors. Studies have found that families who live within a half mile radius of transit are 10 times more likely to take transit and drive 50% less than those who live outside this radius (ABAG 2007, Arlington and Cervero 2008). The most influential factors in increasing ridership include high quality transit service (meaning it is fast, frequent, and comfortable), a constrained supply of parking, and station proximity to trip origin and destination (Arlington and Cervero 2008). TODs seek to address travel behavior variables in order to promote a sustainable agenda, but parking policy must also be addressed to increase effectiveness.

Parking policy exhibits strong influence on travel behavior yet has only been receiving recent considerations at TODs. Developers and city planners tend to assume TODs generate the same traffic as conventional development, leading to an oversupply of parking (Arlington and Cervero 2008). Shoup (1997) and Willson (2005) agree noting that there is an oversupply of parking and recommend the unbundling of parking and rental cost so residents can see the true cost of parking. However as noted above, residents of TODs drive less, demonstrating a need to supply less parking. Green Trip, an East Bay organization recognizes this and certifies developments with parking ratio lower than 1.5 spaces/household, and other reduction strategies such as unbundling parking and offering discount transit passes (Cheng 2011). Providing less parking is important because the valuable space can be used to increase housing units and maximize ridership potential (Arlington and Cervero 2008). While academics agree on the oversupply of parking, TODs with lower parking requirements face barriers to getting planning approval.

While the policy value of TODs is well understood, less is known about the actual trip generation at residential TODs, which can support the justification of lower parking requirements. Through Avalon Walnut Creek at the BART Transit Village, I will use a survey to assess if residents' travel behavior has changed since moving to Avalon. Understanding the travel impacts of Avalon and the factors underlying mode choice can offer development implications. By understanding travel behavior in relationship to these goals, these findings can potentially inform developers and policy makers about the true trip generation occurring in residential TODs. This is important because auto trips are overstated for TODs, leading to an over-allocation of parking that decreases the efficiency and potential of TODs. The results can

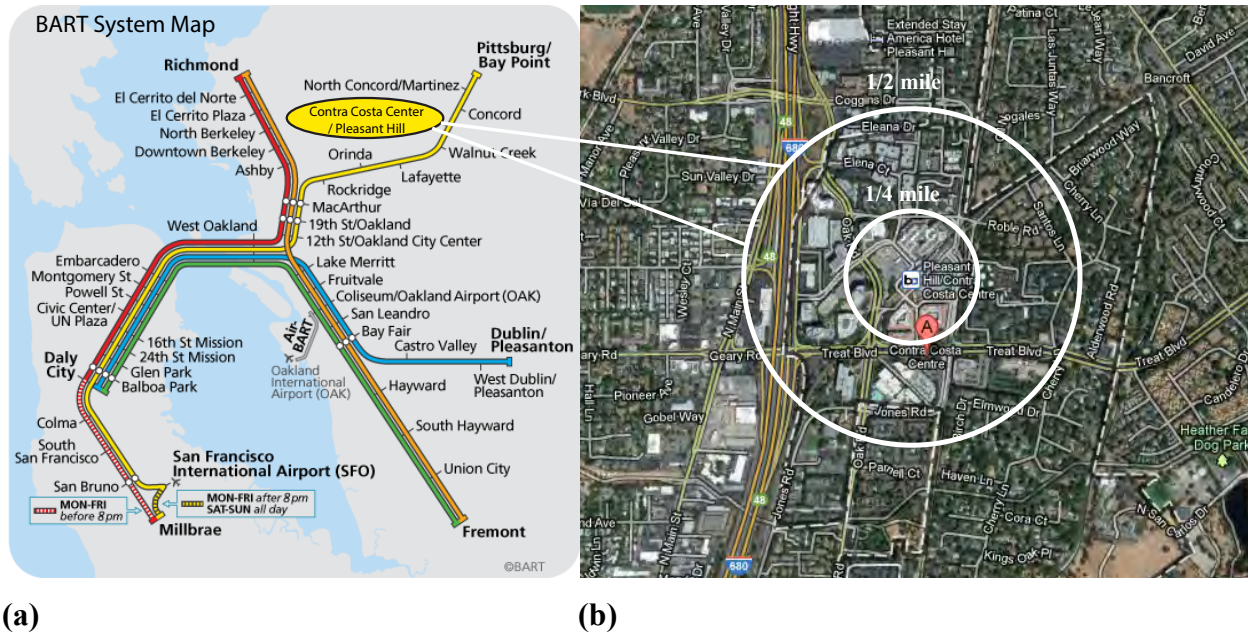
help inform BART's future TOD developments as well as inform the Transit Village of next steps for improvement.

## **METHODS**

### **Study site**

The realization of Contra Costa Center Transit Village resulted from a public-private partnership aimed to bring housing and jobs in close proximity to transit. First conceived in the 1980s, the project gained momentum in 2001 when the Contra Costa Center and the Contra Costa County Redevelopment Agency partnered with BART and Millennium Partners to develop a sustainable mixed use plan for the 125 acre redevelopment project area (California Redevelopment Association 2012). The Transit Village is located around the Pleasant Hill/Contra Costa Center BART Station in unincorporated Contra Costa County (Figure 1). The site is 90% built out with 2700 housing units, and 2.4 million square feet of commercial and office space. It also has the highest concentration of multi-family housing within a quarter mile of any transit hub in Northern California (APA 2013). The Transit Village has received recognition for its achievements through the National Planning Excellence Award for Implementation in 2012 by the American Planning Association and Contra Costa County Redevelopment Agency Sustainability Award (CCC 2013).

My research focused on the residents and physical structures implemented at Avalon Walnut Creek within the Contra Costa Transit Village. Avalon Walnut Creek consists of 418 housing units in five, four story buildings built with 1.4 parking spaces/unit immediately adjacent to the BART station. Avalon was fully constructed and lived in by early Spring 2011 (McVicker 2013). While residential occupancy is generally filled, the bottom floor commercial space is primarily vacant. It is a high quality apartment complex that offers great amenities, is LEED certified, and brands itself as luxury apartment living (California Redevelopment Association 2012, Avalon Communities 2013). Ultimately, this development caters more to higher income residents while other properties on the Transit Village, such as Coggins Square and Cornerstone offer affordable housing.



