ASU METIS CENTER INFRASTRUCTURE & SUSTAINABLE ENGINEERING

ARIZONA STATE UNIVERSITY

Sustainable Infrastructure and South Mountain Village: Transportation

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RIO SALADO 2.0 Project

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Contents

INTRODUCTION:

With the proposed expansions in the Valley around the Rio Salado river, a new opportunity arises to develop and innovate infrastructure which will benefit many city stakeholders. One of the areas affected by this expansion is the South Mountain Village, which is located just southeast of ASU's Tempe campus and is the focused location of this analysis. As it stands, South Mountain Village exhibits a lack luster transportation infrastructure. Underutilized paved asphalt lots, highly distressed and failing pavement as well as inadequate pedestrian modes of transportation are all examples of poor infrastructure in need of renovation. The Rio Salado 2.0 revitalization project provides necessary funding, resources and support of the surrounding community to make progressive changes to the transportation infrastructure of South Mountain. Proposed changes to the existing transportation infrastructure will ultimately encourage connectivity between modes of transportation.

The main objective of the transportation network for Rio Salado 2.0 would be to determine the location of a centralized rail extension within the bounds of the project area. The rail extension would have the capabilities of transporting commuters from the area to Phoenix where most daily activities, such as work occur. The rail extension will focus on being centralized to maximize the accessibility for commuters but will also be influenced by heavily populated areas. In addition, the extension will also be determined by researching the most frequently used transit paths currently. Taking all these factors into consideration, a location for the rail extension will be determined. Once this goal is accomplished, another sub goal is created which involves increasing the connectivity of the transportation system.

The overall connectivity of the system is an important goal when proposing a rail extension, because there must be ways for commuters to get to the rail system. To accomplish this goal, bus routes, bike paths, and walkability of transit will all be analyzed. The system will be connected by having bike paths and sidewalks lead to bus stops that will take commuters to the rail station. In addition, bike paths and sidewalks near the rail extension will lead directly to the station to make rides quicker. Another possible option is adding a bike-sharing program to increase connectivity of the system between lines, especially those that cannot afford the maintenance and upfront cost of a well-equipped bicycle. Also, this may be a cheaper solution, the idea of the bike-sharing connecting transit rail lines, compared to building connecting transit lines, which may take more time as well. Improving the overall connectivity of the system leads to another minor goal of the transportation network for the project area, which will include improving the quality of the system.

Currently, bike paths, sidewalks, and bus stops are unattractive and disincentives the use of non-automobile transportation because of the poor condition they are in. To promote transit use, the system must be safe and desirable to use. The bike paths should be protected in high traffic areas, adequate shading around the paths should be provided for hot summers, and the bike lanes should not abruptly end. In addition, sidewalks should be shaded and be constructed properly with no infrastructure issues, such as large cracks or breaks in the cement. In order to promote cycling, off road infrastructures will be explored along the Salt River and Western Canals. In addition, to increase overall connectivity the configuration of the roadways will need to be adjusted for additional bike lanes and sidewalks. However, it is important to conduct an analysis that configures the roadway to maintain the current level of service with automobile congestions.

LIGHT RAIL EXTENSION:

Scope:

A South Central light rail extension in South Mountain Village, Arizona has been proposed by the City of Phoenix and Valley Metro. The project has also been approved for a $50 million agreement to design the extension and planned for construction completion in 2023. As it stands, the proposed location for the additional 6 miles of bi-directional light rail track, park & rides, power substations and passenger stations runs down South Central Ave extending from the downtown Phoenix station and bridges across the Salt River with a final stop on Baseline Road (Figure 1). The extension essentially ties into the existing system on Washington and Jefferson Street which acts as a centralized transfer hub of stations joining the North and East lines. In addition to more rail, the South Central Ave route will require approximately 5 passenger stations as well as traction power substations. The new bridge spanning across the river is expected to be one of the most expensive components of the scope of work for the 2023 extension.

To achieve peak efficiency for the location of the new extension, a study was carried out by Valley Metro to identify potential impacts and benefits of design alternatives. Some key factors considered in the decision to extend the light rail down South Central Ave includes identifying future commercial and residential development, traffic, land use changes and environmental impacts. As part of this report, additional sustainable and scoping alternatives will be proposed and analyzed.

Methodology:

Per the Locally Preferred Alternative Report for the South Central Corridor (Alternative Analysis, 2014), travel patterns show an increased travel demand of 26% by 2031 in daily person trips between South Central Phoenix and North Central Ave and a 19% increase in trips to Phoenix Sky Harbor International Airport and Tempe by the same year. A MAG study done in 2010 for a regional travel demand model (Valley Metro, 2010) shows that 14% of the South Central Phoenix Corridor residents walk or bike to work. Data from the Valley Metro 2010-2011 On-Board Survey also reveals that 93% of those who take the 3 north-south bus routes will walk to access the bus. These bus routes are already operating at near-full capacity and are regularly delayed. In the MAG 2040 Regional Transportation Plan (2040 RTP, 2017) peak period traffic models of intersections within the South Central Corridor that are expected to be at or over-capacity by 2040.

Planning of the locations of the riding stations, substations and power lines will require coordination and further studying of the impacts to the local grid system. In terms of land use, the corridor encompasses many educational, entertainment and medical facilities. The light rail extension allows the South Mountain Village area to redevelop with a foreseen increase in population meaning more residential and commercial space around the location of the extension. This redevelopment may require land use changes and cooperation with the building development group (Figures 2 and 3). Because the South Mountain Village area is located just south of the Salt River, the floodway and associated drainage considerations should be analyzed in the corridor where the new light rail will be constructed. 100-year floodplains are present along the Salt River area within the corridor and is under the water jurisdiction by the Army Corps of Engineers. Underground storage tanks and wells are located all over the corridor and may also be impacted

by the light rail extension. An environmental assessment and finding of no significant impact (EA/FONSI) assessments were conducted and approved by January 6, 2017. Although there are potential biological (migratory birds) and air quality impacts, the Federal Transit Administration (FTA) deemed that no additional environmental precautions would be necessary for the scope of the South Central Light Rail Extension project.

To justify solar panel implementation for a more sustainable light rail infrastructure, the cost and energy benefits must be identified. This can be achieved by analyzing a hypothetical situation where the available rooftop surface area of all proposed light rail stations is utilized to produce a certain amount of energy per day (kW) and the associated cost savings of that energy being put back into the system. Likewise, for an approximate one mile extension of the light rail from Baseline Road to Dobbins Road the population densities and number of significant facilities (schools, healthcare and churches) would need to be identified and analyzed.

Preliminary Results:

Due to the increase in traffic demand and foreseen level of service changes it is recommended that the light rail be installed down Central Avenue to improve transportation efficiency in the South Mountain area. Through the use of Park & Rides the unused land within the corridor can be utilized for parking which provides incentive to use the light rail and decrease traffic demand and relieve intersections of their peak capacities. By removing passenger vehicles from the system and increasing the use of light rail there will also be significant environmental impact reductions because of the switch from fossil fuel combustion to electricity powered transportation. Approximately one single occupancy vehicle trip will produce over 21 times as many grams of CO_2 as one biking and light rail trip (Figure 4, Chester, Pincetl, Elizabeth, Eisenstein & Matute 2013).

On top of the original proposed location and design of the rail extension, it's suggested that the extension continue past Baseline Road and end on Dobbins Road (station included). This is because of the convenience associated with local South Mountain hiking trails that the area is known for as well as the residential areas south of Baseline Road. This addition to the scope would provide further ease of access for existing and future residents who frequent all the significant facilities such as churches, hospitals and schools that would not be possible with the original Metro Valley project scope. Upon further analysis, it was discovered that along Dobbins Road down Central Avenue there existed blocks of high dense residential. As seen in Figure 5 of this report, areas of at least 7,500 residents per square mile are located just north of Dobbins road which mirrors population densities along Central Ave where the original location of the light is scheduled to be constructed. Increasing the total length of rail another mile south would be extremely beneficial to the thousands of South Mountain residents who would otherwise have to walk a mile to the nearest light rail stop if the scope is not expanded. South Mountain Park is also home to 51 miles of trails and 16,000 acres of land making it a major hot spot for tourism in the area.

