

**Tucson Streetcar Phase Two Expansion**

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## Abstract:

In a society growing towards alternative modes of transportation, this study explores the phase 2 streetcar expansion for the Tucson area. Using case studies and research articles, a criteria of factors were created to best judge three predetermined expansion routes. A case study was then done on these routes to determine which route would be best for the area. In this study, the factors that were looked at and used to rank the three routes included; population density and average annual income of the surrounding area of the route (400 meter buffer), accessibility and connectivity, which includes; bus stops, bike lanes, walkability, traffic counts and possible park & ride development. The last factor used in the case study was proximity to destination, specifically how many 'big destinations' (destinations that experience high volumes of people) each route had. The proximity to destination factor also determined how good of a balance each route had with housing, work and amenities/leisure destinations.

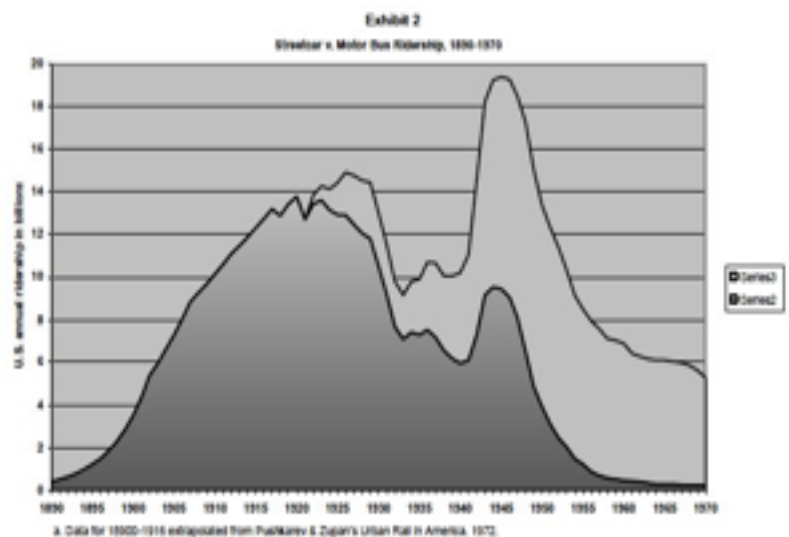


## Introduction:

Throughout the history of the streetcar, the design and use has been ever-changing. The first mass transportation vehicle developed in the United States was the Omnibus in 1827 (Streetcars- Cable Cars, 2006). Soon after, machine powered streetcars were developed that run on electricity with an overhead wire which powered the system and cars (Streetcars-Cable Cars, 2006).

Although the streetcar design was created in the nineteenth century, after World War One the streetcar was removed from cities in favor of the bus. Cliff Slater published an article that explained the streetcars downfall, “They (buses) soon improved enough in safety, speed and comfort to compete with streetcars within the city. In 1920, streetcar ridership began to decline, and by the end of that decade about 20 percent of cities relied entirely on bus transit” (Slater, 2013). Slater goes to explain that economics played a role as well, as maintaining electrical lines and tracks cost a significant sum, while the public emphasized public road maintenance as this was the popular choice during this time (Slater, 2013). Figure 1 shows the declining streetcar totals and increasing bus totals

throughout the twentieth century. As the 1900’s ended, roads became immensely congested and alternative modes of transportation started to become more popular. Planners around the country asked the same question, how can we get cars off the



road yet move an ever growing population from one place to another as efficiently as possible?

Flash forward to today, one can find intricate streetcar systems and plans that run through some major cities and districts, connecting people to the built environment. Some of the best Streetcar systems reside in Portland, San Francisco, Washington D.C and Seattle. Recently, Tucson developed a modernized streetcar system that connects the Downtown area, 4th Avenue Business District, The University of Arizona and the University Medical Center together. Image A shows the modern design of the streetcar and one of the streetcar stops. Since it was implemented in summer 2014, the system has generated development surrounding the tracks, including 1200 new student apartments, 1,490 jobs in the long term and increased property values, with the private sector investing over \$800 million (Tucson Modern Streetcar, 2013). The current streetcar system also has 19 stops and a track length of 3.9 miles, with each car's holding capacity at 148 passengers (Tucson Modern Street, 2013).

Since the first phase of the Sun Link Streetcar has been successful regarding development, tourism and transportation, there has been 3 proposed expansion plans. The first plan proposed is expanding the streetcar down South 6th Avenue, starting where the 6th Avenue stop currently is and stopping just after Irvington Road. The second expansion plan extends the current Broadway stop down Broadway to El Con mall. The final expansion plan extends the end of the current Streetcar path down North Campbell Road to the Tucson Mall (PAG High Capacity Transit System Study, 2009). Image B shows the three proposed routes and the current streetcar route in the Tucson area (Tucson Modern Streetcar, 2013). The criteria of population density and income of the surrounding areas, along with accessibility/connectivity and proximity to destination will be used in deciding what expansion plan will be best for phase two of the

Tucson Modern Streetcar. The main goals of this streetcar expansion is to reduce vehicular traffic, create the highest ridership totals possible, make transportation in Tucson more efficient, encourage regional growth economically, and aid in infrastructure development. Through these three expansion plans, and based on the above criteria, this project will aim to choose what each route ranks in each factor in the criteria and choose what will be best for the city for future expansion.