**Fig. 1. Geographic location of study site.** Map of the (a) BART system, highlighting that Contra Costa Center is in the East Bay. (b) displays an aerial map of the Transit Village with Avalon located within the first ring. This indicates that the study site is within a quarter mile radius of BART and therefore within walking proximity.

## Survey method

Interested in investigating the residents' travel behavior, my research relied on surveys in order to collect household level data directly from the resident. The survey included questions that investigated travel behavior, demographics, and perceptions of the Transit Village. The tested variables were purposely chosen based on travel behavior and TOD research. This research draws on previous studies including, but not limited to: Cervero (2004), Bartholomy et al. (2007), a literature review by Abt Associates Inc. (n.d.), Ewing and Cervero (2010). The end of the survey asked permission to contact the resident in the future, which allows for the possibility of a longitudinal study. I first distributed surveys in person at a community social event and then mailed a packet to all households who didn't respond. The packet included a cover letter explaining the research, a hardcopy of the survey, a return envelope without postage, a personal id code to insure privacy and confidentiality, and a link to the online version. Those who didn't respond within two weeks received a reminder postcard in the mail. I raffled three \$48 BART tickets in order to encourage participation. I collected 80 surveys, totaling a response rate of 20% when subtracting vacant units. See Appendix D for complete survey.

## **Direct observations**

In addition to the survey, I made both quantitative and qualitative observations in order to look at the actual conditions of the Transit Village and compare to primary TOD goals. I collected data through the Internet and site visitation about the number and type of stores, number of stop signs, street width, number of bike racks, bus lines through the station, frequency of BART trains, aesthetics, how people use the plaza, etc. While counts are objective measurements, descriptive observations will be filtered through my own biased lens.

## **Data analysis techniques**

Data analysis relied primarily on descriptive statistics to determine if travel behavior has changed and any resulting development implications within the framework of Transit Oriented Development theory. I used Chi-Squared Tests for binary categorical v. categorical responses to run the dependent variable, variables comprising travel behavior, against employer-provided parking. TOD theory, as elaborated in the Introduction, served as a framework to compare the actual realization in terms of site design and travel behavior against ideal TOD conditions. To address my research question, I framed my data in terms of the following four variables: study site, work behavior, non-work behavior, car ownership and parking, and feedback on Avalon.

## *Evaluation of study site*

I evaluated Avalon Walnut Creek in terms of demographics, infrastructure, and by land use to determine the extent to which it meets TOD objectives. I measured the variables listed above and analyzed them descriptively and qualitatively. A well-designed TOD will have adequate infrastructure, meaning there are provisions for a variety of alternative modes, a mix of land uses, and a pedestrian oriented design. Understanding the quality of design helps contextualize the data regarding travel behavior. I descriptively compared the demographics to Walnut Creek and Contra Costa County to offer broader lessons to other BART stations.

*Means of transportation*

A distinguishing quality of the Avalon Walnut Creek is their lower minimum parking requirements compared to Contra Costa County. Due to the relationship between the cost of parking and car ownership, I collected numerical data about car ownership and if it had changed since moving to the development. Additionally, I asked questions on the number of parking passes and ownership of other transportation modes, signified by bus passes, bikes, and clipper cards. I used a Chi-Squared test to statistically analyze the variables.

*Travel behavior*

I collected absolute counts and percentages to determine whether residents' travel behavior has changed since moving into the Transit Village. I analyzed travel behavior in terms of five modes – car, light rail, bus, bike, and walk – for work and five types of non-work – meal, visit family/friends, recreation, errands, grocery - trip purpose. The survey asked their primary mode to work then and now, and how their behavior has relatively changed since moving. I used descriptive statistics to summarize the data of how many people increased, decrease, or maintained the same level of usage for each mode and purpose. I then compared these findings to several variables to describe why this has or has not changed for each particular mode and purpose type. Such independent variables include car ownerships, employer provided parking, transit availability, and motives for moving into the development.

*Feedback on Avalon*

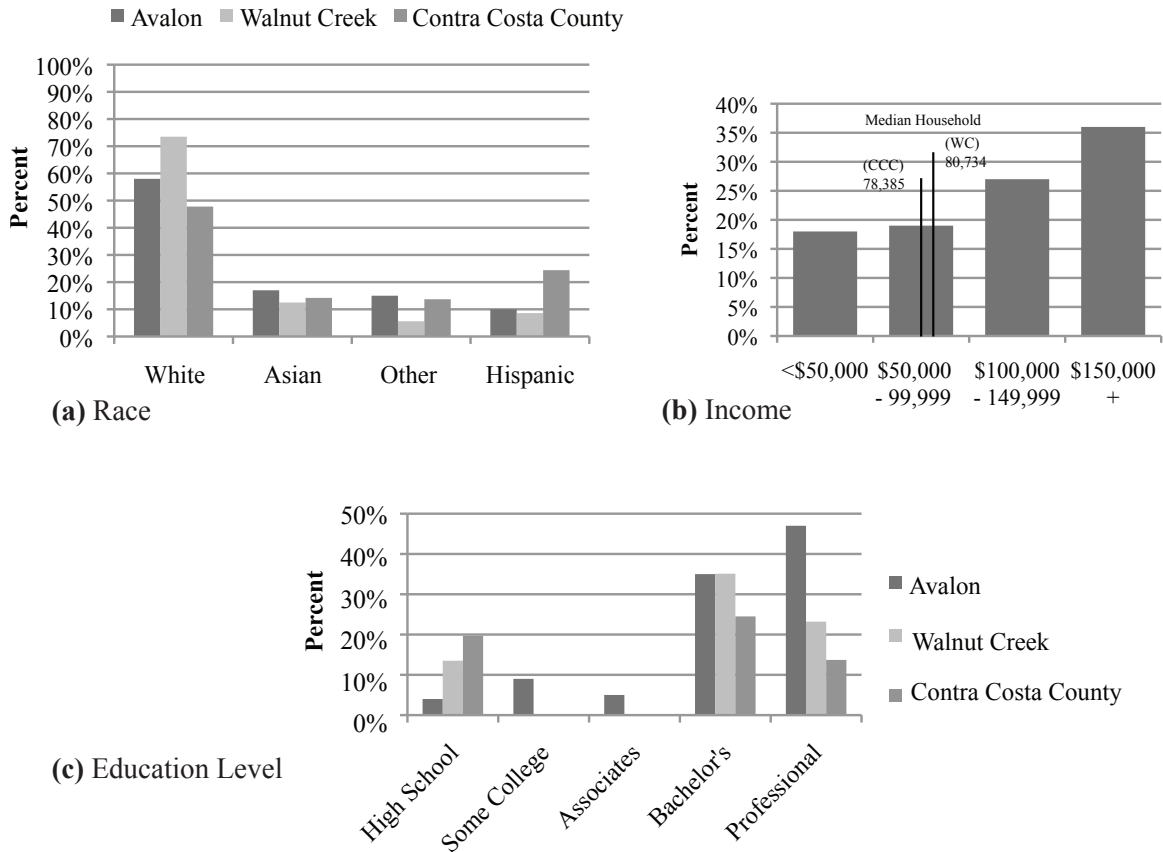
To evaluate the development using community feedback, I asked categorical questions to gauge perceptions of Avalon Walnut Creek. The survey allowed for community feedback by asking questions about residents' perceptions of safety, availability of public transit, reasons for moving there, and availability of retail.