To increase sustainability and resilience within the light rail infrastructure, south-facing solar panels atop station canopies could generate a certain amount of the total energy demand of the structure. Using a typical solar panel structure of 17.6 square feet, 265-watt STC rated panel (20% efficiency) and 1,300 square feet of available space atop a light rail station would yield a total of 54 panels, 14.3-kW of power and an energy savings of $2,744 each year per station. The

power generated would remove a portion of the energy demand for the light rail as the cost of energy savings would accumulate over the years of service before the panels are entirely paid off (Figure 4).

Green roofing could also align the rooftops to reduce storm water runoff or harvest rainwater to use for landscaping irrigation purposes. Vegetation and plant life is installed in small, self-sustaining plant-based gardens on top of open roofing of the light rail stations. This sustainable alternative allows for storm water retention and provide runoff mitigation by removing water sources from a soil layer underneath the vegetation known as a 'growing medium'. The drainage material layer below the growing medium which provides both retention and drainage. With a typical growing media designed at 1" thickness, a water retention capacity of 40-60% by volume can be generated and stored for irrigation or internal plant-based uses (Liu, 2015). Although the structural integrity of the station might play a role in this sustainable alternative, lightweight water retention layers like hygroscopic mats can be utilized in order to maintain low system weight.

BIKE LANE INFRASTRUCTURE:

Scope:

Currently, the South Mountain Village Project is lacking a connective, safe biking network which has a large effect on ridership of cyclists. Increasing cycling has many environmental, economic, health, and transport benefits for a city and can increase the vitality of the area. In Figure 1, to the right, shows a current representation of the biking network in the project area. The blue lines represent paved, dedicated bike lanes on roadways with automobiles, the yellow represents the Western Canal unpaved network, and the red is the South Overbank trail paved. As shown in the figure, the biking lanes along the roadways are not connective, and abruptly ends at major cross roads and make it extremely dangerous for cyclists to continue a dedicated path to get to various locations. In addition, the unpaved biking networks are dangerous and unsuitable for cyclists and hardly encourage ridership in the area. The current proposal for increasing ridership can be broken into three main goals, first creating a biking network and infrastructure along the Salt River, secondly creating a biking network along the Western Canal for bike paths, and lastly adding bike lanes in three major areas along the roadway to provide connectivity to the biking networks along the river and canal. Below is an in-depth analysis on improving the transportation biking network in the South Mountain Village Project to increase biking ridership and reduce roadway congestion.

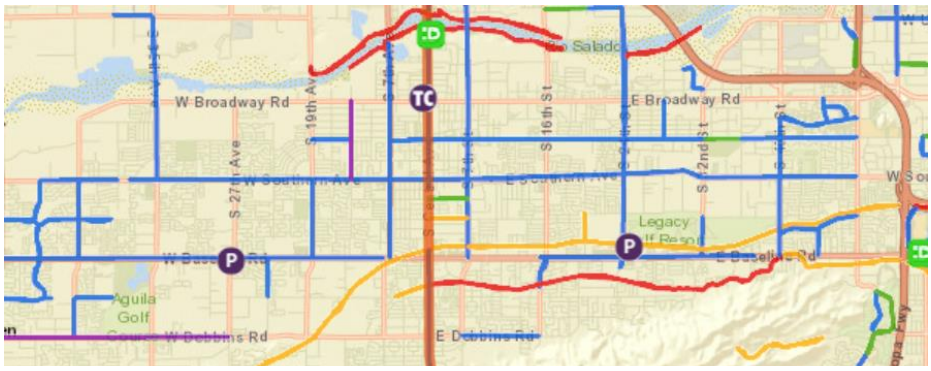

Figure 1: Current Bike Map

Analysis:

Congestion:

The proposed major biking networks along the Salt River and Western Canal run east and west along the project area boundaries, in order to asses the current congestion that could potentially be relieved from these networks, the following AADTs (Average Daily Traffic) of Broadway, Southern, and Baseline were examined. Below in Table 1, lists the average daily traffic for the three main arterials from 27th Ave to 48th St that would be affected by the additional biking networks, the data collection is from Maricopa Association of Governments and dates between 2006-2016.

Table 1: ADT of Major Arterials

Major Arterial	ADT
Broadway	22,100
Southern	28,300
Baseline	35,600
Dobbins	8,300

The Salt River would act as a reliever to the Broadway Rd traffic, while the Western Canal would relieve the congestion on Baseline Rd. Currently, Broadway is three lanes in each direction and Baseline is two to three lanes in each direction from 27th Ave to 48th Street. There is not much roadway space to take away from automobiles and add bike lanes, so creating off road bike path networks is a great alternative for a congestion reliever. Road diets with ADTs greater than 20,000 require a feasibility study to determine good locations for taking out automobile lanes for bicycle lanes, creating off road networks eliminates the risk of have the capacity and congestion effected by a change in roadway configuration. Eliminating this risk is extremely important because in Tempe, Arizona near the site location, on McClintock Rd, that has an ADT greater than 20,000 a bicycle lane was added by taking away automobile lanes, this ultimately led to great congestion and delays, making the city go back and re-add more automobile lanes, costing unneeded spending.

Bike Ridership:

A study conducted by the city of Phoenix has determined the current biking ridership on several of the street throughout the project area. The survey had data on both Southern and Broadway's current bike ridership. It will be assumed that Baseline will act similar to these streets as it is only a block away from the roadways studied. The study took passenger counts of the streets for seven days and determined the percentage of bike ridership along these roadways, Broadway which has no bike lanes, but a lower ADT had 3.12% bike ridership and Southern which has bike lanes, but a higher ADT had 3.03% bike ridership. These percentages are based on the total passengers throughout the week, including passengers in transit, automobiles, and walking.

Building bicycle networks off street along these roadways has the potential to increase bicycle ridership and decrease wait times and congestion for vehicles. A survey by NACTO concluded that people will ride if protected bike lanes are built. When questioned about bike lanes, 60% of people said they were "interested but concerned" to ride and of that 60%, 80% said they would ride if there was a separated bike lane available. See Figure 3 for the breakdown of the total population surveyed in Philadelphia (Ink, S). In addition, NACTO also concluded that by adding protected bike lanes or separated bike lanes, bike ridership increased by a range from 21% to 171% (Ink, S). Using this information, in terms of Baseline and Broadway and the effectiveness of the Salt River and Western Canal biking networks, the potential increase in bike ridership and decrease in ADT were examined.