## Methods:

To understand and implement which route design works best for phase two expansion, a case study of all three routes must be done. Qualitative research was also done to understand what methodologies are best used in determining the best route placement. The case study used to determine the route placement in the exploratory case study design, where it “is used to explore those situations in which the intervention being evaluated has no clear, single set of outcomes” (Yin, 2003). I am not able to manipulate the behavior of the City of Tucson, rather I can view and observe and take away key points in making the correct decision socially, economically, and environmentally for the City of Tucson. A variety of case studies were researched to view what went into an exploratory case study, and this qualitative research, “aims to provide an explicit rendering of the structure, order and broad patterns found among a group of participants. It generates data about human groups in social settings” (Saint-Germain, 2011). The findings in these case studies are important in determining which factors to use for route placement.

Participant observation was also performed to identify the effect the Tucson streetcar has on people, as well as how commuters get from place to place, such as the downtown area to the



University of Arizona campus. Participant observation “tentatively identifies the problem or phenomenon of interest (Streetcar Expansion, 2016), and tries to discern what will yield the greatest understanding of that problem or phenomenon. The researcher then identifies preliminary concepts and what data will be gathered as indicators of those concepts” (Saint-Germain, 2011). Furthermore, population density and income of the 400 meter buffer of each route will be used through City Data and compared to the other routes. Accessibility and connectivity will be researched to see the transportation benefit of the Streetcar to get place to place and how feasible this would be for automobile users, bicyclists, pedestrians and bus users, as well connecting bus stops to streetcar stops. The proximity to destination part of the case study includes what is on actual route in terms of physical buildings and if there is a good balance of live, work and play throughout the route. This will be done using field work of each of the three routes.

### Literary Review:

Many academic and scholarly journals as well as government websites were researched to better understand the benefits and factors that go into a streetcar system within a city. Most sources were general in describing their location of the streetcar, rather they focused on development and what benefits a streetcar would bring to an unspecified city, whether that is economic, social or environmental. A few were specific to a city. The journals researched revolved around economic, social, and environmental benefits of streetcars and the factors in choosing a route placement in a metro city. It is interesting to note that most journals and government sites explain social and economic (development) factors and benefits in regards to a city, however, there is very little to offer regarding environmental benefits that a streetcar can

bring to a city; besides the *Tempe Streetcar Project*. From decreased air and noise pollution to cleaner cities, there is certainly an environmental aspect that one cannot ignore.

The original phase two expansion plans that are the basis for this project are shown in the *PAG High Capacity Transit System Study*, which offers a map outlining the three routes which will be subject to a criteria to choose the best overall route. The purpose of the report is to show the benefits it will have in an expanding Pima County population, “Expansion of the transportation system will be critical to maintain the high level of mobility that supports the quality of life and economic vitality of the region.” Indicated in the report as part of the expansion, are shorter trips and more frequent stops regarding the streetcar.

### History of the Streetcar: The Rise and Fall

The history of the streetcar began in the 1820’s, where it started out as the Omnibus and Horsecar and had animal generated power (Cudahy, 2006). As time passed, the system became more sophisticated and eventually ran off of machines, in 1873 (Cudahy, 2006). Through the end of the nineteenth century, almost every large city implemented a rail system that was electric powered and were called trolley cars (Cudahy, 2006). Because of the rail systems that ran throughout cities, more people were able to commute from outside the city. Growth of the streetcar began kept rising until the end of World War One and the Great Depression of the 1930’s. World War Two also played a part in the decline, with much attention and resources were put towards war jobs and supplies (Tennyson, 1989). Decline hit its low point after WWII, when all resources were put into road infrastructure and the automobile. Ridership decreased dramatically, passenger-miles traveled declining seven percent, from 5.6 billion in 1945 to 5.2 billion in 1975 (Tennyson, 1989).

Also during the end of WWII, and before the eventual rise of the light rail, there is a conspiracy that companies were deliberately trying to run the streetcar out of business. “Transit systems in Baltimore, Chicago’s North Shore suburbs, Kansas City, Los Angeles, Milwaukee’s suburbs, the Twin Cities (Minneapolis-St. Paul), New Jersey, Oklahoma City, Philadelphia and St. Louis were all affiliated with bus manufacturing or oil marketing companies for the specific purpose of replacing rail service with buses” (Tennyson, 1989). This may have contributed to the stark decline of streetcar systems in large cities.

During the 1970’s however, light rail made its return. This increase in demand was due to high traffic counts, slowed transportation and a more modern and sought after design. The first version of this ‘modern streetcar’ implemented high level platforms, which were created to travel at faster speeds as well as hold more people (Tennyson, 1989). Streetcars have experienced a new demand, even today with many cities trying to add a streetcar system. The first city to implement the state of the art system was Portland, Oregon, where the streetcars, “run in mixed traffic and, except at platform stops, accommodate existing curbside parking and loading” (Portland Streetcar, 2015). Not only did people get around quicker, but this project helped the Portland economically and environmentally, creating jobs, and cutting down on CO2 emissions.

### Economic Benefits

Economic benefits of implementing a streetcar system include more development of the surrounding area regarding housing and job creation. In a document entitled *Tempe Streetcar Project*, economic factors are discussed in image C, which shows the increased development and density in the Portland area post streetcar development in a bar graph. The document also goes

onto explain the job creation that comes along with the added development, and this is true regarding that of Tucson's own streetcar, adding "Over 1,500 long term jobs, and that about one-third of the jobs would be in industries which typically employ low-income workers" (Tucson Modern Streetcar, 2013).

In Cincinnati, the population has been steadily decreasing since the 1960's, and officials are using the streetcar to spur development and increase the city's population. The *City of Cincinnati Background & Benefits* Government article focuses on redevelopment of the city's parking lots, which the city will not need with the ridership numbers of a streetcar system. The City is focused on utilizing the streetcar to increase population, with its second priority on improving the transportation network.