## **RESULTS**

### **Demographics**

Avalon Walnut Creek is more racially diverse, wealthier, and higher educated than the adjacent city of Walnut Creek (Figure 2). The dominant racial group at Avalon is White, 58%, followed by Asian, 17%, other, 15%, and Hispanic, 10%. The most populous racial groups in Walnut Creek are White 73.5%, Asian 12.4%, Hispanic, 8.6%, and Other 5.6% (U.S. Census Bureau 2010). Avalon residents report a higher household income than Walnut Creek, with 64% of households at over \$100,000/year compared to a mean household income of \$80,734 in the greater area (U.S. Census Bureau 2010). 82% of Avalon residents have received a Bachelors or higher degree compared to 58% of residents in Walnut Creek. Avalon and Walnut Creek have similar household sizes, respectively 2.0 and 2.08 (U.S. Census Bureau 2010). 88% of Avalon residents are currently employed, compared to 94% at their previous residence. Residents have lived there an average of 17 months with most residents reporting between 6 and 28 months (SD=11). While residents may have learned more about TODs since moving here, before moving here 60% had never heard of a TOD and only 19% were confidently familiar with the concept. See Appendix A for complete demographic results.





**Fig. 2. Demographics of Avalon Walnut Creek.** (a) shows the racial breakdown, and (b) shows the education level, both are compared to Walnut Creek and Contra Costa County.

**Urban form**

*Transportation infrastructure*

The housing area contained infrastructure for each mode of transportation – car, BART, bus, bike, and walking – but some were more established than others (Fig. 3). The housing development had a total of 601 parking spaces for residents and some on street free hourly parking. Compared to Contra Costa County with one parking space/bedroom, and Walnut Creek with a range of 1.25 – 2.25 parking spaces/unit, the project area had a lower required parking requirement at 1.4 parking spaces/unit (Table 1) (Contra Costa County 2013, City of Walnut Creek 2013). The development is regionally accessible due to Highway 680, bus lines, and BART. BART has two lines – the Pittsburg/Bay Point and North Concord (northbound

direction) – that run through the Pleasant Hill/Contra Costa Center station. During peak workday commute hours there are two trains within 15 minutes, while during off-commute hours there is a train every 15 minutes (BART a 2013). In March 2013 this station had a daily ridership numbers of 6825 people/weekday (BART b 2013). The BART station is at most, measuring from the furthest unit, .15 miles from Avalon. Five different bus systems – County Connection, Benicia Breeze, Solano Express, Fairfield and Suisun Transit, and Wheels express – and a total of bus infrastructure was also widely developed with a total of 13 lines serve this area. Buses come between every 30 minutes to every 150 minutes depending on the route and time of day (County Connection 2013). The Iron Horse Trail, a 33 mile regional bike/pedestrian path borders the East end of the property. Additionally, a bicycle bridge over the arterial street, Treat Boulevard, offers safety for users. There were 0 indoor parking bike racks and 16 public street bike racks with 32 spots at Avalon. Avalon is a pedestrian oriented design especially due to street characteristics, a public plaza with interactive elements (i.e. water spouts in the ground and chess tables), and the opportunity for retail. Wide sidewalks, different paving and 8 stop signs in the main three roads of the development also serve as traffic calming measures that make it a more pedestrian oriented site.

**Table 1. Walnut Creek minimum parking requirements.** Below is the codified parking development standards for multi-family residential housing in Walnut Creek and Contra Costa County (the jurisdiction Avalon is in). Avalon with studio, 1, 2, and 3 bedroom units, has a lower ratio than the normal code would have allowed.

	Avalon WC	Contra Costa Cnty	Studio (WC)	1 BDR (WC)	2 BDR (WC)	2 + BDR (WC)
Parking Spaces/Unit	1.4	1/BDR	1.25	1.5	2	2.25

### *Housing development*

I found all three use types at this development, characterizing it as mixed-use. There are 418 residential units (31 studios, 187 one BDR, 171 two BDR, and 29 three BDR), 35,590 square feet of retail and a central open space plaza and adjacent green space. Despite the amount of ground floor retail, there were only three occupied commercial properties – Starbucks, Third Place, All State Insurance, and Avalon Management Center. At full completion there will be an

additional 100 condominium units, 290,000 square feet of office and 2,315 square feet for civic purposes (ITE n.d.).



**Fig. 3. Avalon Transit Village plan.** The above figure shows the development’s design highlight the infrastructure aspects of the site.

### Means of transportation

For many residents, their means of transportation, or items that enable the use of a certain mode, did not change. Car ownership decreased from an average of 1.5 cars/household at their former residence to 1.35 at Avalon. Number of bikes and bus passes also decreased from 1.35 to .81 bikes/household and .17 to .12 bus passes/household. Clipper cards almost doubled from .47 to .96 per household. While parking availability at their former residence is unknown, all residents had one free parking pass and had the option to purchase additional spaces for \$100 per space. There are never vacant parking spaces and 14% (n=11) have more cars than parking passes.