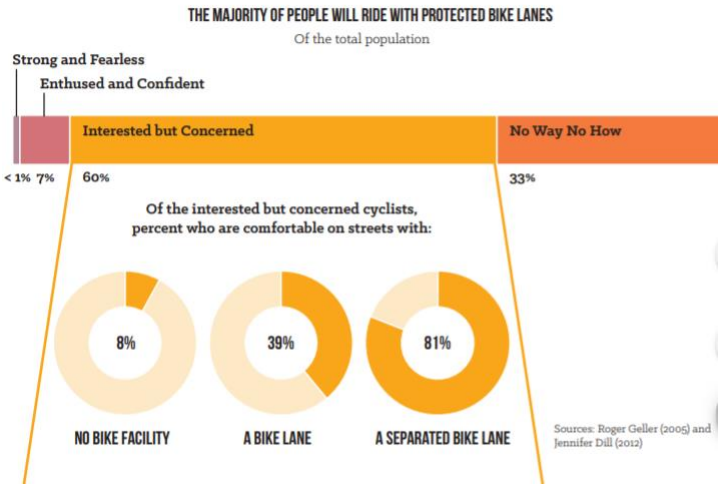

Figure 2: Bike Ridership with Protected Lanes

Based on current data, for the project area the total bike ridership makes up approximately 3.08% of the total passenger travel according to the City of Phoenix. This is the current rate of cyclists on roadways with bike lanes (Southern) and without bike lanes (Broadway), meaning there is extreme potential for increasing the current ridership. NACTO on average reported a 96% increase in bike ridership with the addition of protected/segregated bike lanes. However, it is extremely likely that the increase in ridership would be above the average of NACTOs results because the bike lane would be off-road adding measures of safety and ease for cyclists using the network, which is why it will be assumed that the ridership would increase by 130%. In the study from the City of Phoenix an average of 2,406 cyclists per day on the main arterials within the boundaries of the project area, increasing by 130% would lead to 3,127 more cyclists using the biking each network, totally the bike ridership of each network to 5,533 cyclists. However, it cannot be assumed all the new riders using the network will be coming from using the roadways/automobiles. If 50% of these riders are choosing biking over driving it would relieve

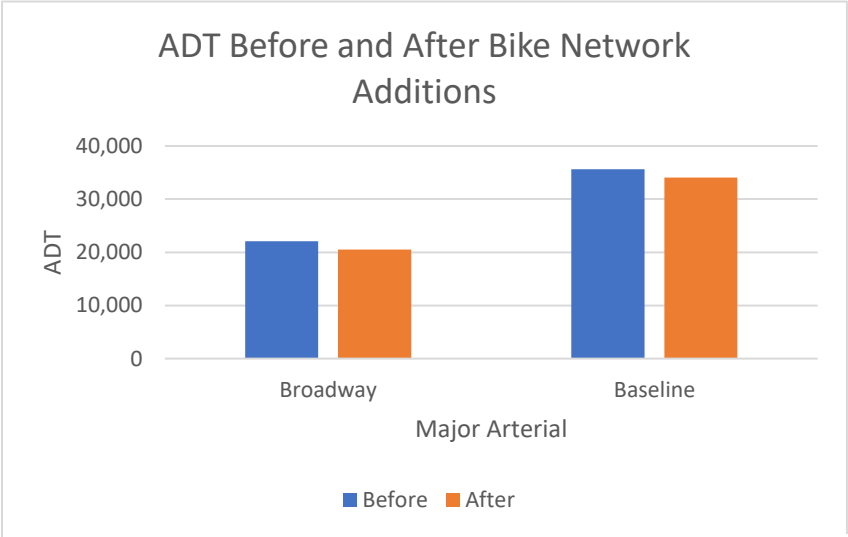

Figure 3: ADT Before and After Bike Network

congestion by 1,564 vehicle passengers on Baseline and Broadway. See the figure below for the change in ADT from the addition of bike lane networks.

Proposal:

Salt River Biking Network:

Currently, there are no bike lanes along Broadway Rd, in the project area boundaries, which is a disservice to businesses and residents along this corridor. The proposal is to build infrastructure, a multi-use path along the Salt River, to compensate for the lack of bike lanes along Broadway Rd. From Figure 1 above, it is noted that there is a paved trail along a small segment of river but is mainly underutilized because of its lack of connectivity with seemingly random start and stop points. The main objective of adding a biking network along the Salt River would be to promote long distance cycling that connects residents/businesses along Broadway to travel from Phoenix to the Tempe Rio Salado area without having to bike dangerously alongside cars.

Western Canal Biking Network:

Located just outside of the project boundaries, in south Tempe, east of the I-10 the Western Canal Path is a paved multi-use path that connects Arizona Mills Mall to Price Road. The city of Tempe is also proposing an extension of the pathway from Kyrene Road to Ken McDonald Golf Course due to the success of the first installation of the pathway. This network Tempe has created along the Western Canal connects directly with the canal in the project boundaries. Mirroring the multi-use path that the city of Tempe has created and building a similar path along the Canal from Dobbins Rd to the I-10 will increase bike ridership along this corridor. In addition, the pathway will address several connectivity issues along Baseline Rd and provide a safer means of transportation for cyclists with a path not connected to roadways.

Bike Lane Connectivity to Canal and River Networks:

In order make the Salt River and Western Canal infrastructure useful there must be bike lanes that cyclists can access when attempting to enter and exit the off-road infrastructure. To obtain this connectivity, three major roadways will need have bike lanes added which are on 19th Ave between The Salt River and Dobbins, 16th St from Broadway to Baseline, and on Dobbin from 27th Ave to the Western Canal. These segments have partial bike lanes that start and stop at random crossroads, to enhance the network it will be proposed to add bike lanes along the entire corridor of the segments listed. See Figure 2, for existing lanes labeled in blue and proposed additions labeled in red.

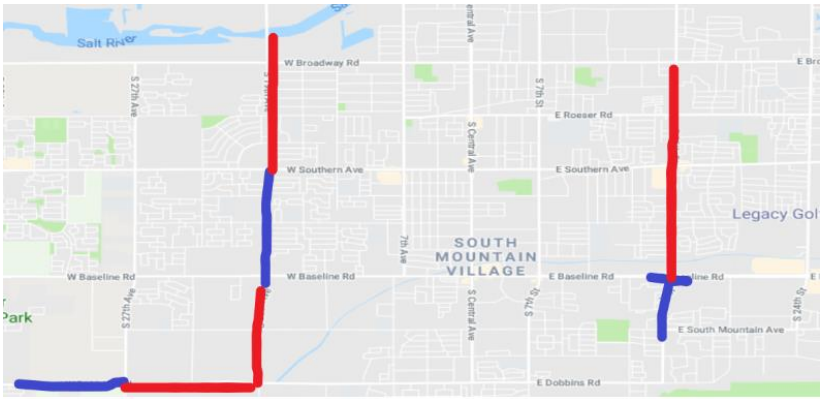

Figure 4: Proposed Bike Lane Additions

VEHICULAR INFRASTRUCTURE:

Introduction:

The purpose of this portion of the study is to assess the existing roadway conditions on the arterial roadways within the study area, identify roadway deficiencies related to not only vehicular travel but the use of bicycles and walking as well, and finally provide proposed improvements that address these deficiencies. The study area is between 27th Avenue and 48th Street, bounded by the South Mountain mountain range to the south and the Salt River to the north.

Existing Conditions:

Within the study area, there are currently seven major roadways operating in the northbound/southbound direction and four major roadways operating in the eastbound/westbound direction. These roadways, as well as their functional classifications defined by the City of Phoenix, and their 2015 Annual Average Weekday Traffic Volume provided by the Maricopa Association of Governments (MAG) are summarized in Table 1 below. The City of Phoenix Street Classification Map and the MAG 2015 Annual Average Weekday Traffic Volume Map are included in Appendix A. It should be noted that the majority of the major roadways continue through the study area, however all northbound/southbound roads do not extend further south than the South Mountain mountain range, any other exceptions to this trend are also noted in the Appendix in Table 1.

In addition to gathering roadway characteristics and traffic volumes, speed and congestion data was obtained from the MAG Performance Measurement Data Archive. This data is included in Appendix A. The majority of roadways are operating at 75% or above the posted speed limit, however 7th Street and Broadway Road experience a significant amount of congestion in the AM Peak Period, while Broadway Road, Southern Ave, and Baseline Road experience a significant amount of congestion in the PM Peak Period. This congestion data correlates with the provided speed data that indicates none of the roadways exhibits average travel speeds higher than 40 miles per hour.

Level of Service Analysis

Level of service (LOS) is a qualitative measurement of a roadways quality of traffic service. The following definition is provided in Chapter 2 of Maricopa County Department of Transportation Roadway Design Manual.

Maricopa County also publishes acceptable service volumes for roadways for urban and rural locations based on roadway classification, number of lanes, median configuration. This table can be seen in the Appendix in Table 2. Based on this information the estimated level of service for each roadway is summarized in Table 2.