### Social Benefits

Along with implementing a streetcar route, more people will gradually move and want to be in that area because of the multiple modes of transportation, and the economic and development boon of the area. *The Streetcar Feasibility Study* found that a streetcar project can revitalize inner-city, low income neighborhoods. The streetcar is cost effective enough where the low income residents can get place to place affordably. The Study also found that the streetcar drastically improves local circulation and connections with other modes of transportation, increasing accessibility. People can move faster from one transit mode to another, and spend less time traveling by car and more time commuting via mass transit, which increases the social aspect of a city. Commuters also prefer the streetcar over other modes of transportation, evident in the *Transportation Research Record 1221*. The report goes on to explain, "It is evident that rail transit is likely to attract from 34 to 43 percent more riders than will equivalent bus service.

The data does not provide explanation for this phenomenon, but other studies and reports suggest that the clearly identifiable rail route; delineated stops that often protected; more stable, safer and more comfortable vehicles; freedom from fumes and excessive noise; and more generous vehicle dimensions may all be factors” (Tennyson, 1989). The literature on this highlights the importance that the streetcar has versus other modes of transportation in a metro area.

### Environmental Benefits

The main environmental benefit research was done through the *Tempe Streetcar Project*, which is highlighted by a Health Impact Assessment done on the Tempe Streetcar System. Overall, the report shows every aspect of health and safety regarding the environment. The streetcar will have a profound impact on air and noise pollution, “The streetcar will decrease air pollution and asthma triggers by reducing congestion and vehicle emissions. A decrease in traffic counts and increase in public transportation ridership is associated with a reduction in the number of child asthma acute care events.” This report also shows reduced air pollution through planned pedestrian and bike networks, and developments that start alongside the Streetcar will be offered an incentive based plan for sustainable construction through the LEED building certification. Noise pollution will also be reduced through the reduction of cars and traffic in the area, replaced by a low noise streetcar system.

### Factors for Route Placement

#### Population Densities and Income

To choose the current route for expansion of a streetcar, one factor includes placing the project in a dense area with middle to high income, however a lower income area could benefit from the redevelopment and relatively cheap costs of riding the streetcar, but higher income areas are preferred. Population density would also indicate future ridership information, as a

streetcar project would be strategically placed to ensure optimal ridership. Transit performance shown in a case study shows that, “There is indeed a relationship between population and streetcar ridership. Thus, one would expect streetcars that serve more people to enjoy higher ridership than those that serve fewer people” (Brown, Nixon, and Ramos 2015). Ridership values could also increase with lower income areas, especially if users do not own an automobile. The income factor is also dependent on how fares of the streetcar are priced. Income includes employment too, which correlates to higher ridership, “employment not only represents a destination for commute trips, but it also serves as a proxy for many other trip destinations that are co-located with employment” (Brown, Nixon, and Ramos, 2015).

### Accessibility and Connectivity

As streetcars are increasingly more popular in American cities, it is equally important to make sure streetcar stops are accessible to everyone in the surrounding area. This is shown through the report written by Osman and Foda, “In general, access to transit stops affects passenger accessibility and represents the opportunity to use the public transport service.” The report explains that a streetcar or all mass transit for that matter is of no good use if no one can get to it. Similar to proximity to the overall destination, accessibility in this phase two expansion refers to the overall placement of streetcar stops based on being the most accessible areas of the route, whether that’s through pedestrian paths, bike paths or park and ride parking lots. The accepted walking distance to a transit stop is 400 meters, or a 5 minute walk, this is considered the universal length in determining streetcar or bus stops. The report, Using GIS for Measuring Transit Stop Accessibility report by Osman and Foda, explains this by placing transit stops in the densest areas and creating a 400 meter buffer around each stop. Another factor in accessibility is

connecting to other transit modes, as explained in the report *Applying a Hybrid Scoring Methodology to Transit Site Selection*, “An equally important function in to accommodate the passengers during the period in which they await their train, buy tickets, meet people, cross crowded concourse or change to other trains or different modes of transportation.” The purpose of this report is to offer guidelines on how and why a transit route or site was selected, offering criteria as to why a site and stops were chosen. The *Tempe Streetcar Project* also outlines accessibility, related to the safety of stops, “Light rails are one of the safest forms of transportation in the United States. All accidents involving light rail in the United States were caused by illegal and improper turns by motorists. The Valley Metro has made efforts to educate the public, and reduce the risk of vehicular and light rail collisions.” The report also examines pedestrian and bike safety, which connect the light rail in Tempe. Conversely, a Case Study by Brown, Nixon, and Ramos outlines the performance of Streetcar in various cities, and offers insight regarding the Streetcar’s poor performance findings, “The author pointed to the slower speeds of streetcars compared with the buses and relative lack of service integration of the streetcar with other transit modes in the studied cities as key contributing factors to their performance.”

### Proximity to Destination

This last factor used in determining route placement focuses on proximity or nearness to destinations such as malls, businesses, households, bus stops, parking and other amenities. This research is primarily done based on case study research as well as field data, showing the work, live and play options each route highlights. Also dependent on field data is ensuring the best route chosen has a balanced set of destinations of those above factors, to make sure the streetcar

is multi-functioned for a variety of destinations. In the report by Osman and Foda *Using GIS for Measuring Transit Stop Accessibility*, it shows that based on accessibility, a route should be chosen overall on how close origins and destinations are, “Physical access to a transit stop is interpreted in terms of the proximity of the passenger’s origin or destination to the nearest transit stop.” This is primarily done by viewing what shops, business and other amenities are featured on the route.