**Table 2. Means of transportation at previous and current residence.**

Average / Household	Car	Bike	Clipper Card	Bus Pass
Former Residence	1.5	1.35	.47	.17
At Avalon	1.35	.81	.96	.12

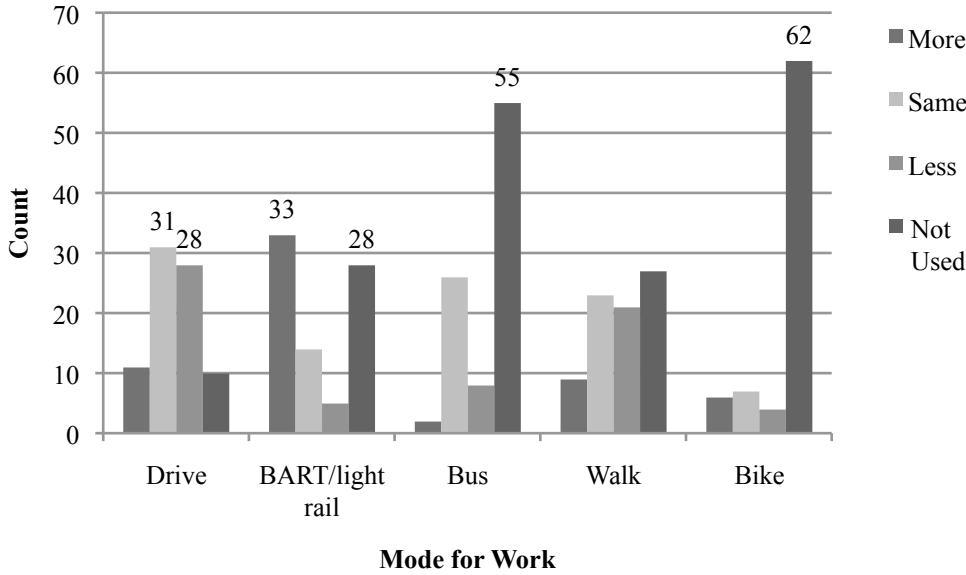
### Work travel behavior

BART is the dominant mode taken to work; however this was not the case at residents' former residence. At Avalon 41% reported car as the main mode they used to get to work, 57% said BART, and 2% walked (n=56) (Table 3). At their previous residence, even though residents used a wider variety of modes the car was overwhelmingly the dominant mode, 67% and BART was only used by 16% (n=57). To further understand this data, residents were categorized by their former residence and whether it was more urban/transit friendly or more suburban/less transit friendly than Avalon. Of the 55 suburban households, 33 used the car at their former residence while 3 used BART. At Avalon, now 16 use the car and 20 use BART (Table 4). From previous residence to living at the TOD, car, bus, bike, and walking decreased while BART usage increased (Table 4).

Employee provided free parking is one factor related to mode choice to work. Residents with free parking at work drove more than using BART while residents without free parking were more likely to use BART than drive ( $p=1.153e-05$ , Table 5) (R Development Core Team 2009).

When I asked residents how they perceived their mode usage to have shifted since moving to Avalon, clearer patterns resulted for all modes (n=80) (Fig.4). 74% of residents reported driving less or the same for work since moving to Avalon. On the other hand, 59% reported using BART more or the same although a higher percentage of residents have never used BART for work while a very low percent have never used the car. A majority of residents reported never using the bus (69%) or a bike (78%) for work. If residents happened to use bus,

their usage is the same or less. Walking to work decreased or stayed the same for 55% of residents. Refer to Appendix B for complete counts.



**Fig. 4. Relative shift in work trips for each mode since moving to Avalon Walnut Creek.** The most notable modes are highlighted with the specific count.

**Table 3. Primary mode to work at current and former residence.** The largest changes occurred for car and BART/light rail use.

	Former	Avalon	Change
Mode	57	56	1
Car	38	23	-15
BART/Light rail	9	32	23
Walk	7	1	-6
Bus	2	0	-2
Bike	1	0	-1

**Table 4. Relationship between work mode choice and former residence classification.** I classified former addresses as more “suburban” or “urban” compared to Avalon, “same” applies living at Contra Costa Center before

**(a) Former Residence**

Classification	BART	Car	Walk	Bus	Bike
Suburban	3	31	3	-	1
Urban	4	3	4	2	-
Same (CCC)	1	-	-	-	-

**(b) at Avalon**

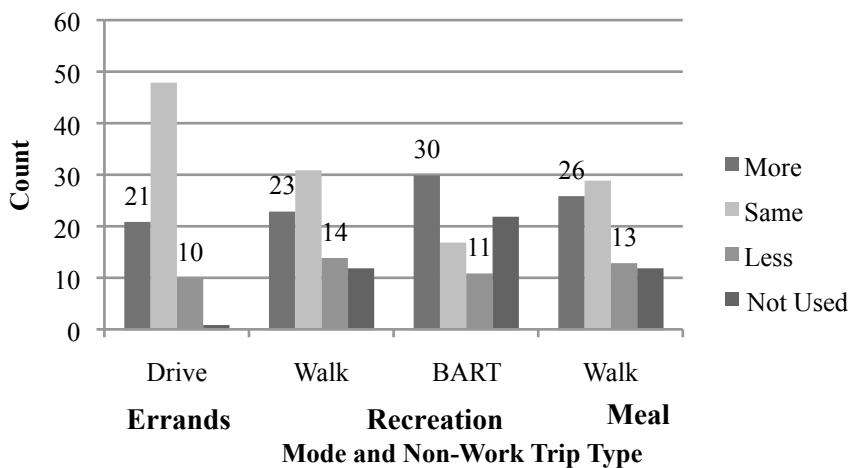
Classification	BART	Car	Walk	Bus	Bike
Suburban	20	16	1	-	-
Urban	9	4	-	-	-
Same (CCC)	1	-	-	-	-

**Table 5. Relationship between work mode choice and free employee parking.** Chi-Squared test found a  $X^2$  value of 24.084 and a highly significant p value of 1.153e-05

Free parking at work	No	Yes
BART	25	4
Car	6	17

**Non-work travel behavior**

While traveling for work offered more clear patterns, some combinations of modes and non-work purposes resulted in interesting and significant relationships. Driving did not significantly change for any non-work purposes; however interestingly, residents would drive more for errands, grocery or family trips compared to their former residence, respectively 23% (n=79), 26%, and 28% (n=80) (Fig. 5). BART usage increased for visiting family and friends (25%) and for recreation (38%). While an average of 2/3 of residents never have used the bus for any non-work purposes, those who did, reported a decrease in bus usage for all non-work purposes of interest. Residents walked more for meals, 29%, and recreation, 33%. If residents perceived to change their walking behavior to visit family, they were more likely to walk less (24%) than walk more. Biking was not a popular mode of transportation for residents, although residents are more likely to bike more for recreation while living at Avalon (15%). See Appendix B for complete data on relative mode choice shifts.