Table 2: Existing Roadway Condition with LOS

Roadway	No. Lanes	Functional Classification	Annual Average Weekday Traffic	Existing LOS
27th Avenue	3-5	Arterial (Broadway Rd -Dobbins Rd)	N/A	N/A
19th Avenue	5-6	Major Arterial (Broadway Rd - Baseline Rd) Arterial (Baseline Rd - Dobbins Rd)	22,400	B
7th Avenue	5	Arterial (Elwood St - Baseline Rd)	29,100	C
Central Avenue	4-5	Arterial (Elwood St - Dobbins Rd)	23,700	C
7th Street	5	Major Arterial (Elwood St - Baseline Rd)	23,300	B
16th Street	6	Arterial (Elwood St - Dobbins Rd)	25,500	B
24th Street	5	Arterial (Elwood St - Baseline Rd)	21,400	B
Broadway Road	6-7	Arterial (27th Ave -24th St)	22,100	B
Southern Avenue	5	Arterial (27th Ave -24th St)	28,300	C
Baseline Road	4-6	Major Arterial (27th Ave -24th St)	35,600	C
Dobbins Road	2-3	Arterial (27th Ave -Central Ave) Minor Collector (Central Ave - 20th St)	8,300	B

MCDOT states that the desired level of service for arterial roads is LOS C. Based on the MAG data collected, all of the arterial roadways operate at LOS C or better.

<u>South Central Light Rail Extension</u>

The South Central Light Rail extension discussed earlier includes extending the existing light rail corridor further south along Central Avenue to Baseline Road. The rail extension is expected to require the transition of Central Avenue from a 4/5 lane roadway to a two lane roadway, one lane in either direction. A Locally Preferred Alternative Report was prepared on behalf of Valley Metro in April of 2014 assess this rail extension. When discussing traffic volumes within the corridor the report notes that, "the largest absolute and relative changes (decreases) are expected on Central Avenue south of I-17, as a result of the reduction in auto capacity along this segment. Traffic increases on 7th Avenue and 7th Street south of I-17 represent diversion from Central Avenue. However, the combined increases on the two parallel

arterials are considerably lower than the corresponding decreases on Central Avenue, suggesting that LRT would divert to transit some journeys that would have been made by auto under No-Build conditions". The extension of the light rail is expected to decrease operational level of service for portions of Central Avenue, 7th Avenue, and 7th Street as seen in the figure in Appendix A, which was presented in the Locally Preferred Alternative Report.

Addition of Bike Lanes

As previously noted in the report, bike lanes are proposed to be added along 19th Avenue between the Salt River and Dobbins Road, 16th Street from Broadway Road to Baseline Road, and on Dobbins Road from 27th Avenue to the Western Canal. These segments currently have partial bike lanes that start and stop at random crossroads, but to enhance the network it is proposed to add bike lanes along the entire corridor of these segments.

It is common for people to associate the addition of bike lanes with an increase in vehicular congestion and a decline in the overall level of service of a roadway, however this is not always the case. In cities such as New York and Minnesota it has been shown that when bike lanes are added to roadways that do not experience bumper to bumper traffic during peak hours, congestion does not significantly increase. One such instance involved the addition of a bike lane along Prospect Park West in New York City. The city ensured that extensive traffic data was collected before and after the addition of a bike lane, and the data showed that, "during weekday morning and afternoon rush hours… there were no changes in traffic volume" (Johnson & Johnson, 2014). Since the number of vehicular lanes was reduced and the number of vehicles remained the same the volume to capacity ratio of the roadway increased significantly however, "Just like the 10 streets in Minneapolis, Prospect Park West was still well under capacity during rush hour" (Johnson & Johnson, 2014). Of course if a roadway is already experiencing heavy congestion, removing vehicular lanes to provide bike lanes will not improve the existing congestion issue alone. In those cases other steps should be taken to incentivize vehicles to use other roadways or alternate forms of transportation such as public transit or bicycles. Not only does the addition of bike lanes impact vehicular traffic congestion, for better or worse depending on the situation, but it can also impact how drivers and pedestrians interact with bicyclists. When adding a bike lane along Prospect Park West the City of New York noted, "The number of cyclists using the road went up, and speeding cars, cyclists riding on the sidewalk and injury-causing accidents went down" (Johnson & Johnson, 2014).

In order to implement a bike lane along 19th Avenue, it is likely that one of the vehicular lanes will need to be removed between the Salt River and Southern Avenue to provide the necessary space for a bike lane. This reduction in lanes would transition the segment of 19th Avenue from a six lane segment to a five lane segment, however based on the MAG volumes collected the roadway should continue to operate at a desired LOS C. There is currently an existing bike lane between Southern Avenue and Baseline Road. South of Baseline 19th Avenue becomes a two lane roadway, and in order to include a bike lane along this portion of 19th Avenue it is likely roadway widening will be necessary.

In order to implement a bike lane along 16th Street, it is likely that one of the vehicular lanes will need to be removed to provide the necessary space for a bike lane. This reduction in lanes would transition 16th Street, between Broadway Road to Baseline Road, from a six lane

segment to a five lane segment, however based on the MAG volumes collected the roadway should continue to operate at a desired LOS C.

In order to implement a bike lane along Dobbins Road, it is likely roadway widening will be necessary. Some additional pavement is available along Dobbins Road between 27th Avenue and the Western Canal, however there are frequent areas that the pavement is in poor condition or nonexistent. Dobbins Road closely borders the canal, making the addition of bike lanes on both sides of the roadway difficult, a two way bike lane facility on one side of the roadway may be a more suitable application along this segment of roadway.

Recommendations & Considerations

As discussed above each of the major roadways within the study area are currently operating at a desirable level of service based on their serviceable volumes and although the roadways experience some significant congestion there does not appear to be speeding related issues. It should be noted that before any recommendations are implemented for any corridor within this study, more current volume, speed, and LOS data, as well as crash data, should be analyzed through a formal traffic study that is based on current traffic counts.

Based on the information provided in this report it is recommended that new bike lanes installed along 19th Avenue, 16th Street, and Dobbins Road. Consideration should also be given to providing additional vehicular capacity along either Central Avenue, 7th Avenue or 7th Street to replace the lost vehicular capacity associated with the light rail extension. General pavement and sidewalk preservation projects should also be considered as there are frequent locations within the study area that require maintenance to the existing infrastructure.

When considering the transition of roadways based on the above recommendations the following should be considered. Some roads such as parts of Baseline Road and Central Avenue are median separated with breaks for left turns. This roadway geometry provides a much safer feel for bicyclists and pedestrians, encouraging these forms of travel, while also making drivers of vehicles feel more constricted which leads to decreased vehicular speed and a potentially safer street. Adding items such as trees or allowing on street parking also add to this tighter roadway feel and contribute to reducing vehicular traffic speeds. Almost all of the major roadways currently have bike lanes somewhere along the corridor, however none appeared to have additional pavement marking that brings attention to the bike lanes such as the green markings or bike symbols. Limiting the driveway access points along roadways also contributes to a safer roadway for bicyclists and pedestrians as it limits the amount of potential conflict points that these travelers have to cross. The National Association of City Transportation Officials (NACTO) has published multiple design guides that focus on designing streets that promote safe multimodal forms of transportation including street guidelines, bike lane guidelines, and drainage guidelines.

BUS TRANSIT INFRASTRUCTURE:

Introduction/Overview:

There are currently 12 bus routes that run within the South Mountain Corridor, as well as two rapid bus lines. In the Phoenix Transportation 2050 plan transit lines are proposed to rapidly grow, including a light rail extension running south along Central and bus routes that cover

nearly every square mile within the South Mountain Corridor. Valley Metro primarily operates its existing bus routes with Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG) busses, although there are 30 hybrid electric diesel busses in operation. As aging vehicles reach the end of their lifespan and expanding routes a new, larger fleet must be acquired to accommodate growth. It is important that a growing fleet of vehicles does not compromised air quality standards. Minimally, total fleet emissions should remain stable to preserve existing air quality, but ideally total emissions should decrease overall.