## Data and Results:

To collect the correct amount of data to analyze in choosing the best route placement for phase two expansion of the streetcar, the project needed to get correct values of income and population densities, viewing what route incorporates accessibility/connectivity the best, and noting the approximate destinations and balance between households, shops and businesses. Seen in images E, F and G, each route is highlighted using a red line, as well as the general buffer area shown in black rectangles.

To measure income and population density, a 400 meter buffer surrounding each proposed route was used. After this step, the total population and average income was found within the 400 meters of each route. The total population was added together and income was averaged for each route. The larger the population density, the higher the ridership values would be and thus provide a more effective mode of alternate transportation for the city. The higher the income is for the surrounding 400 meters, the more commuters will use the streetcar because they have a designated destination they are traveling to, such as a job or shopping. Higher income areas will spur economic growth, such as traveling to Tucson Mall in the Campbell Ave. route to shop.



To measure accessibility/connectivity, maps and field work involving walkability, bike paths, bus stops must be viewed. In order for a successful streetcar project, it should connect commuters in a variety of ways. Bus stops along each route should be noted for streetcar station placement, in order to make it as walkable as possible. Park & Ride programs could be created near the routes and also noted if the programs already exist. This measure was completed using interactive maps online as well as field research, noting what is already implemented in the Tucson area. Traffic count is also important to find out where the most congested areas are and propose how to mitigate that.

Proximity to destination was measured by determining how many and the types of shops/amenities, commercial businesses and offices, and relative amount of households that were along each route. This is also known as the work-life balance. Employment in the immediate surrounding area is important in ridership totals. Of course, development around the route will increase and bring additional shops, businesses and housing. Also included in this factor is the balance of live, work and play. For example, a negative aspect of a streetcar development is if a majority of commuters go the same way to work in the morning, and then commute the same way back home in the evening. There needs to be a balance of people coming and going on the route, thus there should be a balance of households, shops and businesses along the route to ensure balanced ridership.

#### **Average Annual Income and Population Density Results:**

Using the *Tucson, Arizona Neighborhood map, Income and Population Densities* are noted throughout each of the three route placements. This was found using the City Data site, where sections of neighborhoods were used as zones or parcels, each with a designated

population and average annual income per household. This is important in determining route placement because a streetcar system should be put in place where the densest area is while having an adequate annual household income to make sure riders take advantage of the system. Overall, a 400 meter buffer was used in finding income and population density around each route. The methodology used in determining the best route placement based on income and population, was counting all of the neighborhoods sections that cover each side of the each route placement, and tally up the total population and average the income amounts. Table 1 shows the differences in average annual income and population density for each of the three routes. To properly rank each route correctly regarding population density, a ratio between route length and population must be established. The total length of the 6th Ave. route is 4.0 miles, while the Broadway route is 2.9 miles long and the Campbell route is 4.8 miles long. Based on this data, the population per 400 meter buffer is seen in table 1.

### Accessibility and Connectivity Results:

As stated above, to determine the best route in terms of accessibility and connectivity one has to look at connecting all types of transportation modes together. That includes the City wide bus, bike paths, side walks (walkability) and potential park and ride parking lot construction. As explained in one case study, streetcar performance has a lot to do with how it flows with other modes of transportation, where people can move place to place without any conflict (The Purpose, Function and Performance of Streetcar Transit in the Modern U.S. City, 2015). Accessibility also has to do with traffic congestion as well as the speed limit, where a streetcar expansion may help alleviate some of the traffic congestion by taking cars off the road. Field work done showed the SunTran showed a bus system present at all routes, with 29 total bus stops

on the 6th Ave. route, 20 total bus stops on the Broadway route and 37 total bus stops on the Campbell route. Of course, the Campbell route also includes parts of Roger Rd., 1st Ave. and Wetmore Rd. all the way the beginning of Tucson mall. Also important to note is that the bus depot or hub was located directly next to Tucson mall, and very close to the end of the Campbell route on Wetmore. All three proposed routes had bike lanes throughout, indicating that the routes are very bike accessible. Sidewalks and crosswalks are present on each side of the road in all routes except on Roger Road on the Campbell route.

Park & ride possible locations were also looked at, with empty properties that could be used for free parking before taking a streetcar into the downtown area or other destination. A Park & ride system is designed to allow free parking in exchange to use mass transit, such as a bus or streetcar system. Using alternative transit saves the user gas, reduces stress and helps alleviate traffic within the surrounding areas. On the 6th Ave. route, 6th Avenue and 22nd St. presents an empty lot that could be used for park & ride, as well as the 6th Avenue and 26th St. For the Broadway route, the Broadway Blvd. and Country Club intersection has an empty lot that could be utilized. Finally, the Campbell route has an empty lot on 1st. Avenue and Lumberlost Rd.

The last aspect covered in the criteria for route expansion and specifically accessibility and connectivity is traffic counts per day for each route. Using the PAG Traffic Volume Database, the traffic count for each route was found within the designated mileage of streetcar expansion. For the 6th Avenue route, 22,990 cars go through that route a day traveling north and southbound. The Broadway route was found to have 37,137 cars go from the downtown area to El Con mall and vice versa a day. Finally, the Campbell route had the most congestion each day,

because it is a very congested street in Tucson overall and it is the longest route proposed. The route experiences 60,242 cars a day, when adding up the cars on Campbell, Roger Rd., 1st Avenue and Wetmore Rd (PAG Traffic Counts, 2016).