**Fig. 5. Relative shift in non-work trips since moving to Avalon Walnut Creek.** Due to the less clear shifts, I displayed combinations of mode and purpose that had a larger difference between more or less.

### Feedback on and perception of transit and Avalon

Residents had a positive perception of transit and safety at Avalon for 9 out of the 10 measured qualities. They reported positive perceptions on a likert scale of 1 (never) to 4 (always) for the following characteristics a) arrives on time (3.17), b) comes frequently enough (2.97), c) eliminates car for daily needs (2.53), and d) eliminates car for social needs (2.21). Residents did not perceive transit as capable of eliminating needs for errands (1.64). On a likert scale from 1 to 5, with 5 being the safest, residents overall felt safe at Avalon and using certain modes. All scenarios received positive perceptions, walking (4.08), biking (4.15), on transit (3.97), during the day (4.35), and at night (3.52).

Residents reported being close to transit, convenient to work, and close to freeway as the top reasons for choosing to live at Avalon (Fig. 6). While almost every respondent frequented Starbucks, there was an overwhelming desire for additional retail/services at the project area. The most mentioned retail/service ideas include restaurants, convenience store, grocery store, dry cleaners, and other services.

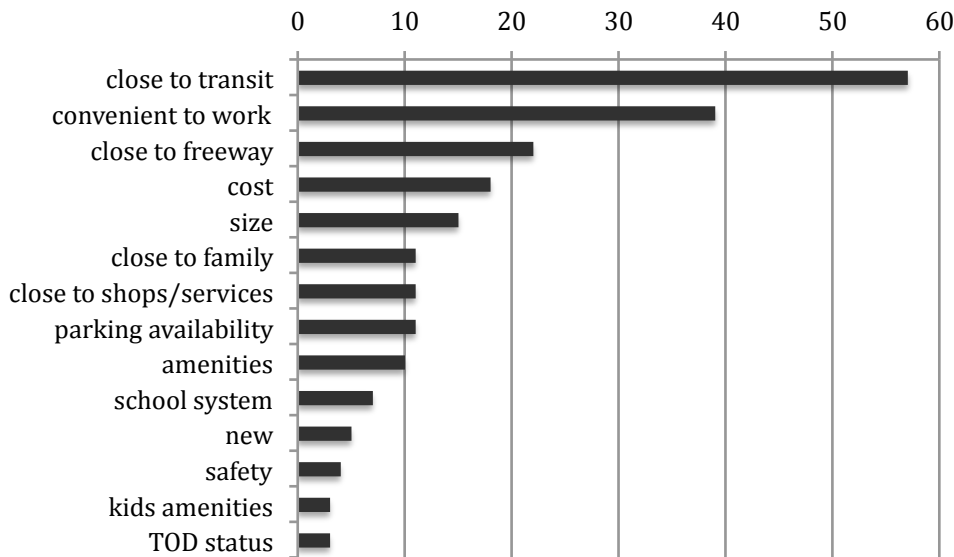


Fig. 6. Top motives for moving to Avalon Walnut Creek

## **DISCUSSION**

Avalon Walnut Creek has been very successful in increasing transit ridership for work trips, but has had mixed results with respect to non-work trips. BART was the most reported mode to work at Avalon, compared to the car at their former residence. This demonstrates a shift in mode shift, consistent with a primary TOD goal. However, while car trips for work have decreased, the change is less than the increase in BART ridership. This could mean that BART ridership has pulled from other transit modes, an example of a negative unintended consequence of TODs. Work mode selection in my survey was strongly correlated with whether the commuter's employer provides free parking; those with free parking were more likely to drive than those without. Non-work trips demonstrated less clear mode selection shifts, except for those made for recreation, which increased for walking, biking and BART. While I expected mode choice to change less for non-work trips compared to work trips (Arrington and Cervero 2008), I also expected to see more walking (a primary TOD goal) for meals, errands, grocery, and family purposes. Fewer than expected gains in walking and bicycling could be due to vacant retail space. All residents reported wanting to see more retail and services. Ultimately, Avalon Walnut Creek hasn't fully developed most likely to its young age and will need to add more services within a quarter mile radius to support TOD goals of reducing car travel and increasing walkability.

### **Urban form**

The infrastructure and land use design of Avalon matched TOD characteristics, suggesting that Avalon potentially can support favorable transportation behavior. Consistent with TOD principles, the development provided basic provisions of infrastructure for all modes of transportation; however not all modes were equally used. While Avalon had onsite provisions for each mode, only some modes could connect to a larger network, which might explain why BART and cars were more popularly used over other modes. Both modes are regionally well connected by respectively, the 44 station extensive network, and the interstate system that was aggressively built under the Federal Highway Act of 1956 (BART 2013, FHWA 2013). On the other hand, people are only willing to walk or bike a quarter mile and without local



concentrations of activity and auto dominated streets outside the development, people are likely to still use their car (Arlington and Cervero 2008). These two modes were less popular for trip purposes other than recreation most likely due to the lack of an extensive bike lane network and walkable streets between the development and major economic nodes. The bus station, while serviced by many lines, came infrequently and was hardly used. System extensiveness, and comfortable and frequent service are positively correlated with transit ridership, thus explaining why BART succeeds while the bus may not despite having several lines servicing the area (Arlington and Cervero 2008). Land use was diverse, had density, and sited so residents had destination accessibility via infrastructure. In addressing some of the 5D's associated with travel behavior, Avalon has the potential to influence behavior (Ewing and Cervero 2010). While Avalon exhibits regional accessibility via the car and BART, it lacks local accessibility until the onsite commercial spaces are leased. Walking for non-work trips is possibly affected and has the potential to increase once further developed. Therefore, planners closely aligned Avalon's design with TOD characteristics; however, it might take time and broader area planning to help improve other modes' networks and the commercial character of the development.