Methods:

The objective of this section is to determine the most feasible option to expand bus transit without compromising the public health. Research pertaining to bus transit infrastructure is thus focused on the routes of bus systems within South Mountain Village and vehicle efficiency. Existing bus line data may be acquired from Valley Metro. Such data will provide information regarding utilization which may draw attention to areas with excessive or absent transit lines. The Phoenix Transportation 2050 plan will provide data pertaining to proposed bus routes and alternative public transportation lines, such a light rail. This information is necessary to review to ensure transportation needs within the South Mountain Corridor are met.
Studies conducted by the California Environmental Protection Agency Air Resources Board and Columbia University provide comparative analysis of various bus engines of numerous varieties, including electric, CNG, hybrid, and diesel.

Results:

In the South Mountain Village there is already extensive transit routes, however, there appear to be pockets largely inaccessible by public transit. In Figure 5 the existing bus routes are displayed, bounded in yellow to highlight the South Mountain Village boundaries.

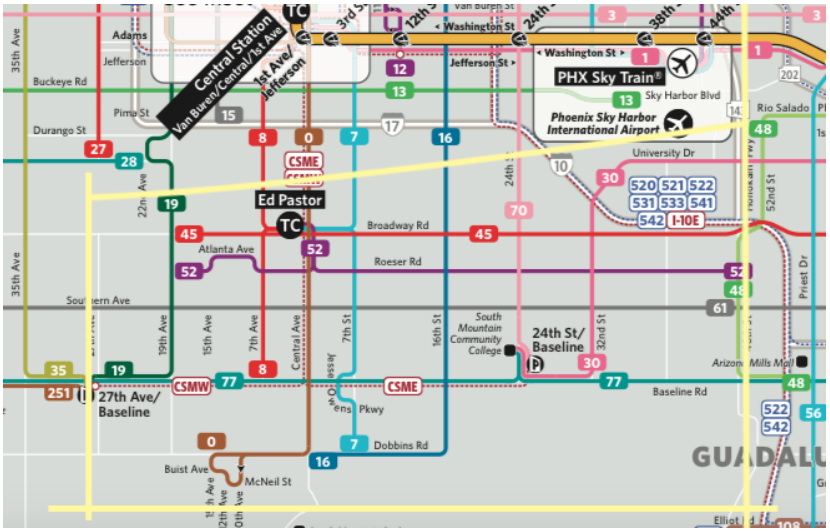

Figure 5: Current Bus Routes in South Mountain Village

From the figure, one of the largest areas of concern is the bottom left corner along Dobbins Road. The areas south of Baseline Road are primarily residential, and without transit lines extending along Dobbins Road a whole community lacks access to transportation within a reasonable walking distance. Heat map data collected from Strava, a company that compiles

smartwatch user activity, shown in Figure 6 shows a heavy amount of activity along Central, 7th Street, and Dobbins. There is significant amounts of activity in this region that suggests a potential demand for transit services in this largely residential strip. Economic information collected from census data also supports this claim. In neighborhoods located along Dobbins Road between 7th Street and 7th Avenue 27.2% of households rely on food stamps, and between 7th Avenue and 27th Avenue 14.7% of households rely on food stamps. Based on the data it may be concluded low income households heavily rely on walking and bicycling in the Dobbins area.

Figure 6: Hear Map of Dobbin Road

Citizens attempting to walk or bike to public transit from this region are exposed to extreme heat in the summer months putting their health at risk. This issue, however, is addressed in the Phoenix Transportation 2050 Plan. In this plan, a new line is proposed to extend access along Dobbins Road westward to 59th Avenue.

Despite the lack of public transit in some areas, other areas are accessible with multiple bus lines (for example, CSME, CSMW, and line 0 along central). Ridership data specific to existing routes may be found in Table 3 in the appendix. With the recorded data it is important to consider not all routes are equal in the total area they cover. Although the routes recorded are only those within the South Mountain Village, some extend to areas outside the focus area. These routes will naturally provide disproportional total boarding's but may be useful in comparing internal routes. For all other routes the boarding's per mile may yield a more accurate comparison as it takes an overall average.

From the ridership data it may be concluded that multiple accessible lines positively impact a transit network. The light rail and rapid bus lines all run along Central, yet they still have a higher boarding's per mile rate than any of the bus routes. The lack of extensive transit along other roadways is an issue addressed by the Phoenix Transportation 2050 Plan. The plan proposes improvements to nearly every bus route in the valley with such improvements including increasing bus frequency during peak hours, extending routes, and extending services to early morning and late-night hours. With such improvements to the accessibility of the system, fewer citizens may encounter health risks and line redundancy will be increased. Thus, it is recommended that Valley Metro continues forward with the proposed bus route alterations found in the Phoenix Transportation 2050 plan.

To implement route improvements, case studies suggests that electric busses may be the most economically feasible and environmentally conscious option. In a study conducted by

Columbia University for New York City it was discovered that the lifetime costs associated with owning and operating an electric bus is less than half that of a standard diesel bus. Results of the study regarding cost breakdowns may be found in Figure 7.

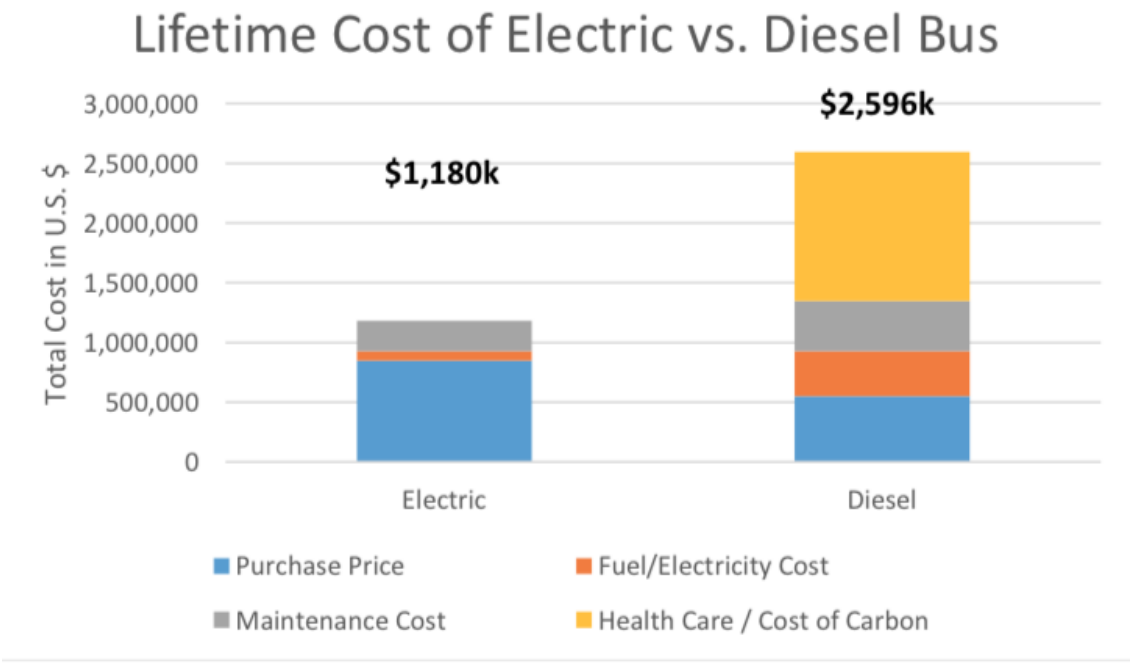

Figure 7: Lifetime Cost of electric vs. Diesel Buses in U.S. (Credit Columbia University)

The costs considered for lifetime ownership are the purchase price, maintenance cost, fuel or electricity cost, and costs associated with pollutants and health effects. Apart from minimal health effects, the electric bus also requires little maintenance over its lifetime in comparison to the diesel bus.