#### Proximity to Destination Results:

Results in this section include the amount of shops/amenities, commercial business and types of housing on the specific, or in broader terms, live, work, play. Streetcar stop placement will have a big influence based on the proximity to destination results, since users will want streetcar stops that are near their residence as well as their destination. The results in this factor were determined through what was outlined above; live, work and play. To properly note what is on the route, living refers apartments, hotels/motels, restaurants, health facilities, schools and grocery stores. Work refers to commercial business and office space (small business owners are excluded), and the University of Arizona, specifically the students located on or within a 5 minute walk of the route that need transportation to and from campus. Finally, play refers to malls, strip malls, places of worship, parks, bars, fitness centers and other amenities or places of leisure.

While it is important to highlight the balance of live, work and play throughout the route, the main factor in determining where a streetcar will fit best in Tucson is the big destination concept. The big destination concept refers to destinations where large groups of people gather. Often times, there is vehicle congestion around these areas, thus a streetcar system would help decrease the congestion and allow for commuters to get to these places quicker and more efficient. Once a route is picked, the big destinations will have a large impact on streetcar stop placement, since these areas represent are dense with people in nature. Some big destinations that

were found along the three routes include; malls (shops and restaurants), strip malls, grocery stores, schools, hospitals, student apartment complexes, parks and hotels.

For the 6th Ave. route, there were 5 apartment complexes, 5 hotel/motels, 25 restaurants, 1 hospital, 3 urgent care clinics, 1 elementary school and 3 grocery stores for the live section, which comes out to 43 total 'living' structures. For work, 10 commercial businesses were found and this includes some high-rise downtown businesses. There was also no student housing found along this route. For play, there were 2 strip malls, 2 churches, 2 parks, 1 fitness center and 8 other amenities (movie theater, bars, museums, etc.). This comes to 15 destinations for the play section. All other structures along this route are mainly industrial business use and single-family housing. Overall, the 6th Ave. route had 14 big destination identifications, and this is a determining factor in platform placement.

The Broadway route employs 4 apartment complexes (2 are just off of Broadway), 11 restaurants (not including El Con mall), 1 urgent care clinic, 1 school and 2 grocery stores which brings the living value to 19 destinations. There are 9 commercial business offices and no student housing was found therefore there is no connection to the University from this route. For play, there are 6 strip malls and this includes Broadway village, 1 large park and 1 large mall, which brings the 'play' to 8 destinations. Finally, the Broadway route has 11 big destinations in its 2.9 mile proposed track.

Finally, the 4.8 mile long Campbell route has 12 apartment complexes, 2 hotels, one near Tucson mall and the other near University Medical Center, 43 restaurants (not including Tucson mall), 1 hospital, 11 various medical offices, 1 elementary school and 4 grocery stores, for a total of 73 'living' destinations. For work, there were 12 commercial business offices, one University

of Arizona property and 2 University of Arizona student housing apartments, which is related to work and commuting as a college student. Overall, there are 14 business destinations. Finally, for play there are 4 strip malls, 1 very large mall, 4 churches, 1 fitness center and 5 other amenities (Funtasticks, etc.) for a total of 15 ‘play’ destinations. Other buildings not noted in these results include small businesses and single-family style homes. Finally, there are a total of 15 big destinations with this route, especially the ending location at Tucson mall. Funtasticks was added as a big destination because of its popularity around Tucson and its ability to draw a large number of people. Below shows table 1, which summarizes the findings for each route. Along with the value found for each factor, a ranking of 1 to 3 is also found next to the value, ranking from best to worst the way the route performed.

Table 1

<b>Route Factor</b>	<b>6th Ave. Route</b>	<b>Broadway Route</b>	<b>Campbell Route</b>
Income	\$25,279 (3)	\$42,299 (1)	\$36,492 (2)
Population	18,791 (2)	4,563 (3)	28,250 (1)
Population/Mile of Buffered Area	4,698 (2)	1,573 (3)	5,885 (1)
Bus Stops	29 (2)	20 (3)	37 (1)
Park & Ride Option	Yes	Yes	Yes
Traffic Count/Day	22,990 (3)	37,137 (2)	60,242 (1)
Bike Lanes	Yes (throughout)	Yes (throughout)	Yes (throughout)
Pedestrian Side Walks	Yes	Yes	Yes
Living Score (In number of destinations)	43 (2)	19 (3)	74 (1)
Work Score (In number of destinations)	10 (2)	9 (3)	14 (1)

Play Score (In number of destinations)	15 (T 1)	8 (3)	15 (T 1)
Big Destinations	14 (2)	11 (3)	16 (1)

## Discussion:

In each factor in determining the best route, the results show which route would make the most sense. In a ranking system of 1 to 3 shown next to each value of table 1, (1 indicates the best route for that factor), the system shows the data that have been compiled. What was found was that the chosen route should be in a dense area, with mostly middle income residents, connectivity with bus routes and stops, biking networks and pedestrians. The route should also have a good balance of destinations, ranging from housing, to work and to amenities and leisure. The more balanced this is within the route, the better the ridership totals will be. All of the factors are related in some way, the Journal of Public Transportation explains that, “A stop is considered more accessible if the pedestrian road network surrounding it is denser” (Using GIS for Measuring Transit Stop Accessibility Considering Actual Pedestrian Road Network, 2010). Since the criteria factors all relate to each other in some way, the Campbell route took the best ranking. The Broadway route took second and the 6th Ave route took third. Although Campbell is the largest route design and thus has more destinations overall, it is the densest route, is the most accessible to bus stops, is the most congested has the biggest destinations in its route and would be able to commute students living far off campus in University sponsored housing.