### **Means of transportation**

Ownership of the means of transportation for each mode first suggests whether a household has the ability to use that mode. Therefore a change in ownership, could potentially suggest a change in mode usage. Car ownership slightly decreased, clipper cards dramatically increased, bicycle ownership decreased, and bus passes stayed the same with zero to low usage. Car ownership only slightly decreased, most likely because due to the high income status of the residents, they could afford to purchase a second parking spot if they owned more than one car. Interestingly, driving to work decreased, which maintains the findings that a change in car ownership leads to a change and car use (Mitamura 1989). On the other hand, residents didn't significantly change their car usage for non-work purposes, offsetting this gain. Clipper card ownership dramatically increased because of two possible reasons. First, residents might be using BART more often and regularly as suggested by a large proportion of residents who reported using BART more for work, recreational, and familial purposes. Second, since the introduction of clipper cards in 2010, their popularity has increased (Kahn 2011). Less is known

in the literature about the relationship of clipper cards and BART use; however, it is more convenient which might be attractive to those using BART frequently. These two means received the most attention because residents reported low bike and bus usage making changes in those means irrelevant to the findings of this paper.

It is important to understand parking inventory at Avalon due to the large role parking availability plays in influencing travel behavior. Avalon had more cars than parking passes, suggesting that some residents found alternative places to park their car (most likely after hours street parking). Looking at Avalon as a whole, I found car ownership per household and the overall parking requirement were equivalent. Only in a sample of the individual households did I find that some households, while needing an extra pass chose not to buy one. Avalon unbundles the cost of the second parking space, which shows the cost of parking and might deter residents from purchasing an additional pass (Willson 2005). Nonetheless, Avalon correctly estimated a lower parking requirement that accounts for lower automobile trip generation that likely occurs at TODs (Arlington and Cervero 2008, Willson 2005).

### **Work travel behavior**

Mode choice and relative usage for work purposes shifted in favor of BART use, suggesting a partial achievement of TOD goals. Factors including motives for moving to Avalon, availability of employee provided parking, and location of previous residence help explain this shift. BART and car were the primary modes used to get to work, while the bus, walking, and biking either decreased or were not used most likely due to their inability to provide regional accessibility (Handy 1992). The increase in BART use and decrease in car use coincide with findings that residents of a TOD are more like to use transit and drive less (ABAG 2007, Arlington and Cervero 2008). This shift becomes more dramatic, when noted that household who moved from less transit oriented locations primarily shifted from car to BART for work. This is not surprising because households reported being close to transit as the most important reason for moving to Avalon, with being convenient to work as the second most frequent response. BART usage increased more than the amount car usage decreased, suggesting that BART ridership is also pulling riders from other non-vehicular modes. This raises a problem for TODs if rail ridership shift people from zero emission modes such as walking and biking.

Consistent with other studies (e.g., Willson 2005, Chung 1997, Moral and Bolger), those with employer provided free parking tended to drive to work and were less likely to use BART. This suggests that parking policy at destination ends might be influencing transit usage (Arlington and Cervero 2008). Based off March Ridership Data, a majority of people who enter this BART station exit in Downtown Oakland or San Francisco, two locations where employment density is high and parking availability is lower. Therefore parking policy and employment location might influence BART ridership for work. These findings could have been further supplemented if I had asked a) whether they have the same job they had at their former residence, and b) if not, whether their former employer paid for parking.

Perceived mode shift matches findings with primary mode shift, with a high proportion of residents driving same or less and a high proportion using BART the same or more. Residents unanimously didn't use the bus, most likely due to its infrequency and their high-income level. Additionally, despite being cheaper and more flexible, buses receive little respect in the US and face a stigma (Knack 1994). Ultimately, residents who moved from a more suburban environment drive less or the same, suggesting that TODs might be able to shift work travel behavior if employment is located close to transit (Arlington and Cervero 2008).

### **Non-work travel behavior**

Similar to my assumptions, residents did not perceive large shifts in their non-work travel behavior except for a few combinations between mode and purposes, notably biking and walking for recreation, highlighting some shortcomings of Avalon. The community exhibits high regional accessibility, but currently low local accessibility (characterized by having activity within or adjacent to the development) and therefore doesn't support as many walking or biking trips (Handy 1992). Additionally a BART Study found that 86% of trips from this station are made for work, while non-work purposes such as meals (2%), errands (2%), and visiting family/friends (2%) comprise of a smaller proportion of BART trips (Corey, Canapary, and Galanis Research 2008). On the other hand Cervero and Radisch (1996) found that mixed use areas, such as what Avalon aims to be, have more non-work trips by non-vehicular modes. While Avalon did not meet these findings, I was not surprised because my findings found that it lacked mixed-use vibrancy.

For certain mode types and purposes I noticed clear relationships although they did not always seem logical. For example, residents noted they are driving more for errands, groceries, and to visit family. However, they reported being close to family and friends and shops/services as top reason for moving to Avalon. These findings oppose the TOD goal of trip substitution through walking (CTOD 2010). Despite taking more trips, perhaps Avalon is more centrally located to activity centers and thus residents are taking shorter trips. This would suggest greater local accessibility for the car, but not necessarily for non-vehicular modes (Handy 1992). A travel diary and knowing their trip destinations could help decipher these findings. An additional illogical relationship that emerged relates to grocery trips and mode choice. People said they are using BART less for groceries/errands, but people don't usually use BART for those purposes (Corey, Canapary, and Galanis Research 2008). As someone who does not own a car, I use car-sharing programs instead.

As expected, residents used BART more for recreation and walked more for meals and recreation. This fits with the purposes of TODs and hopes to provide pedestrian walkability and transit access to regional destinations (CTOD 2012). Biking, which is otherwise not popular, increased for recreation as well. I expected an increase in recreational use because there is a strong biking culture in the East Bay and it is close to Mt. Diablo.