While Valley Metro's fleet is not primarily diesel based, other studies have compared electric busses to CNG and hybrid diesel busses. In 2006 in King County Washington, the maintenance cost per mile for a 2002 CNG versus a 2002 hybrid diesel was 2.32 and 2.30, respectively. Comparatively, 2014 CNG and electric busses were tracked in a 2016 study in Los Angeles County, California. In this study, it was determined that the maintenance cost per mile 0.28 and 0.22, respectively. For the CNG busses of the different study, it is important to note that the studies were conducted 10 years apart and that the Washington Study used nearly four year old busses while the California Study used busses only two years old. For instance, it is typical for a bus to require a new transmission near the four-year mark, while at two years it will likely only require new tires.

The useful lifespan for a city bus is roughly seven years, at which point major mechanical components require replacements, such as the transmissions and engines (refer to Figure 7 in appendix). After 14 years the structure of the bus typically experiences failure and at this point the bus is rarely salvageable. To implement electric busses as a cleaner mode of public transportation, it is recommended that Valley Metro replaces the aging fleets as they reach the 7 year mark. At 7 years it is likely the bus is somewhat salvageable and could be sold off or disassembled for spare parts as needed, where at 14 years a bus no significant value. Funds accumulated from sold fleets may be used towards the new electric busses.

Although exact prices vary by manufacturer, it is reasonable to expect a new electric bus to cost around $800,000 with an additional $50,000 charging station. While the price tag is significantly higher than alternative models, there are several government programs available to assist in the purchasing of electric busses. In addition to maintenance savings and bus resales, these programs will help Valley Metro offset the upfront implementation costs. Two grant programs currently offered are the Transit Investments for Greenhouse Gas and Energy Reduction Grant Program through the FTA and the Clean Fuels Grant Program through the U.S. DOT.

Aside from financial feasibility, functionality is often a major concern with any new technology. Electric vehicles require charging and are potentially limited in functionality based on charging times and range. Most electric busses are capable of charging within on to four hours with a range up to 400 miles, so they are fully capable of supporting existing and future ridership demands. While charge times are significantly longer than the time it takes to refuel a vehicle, these charge times may provide a restructuralization of bus upkeep. During charging a bus can undergo interior cleanings and inspections while a different bus is sent out in its place if needed. Assuming a range of 400 miles and average speed of 30 mph, an electric bus can operate for just over 13 hours. It is far more likely charging will only be needed overnight, however, shorter range buses or extended operational hours may require the use of daytime charging and the use of an alternate bus.

It may be concluded that CNG and diesel busses do not very much in maintenance costs while the electric bus costs noticeably less than the CNG. Federal grant programs are also currently in place to also aid in the implementation of more sustainable transit which will significantly reduce the burden of upfront implementation costs. In addition to overall cost, an electric bus can function at the same level as existing buses while also reducing Valley Metro's carbon footprint. In terms of the public's long-term health, sustainability, and funding, it is more feasible to implementing electric busses than to maintain aging existing fleets.

PUBLIC OUTREACH AND STAKEHOLDER INVOLVEMENT:

Method:

While the extension of the light rail has already been determined, it is important to include stakeholder engagement throughout the process of continuing the extension to Dobbins road, as well as implementing protected bikeways. For change to be accepted and used by the residents, it is crucial to include them in the process. Social equity is also one of the main branches of sustainability and should be considered in any city project that is meant for the betterment of the people. An example is the protected bikeway project along McClintock road. While the idea may seem great and is meant to keep riders safe, it was not something widely discussed with the residents, who mostly depend on cars to travel. the

With this example in mind, some South Phoenix residents may not want the extra traffic and commute time by car associated with taking away lanes and bringing in more people to the South Mountain trails. This is made clear by a recent article that reported the pushback from the local businesses lining the planned light rail extension route. Over 3,000 businesses have signed a petition to keep the construction at bay as they believe that reducing the four lanes to two will cause people to go around where their businesses are located and find new routes. They also believe this is the start of gentrification, and these owners will lose their

businesses (Boehm, 2018). While this idea of decreased traffic and business is unfounded, as seen by other rail development even within Arizona (Boehm, 2018), one of the root causes as mentioned by the people was the lack of information. They were not made aware of the decrease in lanes and are now upset and asking for change before construction begins this summer.

In regard to stakeholder engagement, the City of Phoenix has held community meetings for the past six years. At these meetings, the plans were discussed, and the public was able to express any concerns or ideas for the future. Five essential stakeholder categories were also defined to create focus groups. These groups could come together as a forum to identify issues and potential solutions (Wilson & Company, 2014). However, the City did not consider the various types of people within these groups and whether or not they came to meetings. Often, it was the same people. This was a problem seen in the City of Portland as well. Low-income communities often have the lowest diversity in stakeholder meetings. The City of Portland noted that it was the same people coming to each public discussion, and only those with the loudest voices were heard, while others stayed quiet (City of Portland, 2017). This is a common issue that will be addressed in the recommendations section.

The second concern mentioned by the citizens of South Phoenix is a genuine and viable one. Gentrification has long been a problem in the pursuit of sustainability, and consequently in this extension and overall project.

As seen in the figure 8 below on the left, the median income of Phoenix, and most notably the areas around the proposed project, are all low (*Phoenix Income Statistics*, 2016). A majority of these blocks are considered below the poverty line. It is known that increased construction of fixed structures, such as rail, increases development and thus increases land value. This increase in the value of land causes rent prices to rise, and forces those renting in the area to move businesses and homes as they can no longer afford to live next to new development. This takes away the original culture and people who may have been in the area for decades, making way for elite businesses and high-rise apartments.

The figure below, figure 9, on the right shows average income to rent in the area (*Phoenix Income Statistics*, 2016). It is clear that the lighter colors are the area's most in danger of gentrification because areas with a higher ratio show greater affordability of rent in accordance with income, while lighter colors show the opposite. This increase in the value of land causes rent prices to rise, and forces those renting in the area to move businesses and homes as they can no longer afford to live next to new development. As over thirty percent of low-income families are renters, this makes them especially vulnerable to displacement (Salmonsen, 2017). This takes away the original culture and people who may have been in the area for decades, making way for elite businesses and high-rise apartments. Therefore, the blocks surrounding the development of the new light rail extension is at great risk for gentrification. This is a serious issue to be addressed and will need to be handled with care.