As previously stated, the goal of streetcar expansion is to reduce traffic congestion and move commuters from one place to another as efficiently as possible. Another common goal with a streetcar project is economic and developmental growth as well, as seen with the original

streetcar route in Tucson. By choosing the Campbell route, it represents the densest area out of the three, which will in turn have higher ridership totals than the other routes. Although the income isn't as high as the Broadway route, the \$36,492 average income shows that most people around the area are employed and have a work destination to get to everyday, which also increases ridership. The 28,250 person population refers to the immediate area, and the expected value of ridership from the surrounding area will correlate. The 37 bus stops for the Campbell route represent flexibility when choosing where to place the stops. Commuters will move from each transportation mode easily. Another added benefit is having the bus depot near the streetcar route as well. This will increase flexibility between the bus and the streetcar. The Campbell route had the highest traffic count per day, which suggests that this area needs the streetcar the most to help calm traffic and decrease vehicular traffic. Similarly, the Park & Ride system will help this as well, as a possible destination for this is the empty lot at the intersection of 1st Avenue and Lumberlost.

Commuting University of Arizona students had an effect on choosing this route. Along the route there are two University sponsored apartments, The Seasons and Northpointe. These students mainly drive to campus and have to buy an expensive parking pass in doing so, not to mention increasing vehicular traffic. Bringing a method of transportation that is cheaper, safer and as fast, students would increase ridership totals considerably especially since the route plan is directly next to the apartments.

Another aspect that helped choose this route is the big destinations that were noted along this route. This will help create the stops and platforms easier, as this route had the most, big destinations and was ranked accordingly. Placing stops near these big destinations will increase



ridership totals and hopefully the amount of people traveling to these big destinations. The Campbell route overall had a good balance of apartment complexes and single-family homes compared to businesses and shops. Single-family homes and local, small businesses were not used in the proximity to destination factor because of their insignificance toward being a destination for users. The big destinations are the most important because they represent large numbers of people going to and from the location, and the streetcar's design is to help make that more efficient. The biggest destination is the Tucson Mall out of any of the routes. Adding shoppers to this area will undoubtedly create a great, positive economic impact and create jobs with the shops and surrounding area.

### Campbell Route Streetcar Stop Placement

Streetcar placement is dependent upon three factors, proximity to big destinations, proximity to bus stops and safety. In general, the mixed use balance of the route will connect housing to work and amenities. On the 4.9 mile proposed route, 13 stops have been created based on the factors listed above, and image G shows visually where each of the stops would go. To recap, the route extends off of Helen St. and onto Campbell Ave to a left onto Roger Rd, where it extends to 1st Ave. After a right, the route extends to Wetmore Rd. where it takes a left and stops at Stone Ave., where Tucson Mall begins. Also to note is that each streetcar stop has been strategically placed near bus stops to enhance ridership of both the SunTran and streetcar.

Starting from the last Helen St. stop, the first stop is between Adams st. and Mabel st on Campbell. This is because of nearby big destinations, the hospital, elementary school and places of worship. The second stop is near Waverly St. and this spot was chosen because this is where

many college students reside in single-family structures, and their clear destination each day is main campus. This will take cars off the road and bicyclists from bike lanes, which increases safety switching from bicyclist to streetcar user. The third stop is placed just after Grant Rd, where there is a strip mall and many restaurants. The fourth stop is right after Glenn St, which has another strip mall and an Albertsons grocery store, which is labeled as a big destination. There are also many popular restaurants within the strip mall. The fifth stop is right after Fort Lowell, where there is a bus stop on each side of the streetcar stop, as well as many medical clinics, services and an urgent care. The sixth stop is just before the intersection of Campbell Ave. and Prince Rd. At this stop there is a Safeway and apartment complexes nearby. The seventh stop is just before Roger Rd, where there are apartment complexes as well as the Campus Agricultural Center. This route and stop can connect students to this center directly from campus. The eighth stop is on Roger Rd and is just after Mountain Ave. where it is near a bus stop and is designed to increase the ridership of many single-family household residents in this area. The ninth stop occurs on 1st Ave. just after the right turn where there is a Fry's grocery store and accompanying bus stop. The tenth stop is just after Limberlost Dr. on 1st Ave., near an apartment complex, LA Fitness and Sprouts Farmers Market. The fitness center and grocer are labeled as big destinations. The eleventh stop is at the nearest point of the student apartments, where students can easily and accessibly ride the streetcar to campus daily. The twelfth stop is by the Holiday Inn Express on Wetmore Rd., where visitors without a car can utilize the streetcar system. This stop is also near a Walmart. Finally the last stop ends at Stone Avenue, which is where the Tucson Mall begins, this is also near Funtasticks. All streetcar stops will be accommodating with bikers, walkers and special needs individuals. Safety is also a main goal- crosswalks will be

designed into each streetcar stop, with illuminating lights and stop signs, to ensure the safest travel of commuters. There will also be safety help signs, which will educate the commuter on how to stay safe while riding the streetcar.