### **Feedback on and perception of transit and Avalon**

Residents had overall positive perceptions of transit and safety, which might relate to transit usage. Residents likely perceive transit to be convenient because of the connectivity of BART and overall positive opinions of the BART system (Corey, Canapary, and Galanis Research 2008). The reported transit perceptions likely only refer to BART because residents didn't use the bus and most likely didn't consider it when answering the question. To draw more conclusions, separating BART and bus perception would help understand if perception explains why residents' don't use the bus. Avalon is designed as a pedestrian oriented, luxury rental located in a safe area. Therefore, I was not surprised that residents perceived Avalon as safe. The pedestrian elements and atmosphere such as fountains, benches, and crosswalks all help contribute to a feeling of safety at Avalon. Additionally, Avalon's census tract and this BART

station have less crime than Contra Costa County and other BART stations (U.S. Census Bureau 2010).

The top reasons for moving to Avalon, ease of getting to transit, work, and freeway, suggest residents' desire for accessibility and mobility. This agrees with the results showing different mode usages since moving to Avalon, especially for work. Residents also moved there for the cost and size of the apartment, demonstrating a successful example when a TOD was competitive in the market. Market analysis predicts that apartment and townhouse living near transit will drive housing demand in future (Calthorpe 2011). On the other hand, the top reason for moving there is not because it is a TOD demonstrating the need for more TOD exposure.

### **Limitations**

My study design and specific survey instrument limited the level of detail of my findings. Due to funding and resources necessary to carry out a travel diary survey, I resorted to a simpler survey that asked respondents to recall their travel behavior and relatively compare it. A more accurate method would have had respondents list all trips taken in a given time period, trip origin and destination, mode, trip cost, and purpose. While my survey was able to determine relative change, recall surveys aren't as accurate because they rely on distorted memory. Additionally, asking residents if they have changed jobs since moving and their job location would have made a more rigorous analysis. Nonetheless, my survey instrument was able to answer my research question and see if residents thought their travel changed.

### **Future directions**

During my analysis, several ancillary questions emerged that can be investigated with further research. Because of the strong relationship between employer provided free parking and mode selection, more research could investigate this connection. For example, the availability of convenient, cheap (or free) parking at destinations for non-work trips could impact travel behavior for those trips. Additionally, more information could be gathered about the mobility provided by living at Avalon, which could help explain the frequent (and increased) use of automobiles for routine tasks (e.g., grocery shopping). Due to the low bus ridership and reported

decrease in use, I would look at the accessibility of the bus to employment and other locations to evaluate the system. Longitudinal studies could be conducted to see how their behavior has changed once Avalon develops more or if they move to another location.

## **Conclusions**

Efficient urban development can play a role in linking residences and lower emission transportation modes, which ultimately contributes to greenhouse gas emission mitigation. Transit-oriented development aims to reduce car ownership and increase transit use and other non-motorized modes of transportation. By reducing vehicle miles traveled per household, greenhouse gas emissions might reach 2040 reduction goals. This study shows that residents of Avalon Walnut Creek are using cars less for work than their previous residence, which for many residents was less transit-friendly. While residents who moved there for transit convenience exhibit a self-selection bias, Avalon still enables more mobility and accessibility and shifted people in the car to BART. This study also provides an example of a TOD with lower parking requirements that successfully matched car ownership. Generally, parking requirements for TODs tend to be equivalent to conventional development, which undermines the potential for TODs to meet their goals. Avalon, however, has not had a spillover of parking impacts because there has been a slight decrease in car ownership since moving to the development. Lessons learned from this study can be used to plan future TOD communities around Bay Area BART Stations and other transit facilities throughout the country.

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**APPENDIX A: Demographics of Avalon Residents**

## Socio-demographic profile of Avalon Walnut Creek residents

	Avalon (n)	Avalon (%)	Walnut Creek (%)	Contra Costa (%)
Race/Ethnicity	78			
White	45	58%	73.5%	47.8%
Asian	13	17%	12.5%	14.2%
Other <sup>1</sup>	12	15%	5.6%	13.7%
Hispanic	8	10%	8.6%	24.4%
Annual Household Income	74			
< \$50,000	13	18%	<i>median</i>	<i>median</i>
\$50,000 – 99,999	14	19%	\$80,734	\$78,385
\$100,000 – 149,999	20	27%		
\$150,000 +	27	36%		
Education Level	78			
High School	3	4%	13.5%	19.7%
Some College	7	9%		
Associates	4	5%		
Bachelor's	27	35%	35.1%	24.5%
Professional	37	47%	23.2%	13.7%

**APPENDIX B: Perceived Travel Behavior Shift**

	n	More	Same	Less	Mode not used
<u>Drive</u>					
Work*	80	11	31	28	10
Meal	79	17	43	15	4
Errand	79	18	51	8	2
Grocery*	80	21	48	10	1
Family*	80	22	39	15	4
Recreation	80	19	43	16	2
<u>BART/Light Rail</u>					
Work*	80	33	14	5	28
Meal	80	12	20	9	39
Errand	78	10	21	9	38
Grocery	80	5	19	9	47
Family	80	20	16	8	36
Recreation*	80	30	17	11	22
<u>Bus</u>					
Work	80	1	16	8	55
Meal	80	2	11	13	54
Errand	80	2	9	15	54
Grocery	80	2	9	15	54
Family	80	1	11	13	55
Recreation	80	3	14	13	50
<u>Walk</u>					
Work	80	9	23	21	27
Meal*	80	23	31	14	12
Errand	80	11	28	16	25
Grocery	80	11	27	18	24
Family	80	6	27	19	28
Recreation*	80	26	29	13	12
<u>Bike</u>					
Work	79	6	7	4	62
Meal	79	6	13	4	56
Errand	78	5	11	4	58
Grocery	78	6	11	3	58
Family	79	4	13	3	59
Recreation	79	12	16	5	46

**APPENDIX C: Pleasant Hill BART Ridership March 2013**

Exit	RM	EN	EP	NB	BK	AS	MA	19	12	LM	FV	CL
	17	22	20	17	159	24	135	346	344	26	33	66
Exit	SL	BF	HY	SH	UC	FM	CN	PH	WC	LF	OR	RR
	19	13	29	15	18	33	122	14	150	66	37	117
Exit	OW	EM	MT	PL	CC	16	24	GP	BP	DC	CM	CV
	17	1941	1455	474	420	99	54	42	40	99	18	5
Exit	ED	NC	WP	SS	SB	SO	MB	WD				
	7	50	150	20	27	150	21	5				

## Relevant Abbreviations for Stations:

19 – 19<sup>th</sup> Street12 – 12<sup>th</sup> Street City Center Oakland

EM – Embarcadero

MT – Montgomery

PL – Powell

CC – Civic Center

## Avalon Walnut Creek Travel Survey

Please answer the following questions to the best of your ability and return the survey in the provided envelope. There is a **FRONT & BACK** to each page. You may also answer this survey at <http://tiny.cc/ucberkeleyavalon>. Your answers are completely confidential. Thank you for your interest in my research.