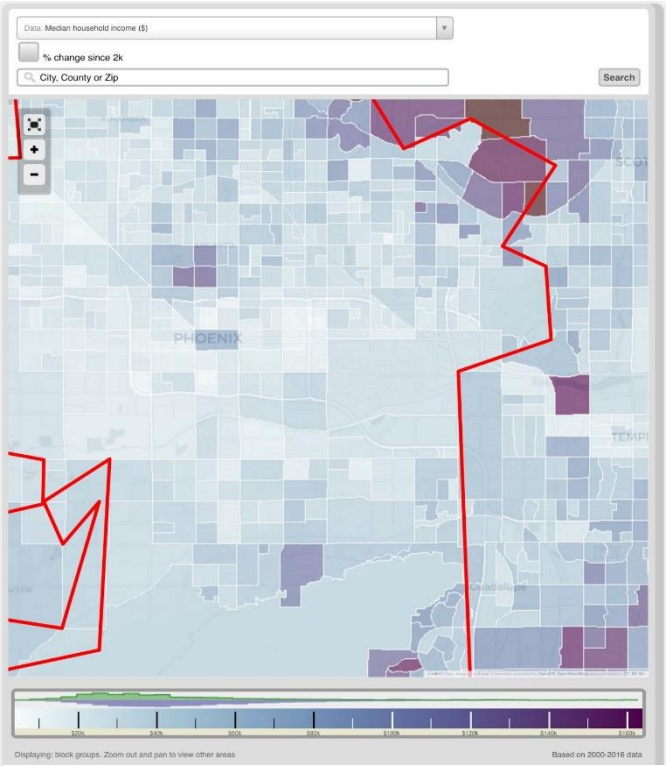

Figure 8: Average Income Phoenix

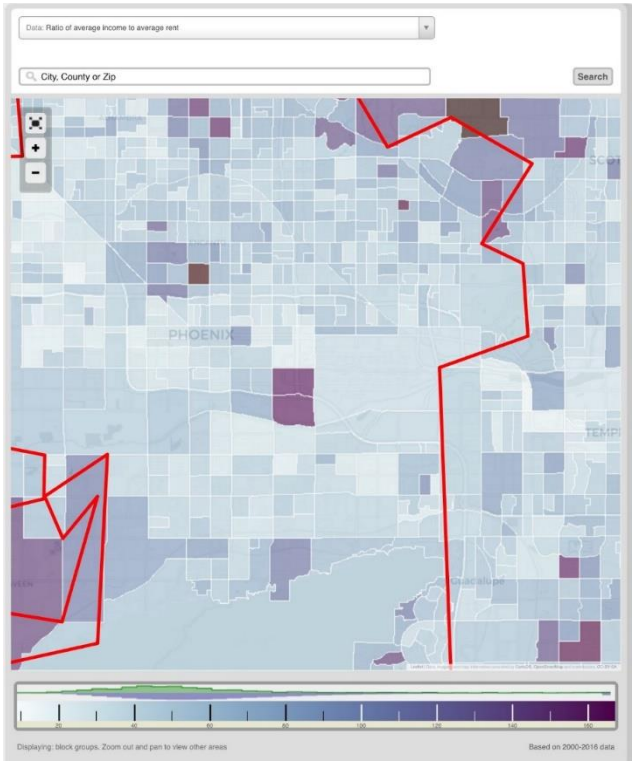

Figure 9: Income to Rent Ratio

Recommendations

As this project moves forward, it is critical to take the above findings into account. In order to ensure higher stakeholder engagement and involvement, the City of Phoenix will need to hold regular, but diverse meetings. Public meetings may need to be held at various times, including late at night and early in the morning, to target those groups that must work odd hours to make meets end in a low-income area. Also, providing child care and food at these meetings is essential to increase turn-out. One of the problems mentioned by the residents themselves was the lack of knowledge of the two-lane consequence of the light rail. The residents even felt betrayed and hurt by this "sudden" development. To ensure this does not continue and construction can begin promptly, the city must promise and uphold transparency. Complete plans for the light rail will need to be given and explained to the residents and business owners. Specific meeting to voice concerns and propose solutions should be added every time new information or changes to plans are issued. It is also important to show examples of how rail construction has increased business rather than hurt it. Simple posters can be made, as well as mock ups of before and after in different cities.

The residential neighborhoods surrounding South Mountain should also be contacted to ensure their agreement and participation as it is likely more hikers will be going through the neighborhoods and the likelihood of trash will also increase. Surveys and interactive, stakeholder meetings would be highly encouraged to move forward with our planned projects. Overall, The diversity of these meetings, as well as the number in attendance are important measures to take into account.

While it is important to show the likely increase in business from the light

rail extension, it is also important to show how the city is planning on combating the consequences of gentrification. The City is already planning on adding business incentives and reductions in taxes during the construction phase to help, but what can be done after? A few ways to move forward include rezoning the area so that low-income property is required along with any new, higher-end development. The current landlords can also be contacted, and an agreement can be set up beforehand where, instead of raising rent prices, a portion of the new and higher sales from the businesses can be given to them instead. Another possible route is to make the surrounding land into a cooperative. The business owners can come together and, most likely through a loan, purchase the land. Gentrification is an area to be traversed with care, but it is at least important to note that the team is aware of it and will be working to fight against it occurring.

DISCUSSION:

All modes of transportation were explored in the scope of the project area to eliminate connectivity issues throughout the system. Transportation has many categories and is defined as a complex system, and within this system there is light rail, bike lanes, roadway configurations, bus transit lines, and fear of denitrification. In order to have a successful transportation system these modes must interconnect and complete each other to create a city with mobility and accessibility to travel.

Within the Rio Salado 2.0 project the centralized form of transportation is the light rail extension as it will attract the most travelers. There were several studies conducted that concluded the most frequently used bus transit, bicycle lanes, and sidewalks were used along Central Ave. For this reason, the light rail extension was proposed to be installed along this corridor. However, to create a more robust transportation network it is important to create connectivity along this propose extension. This involves have accessible bike lanes leading to the rail and bus transit lines to have pick up and drop off locations near the rail extension. Currently, the bike map indicates there are bike lanes on all major arterials leading to the rail extension and therefore promote overall connectivity with in the system. In addition, the current bus transit lines run along the rail extension. However, along Dobbin Rd, a mainly residential area, there are a lack of bus transit lines that can take passengers to and from the rail extension, so it is important that Valley Metro increase their bus transit system along these corridors to increase overall connectivity. Valley Metro is seemingly having the ability to take many buses out of service when the rail extension is complete, in order to improve accessibility and mobility with bus transit these buses are to be dispersed throughout the neighboring communities to attract more passengers to using transit.

In addition to bike lane improvements and bus transit, the roadway configuration is extremely important to reducing congestion, while making room for new modes of transportation. The addition of bike lanes can cause bottle necks and increase congestions, but to have constant or increased level of service, the roadway configuration must be analyzed. Within the scope of the project, it was mainly proposed that biking infrastructures be configured off road, along the Salt River and Western Canal to avoid complications of implementing a road diet. Located just outside of the project area in Tempe, along McClintock, the addition of bike lanes caused increased congestion and created turmoil between automobilist and cyclists. To

avoid this conflict, the biking paths along the Salt River and Western Canal will increase bike ridership without sacrificing lanes along the roadway. Arizona is labeled as an automobile centric, urban sprawl city that uses cars as it's main form of transportation, taking away lanes has possible consequences. However, in order to increase connectivity along the proposed biking infrastructures, there were section of roadway where the addition of bike lanes are needed. These corridors would require taking away a vehicular lane and implementing a road diet, however the analysis concluded the roadway would continue to operate at a LOS C, this is most likely due to the smaller ADT along these proposed roadways. In addition, the light rail expansion will take cause a change in roadway configuration and it is important to create a geometric design of the roadway that will allow all modes of transportation flow easily through the system. This includes a roadway configuration that meets the needs of the light rail, bicyclists, automobiles, and bus transit line along Central Ave. However, the implementation of these changes can cause public outcry and stakeholder complications.

Increasing the desire of the South Mountain Village makes the area susceptible to desertification. Without having public involvement in the changes that are being made to the area, issues can arise leading to a push for current community members to sprawl out to other areas. In recent meeting regarding this project, public members identified problems within transportation, loss of connection to central city, lack of big roads, mobility, and fear of gentrification. The purpose of creating a functioning transportation network it to provide travel to community members within the South Mountain Village. The lack of big roads in the area, gives a sense that automobiles are a main form of transportation and congestion is an issue among the public. However, there is a large income variation within the area, which leads to a wide variety of people and the modes of travel that are used. This concludes that all transportation networks must work as one to create a public that enjoys using the transportation system. In order to create bigger roadways for car users and increase mobility for low income families without cars, it to provide various modes along the roadways while making them as efficient as possible. The configuration of the roadways must be optimized to include the light rail extension along with bicycle lanes along with bus transit system. In order to accomplish this off-road bicycle infrastructure are being proposed, along with a plan to install the light rail without comprising roadway congestion (by increasing ridership and directing traffic to other roadways). In addition, transit lines are being optimized and made efficient to increase the level of service in residential areas and increase ridership.

Overall, all the mode of transportation within the project overlap with one another and add levels of complexity to the system. In order to create a smooth transportation network in the South Mountain Village area the centralized light rail extension, bike lane connectivity, bus transit efficient, and roadway configuration must work together with one another to promote safe, efficient travel. In doing this, the public's concerns are addressed and will increase their mobility and accessibility to travel within South Mountain Village and connect them to the neighboring cities such as Tempe and Phoenix.