## Conclusion:

Throughout all the research gathered and field work findings, there is no doubt that each route would improve the Tucson area economically, socially and environmentally. The social and economic impact would have been greatest on the 6th Ave. route due to the low income and lower class area it was proposed to be built in. The social and economic impact will still be very positive with the Campbell route, as jobs will be created and shops and businesses will see an economic gain. This will spur more development within the area and raise property costs. Of course, environmentally it will reduce greenhouse gas emissions by reducing vehicular traffic. However, the project can also reduce greenhouse gas emissions through a better network of alternative modes of transportation, referring to biking, walking, bus transit and the streetcar. Along with these goals, the purpose was to choose a streetcar route that is designed to decrease vehicular traffic while efficiently moving commuters place to place safely in as short a time as possible. There were three routes designated to possibly accomplish this. Through this case study, each route was analyzed using a set of criteria and based off of that information, the best route was chosen. The Portland streetcar model has a similar criteria as this project, which many awards, “Planners’ decisions to locate the streetcar lines in an area with strong ridership potential combined with decisions to provide frequent service that is well integrated with other transit services help to explain Portland’s strong performance” (The Purpose, Function, and

Performance of Streetcar Transit in the Modern U.S. City, 2015). High ridership is a high priority among planning officials as well as this project because it influences many other factors positively, including social, economic and environmental benefits.

The criteria for choosing the best route placement included population density and average annual income of a 400 meter buffer around each route, as highlighted in Images E, F and G. Also included was accessibility and connectivity of each route, this refers to how the streetcar connects to other modes of transportation such as bus transit, biking, walking and even automobiles with the Park & Ride system. Traffic counts were also included in this section, the worse the congestion the less accessible any transportation is, thus higher traffic counts were better due to the idea that the streetcar will alleviate some of the congestion by decreasing vehicular traffic. Finally, proximity to destination was researched and viewed at each route, to establish how many destinations were at each route.

The Campbell Avenue route was determined to be the best route for phase two expansion. The route took first in most ranking categories, seen in table 1. Based on this chosen route, 13 stops were found throughout the route. The three factors that determined this were proximity to bus stops, proximity to big destinations and safety. To review, big destinations are destinations that are dense with people, are popular and have congested roads in or around the area. Examples of this include malls, grocery stores and movie theaters. Streetcar stops were placed near bus stops and big destinations. Upon implementation, Tucson will be hopeful that the expansion will bring similar benefits to the original phase. Through this study and route criteria, the streetcar in Tucson has a bright future.

## Limitations and Recommendations

The research and field work done had some potential errors that need to be considered. In this exploratory case study design, many factors were noted, however the cost of building the route was not included in any findings. If cost were included, the best route may not be the Campbell route due to the size of the project since it was the largest streetcar route and would have cost the most money to implement. Since cost wasn't included, research was more focused and specific to the factors included in this study. Another limitation to research is the 400 meter buffer used to find the population density and average annual income of the surrounding area of each route. The 400 meters was not exact, rather parcels were used surrounding each route, and this suggests that the population may not be accurate to the 400 meter buffer. The population number was accurate according to the parcel, and this was the most accurate way to measure this factor. The last limitation that needs to be considered is within the field work done. Not every destination (live, work and play) was recorded on each route. A very specific search was done and most were recorded, however some may not be noted in table 1.

In the future, research can be taken a number of different ways with this project. Research could be done to see how much ridership increases from implementing streetcar stops to big destinations. Once the phase two expansion is complete, research could be done to see how ridership has changed, or how development and the local economy have changed. Research could also be done to determine which phase of the streetcar is performing better, the first or second.



Appendix:

Image A



Image B





Image C

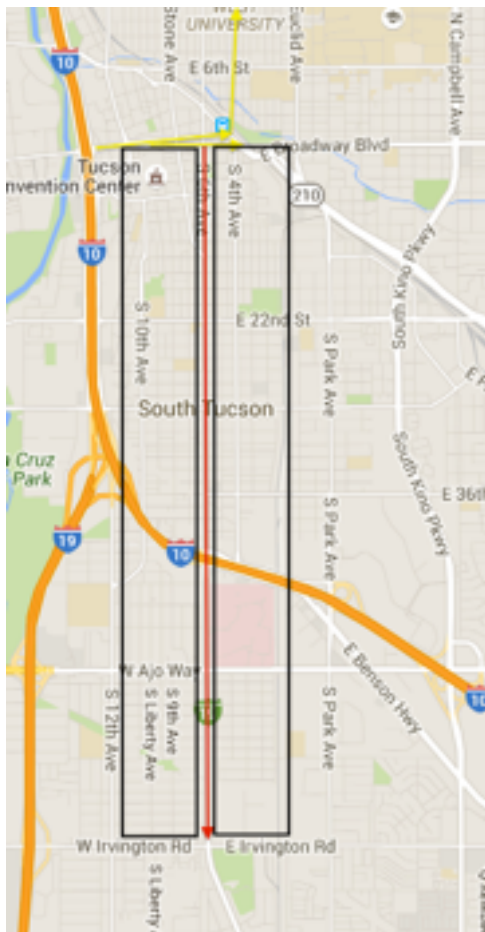


Image D

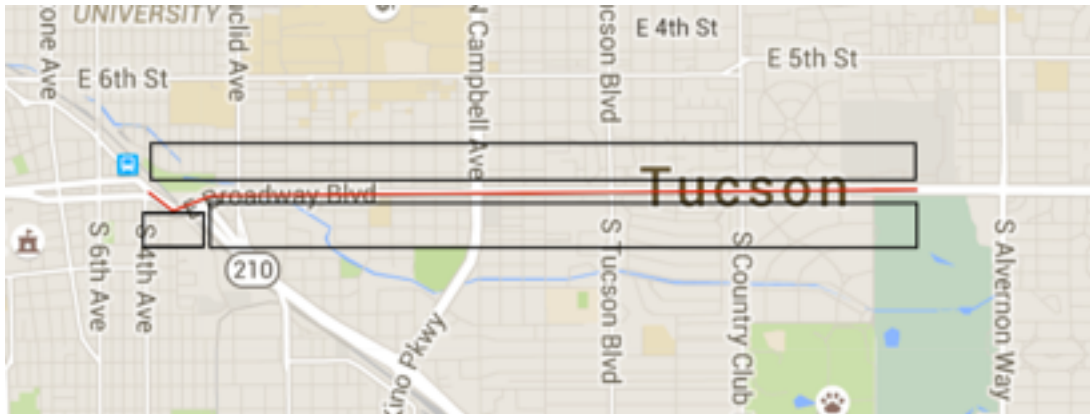


Image F

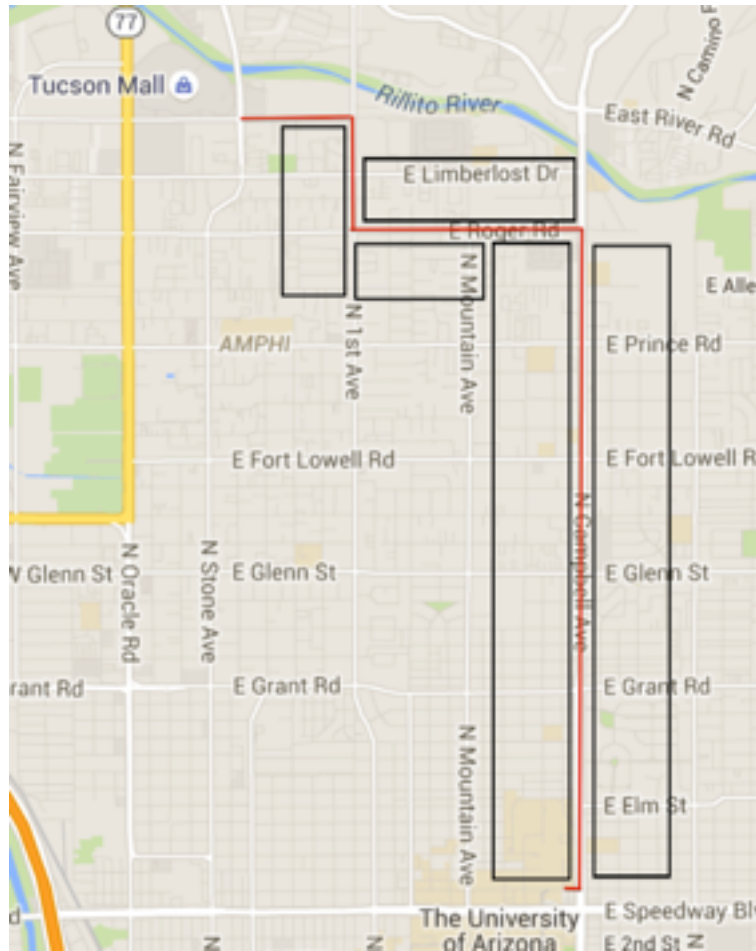
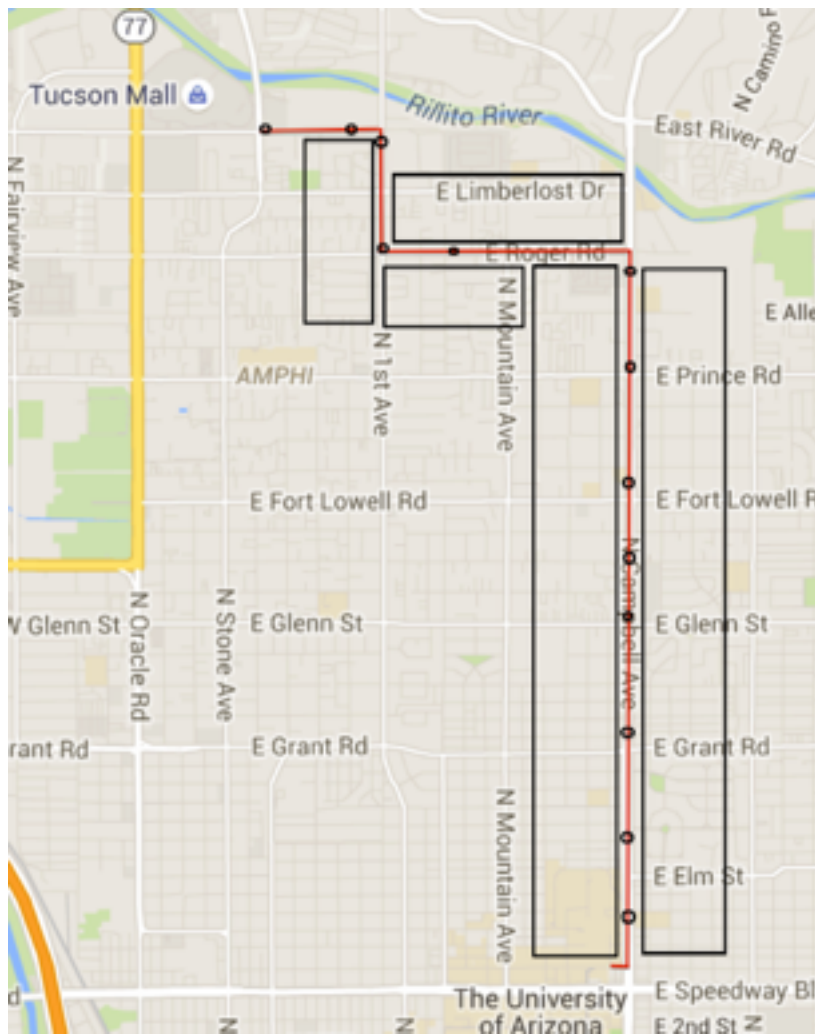


Image G



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