### Information on your Household

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**Q1-6.** Please fill out the table using numbers to provide information on your Household.

\*\* Leave column 2 ("first year") blank if you've lived in Avalon less than 1 year.

How many ....	Previous Residence	Within 1st year living here	Currently
1. People in Household	_____	_____	_____
2. Licensed Drivers	_____	_____	_____
3. Cars Owned	_____	_____	_____
4. Bicycles Owned	_____	_____	_____
5. Clipper cards in use	_____	_____	_____
6. Bus passes in use	_____	_____	_____

7. How many Avalon Parking passes does your household have? \_\_\_\_\_

8. What is CURRENTLY the main way you get to work?

\_\_\_ Car      \_\_\_ BART/light rail      \_\_\_ Bus      \_\_\_ Walk      \_\_\_ Bike

9. At your PREVIOUS RESIDENCE, what was the main way you got to work?

\_\_\_ Car      \_\_\_ BART/light rail      \_\_\_ Bus      \_\_\_ Walk      \_\_\_ Bike

### Information on your Travel

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10. Are you a member of any car sharing programs, i.e. zipcar?    \_\_\_Yes      \_\_\_No

11. Does your employer provide free parking?

\_\_\_Yes      \_\_\_No      \_\_\_No, but they help pay for other commuting costs

**Q12-16.** The next questions ask how (if at all) your travel habit has changed since moving to Avalon Walnut Creek. Please select not applicable if you never use(d) the transportation mode for the specified purpose.

12. How often do you **DRIVE** compared to your previous residence?

	More Often	The Same	Less Often	Not Applicable
a. go to WORK	_____	_____	_____	_____
b. get a MEAL/SNACK	_____	_____	_____	_____
c. run ERRANDS	_____	_____	_____	_____
d. buy GROCERIES	_____	_____	_____	_____
e. VISIT FAMILY/FRIENDS	_____	_____	_____	_____
f. for RECREATION	_____	_____	_____	_____

13. How often do you use **BART/RAIL** compared to your previous residence?

	More Often	The Same	Less Often	Not Applicable
a. go to WORK	___	___	___	___
b. get a MEAL/SNACK	___	___	___	___
c. run ERRANDS	___	___	___	___
d. buy GROCERIES	___	___	___	___
e. VISIT FAMILY/FRIENDS	___	___	___	___
f. for RECREATION	___	___	___	___

14. How often do you use the **BUS** compared to your previous residence?

	More Often	The Same	Less Often	Not Applicable
a. go to WORK	___	___	___	___
b. get a MEAL/SNACK	___	___	___	___
c. run ERRANDS	___	___	___	___
d. buy GROCERIES	___	___	___	___
e. VISIT FAMILY/FRIENDS	___	___	___	___
f. for RECREATION	___	___	___	___

15. How often do you **WALK** compared to your previous residence?

	More Often	The Same	Less Often	Not Applicable
a. go to WORK	___	___	___	___
b. get a MEAL/SNACK	___	___	___	___
c. run ERRANDS	___	___	___	___
d. buy GROCERIES	___	___	___	___
e. VISIT FAMILY/FRIENDS	___	___	___	___
f. for RECREATION	___	___	___	___

16. How often do you **BIKE** compared to your previous residence?

	More Often	The Same	Less Often	Not Applicable
a. go to WORK	___	___	___	___
b. get a MEAL/SNACK	___	___	___	___
c. run ERRANDS	___	___	___	___
d. buy GROCERIES	___	___	___	___
e. VISIT FAMILY/FRIENDS	___	___	___	___
f. for RECREATION	___	___	___	___

**Information on Contra Costa Center**

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17. Please rate how well the following characteristics of Public Transportation (bus and BART) near your current residence meet your needs (select one for each row):

	Never	Sometimes	Most of the time	Always
a. Arrives on time				
b. Comes frequently enough	___	___	___	___
c. Eliminates need to use car for daily activities (i.e. work, school)				
d. Eliminates need to use a car for social and recreational activities				
e. Eliminates need to use a car for errands				

18. Which retail/service at this development do you use? (Please select all that apply)

\_\_\_ Starbucks      \_\_\_ All State Insurance      \_\_\_ Third Workplace      \_\_\_ Other \_\_\_\_\_

19. Are there any retail/services not available that you would like to see at this development?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

20. What are the TOP 3 reasons you considered when choosing to move to this specific residence? Please rank using a "1", "2", and "3".

\_\_\_ Cost of housing      \_\_\_ Close to shops, services      \_\_\_ It's status as a Transit Oriented Development  
 \_\_\_ Size of home      \_\_\_ Close to freeway      \_\_\_ Parking availability  
 \_\_\_ School system      \_\_\_ Close to public transportation      \_\_\_ Close to friends and family  
 \_\_\_ Good amenities for kids      \_\_\_ Easy for getting to work      \_\_\_ Other \_\_\_\_\_

21. On a scale of 1-5, how **SAFE** do you feel at or around the Contra Costa Center:

	Not safe				Extremely safe
While walking?	___ 1	___ 2	___ 3	___ 4	___ 5
While biking?	___ 1	___ 2	___ 3	___ 4	___ 5
While on public transportation?	___ 1	___ 2	___ 3	___ 4	___ 5
During the day?	___ 1	___ 2	___ 3	___ 4	___ 5
During the night?	___ 1	___ 2	___ 3	___ 4	___ 5