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APPENDIX:

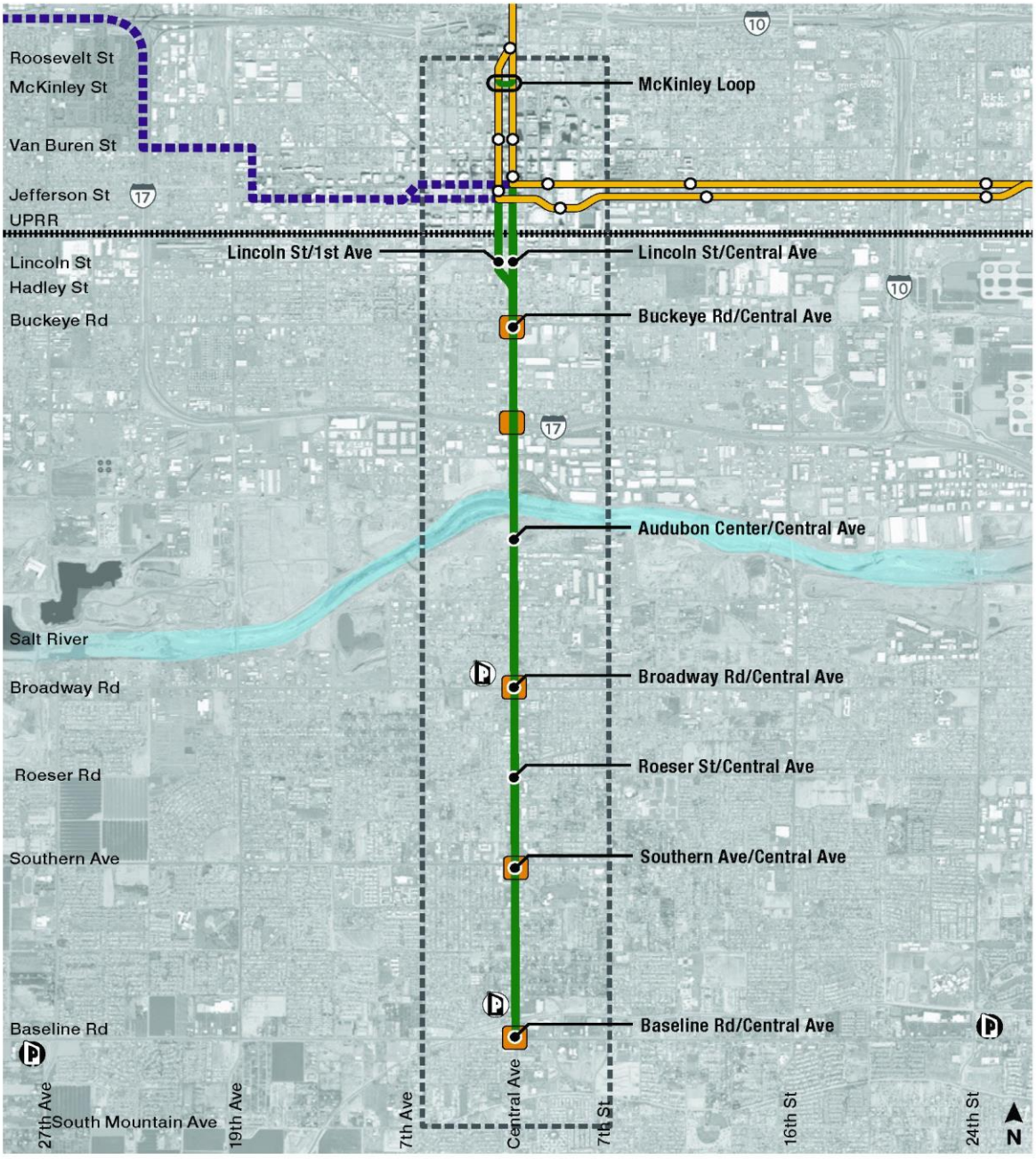
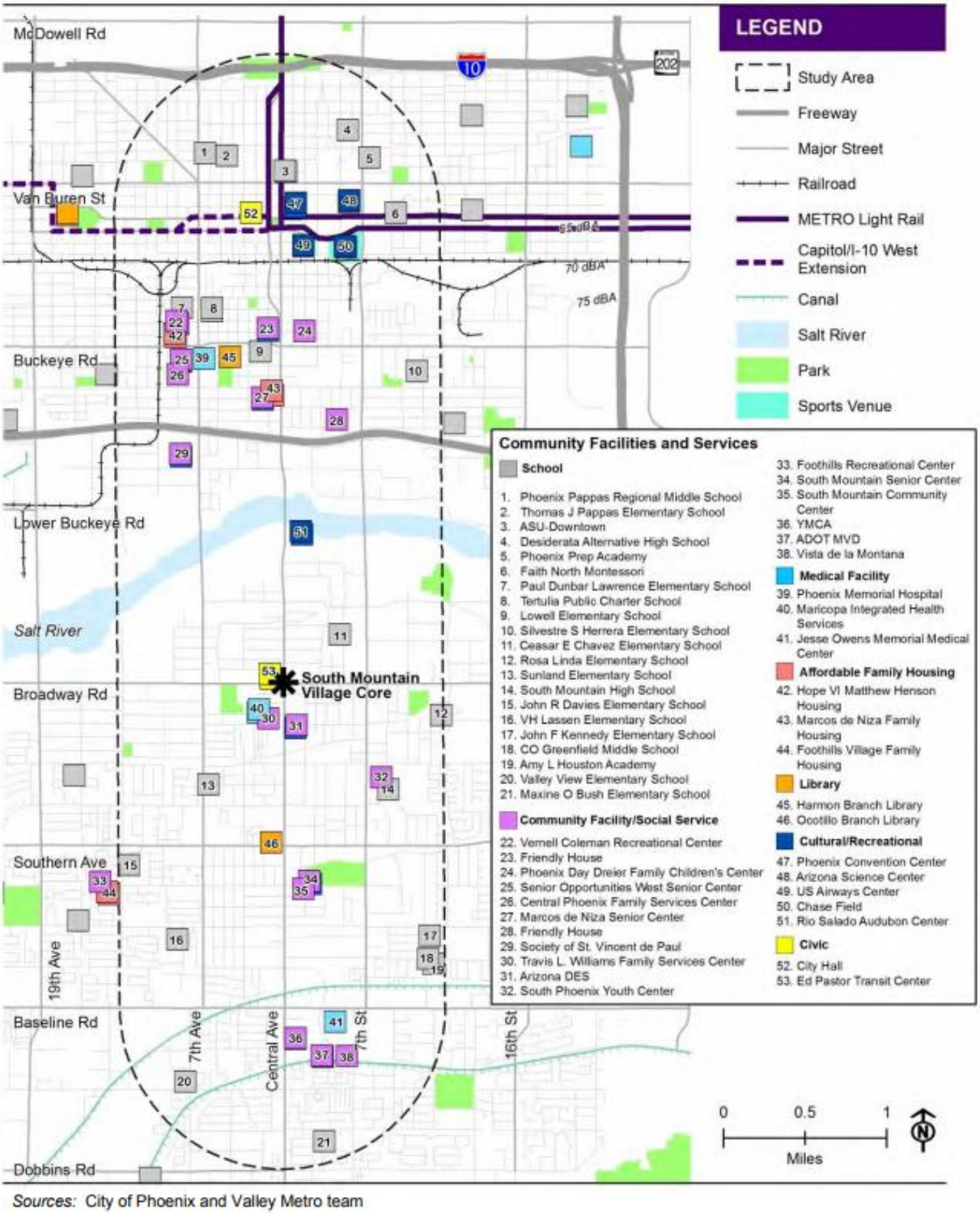
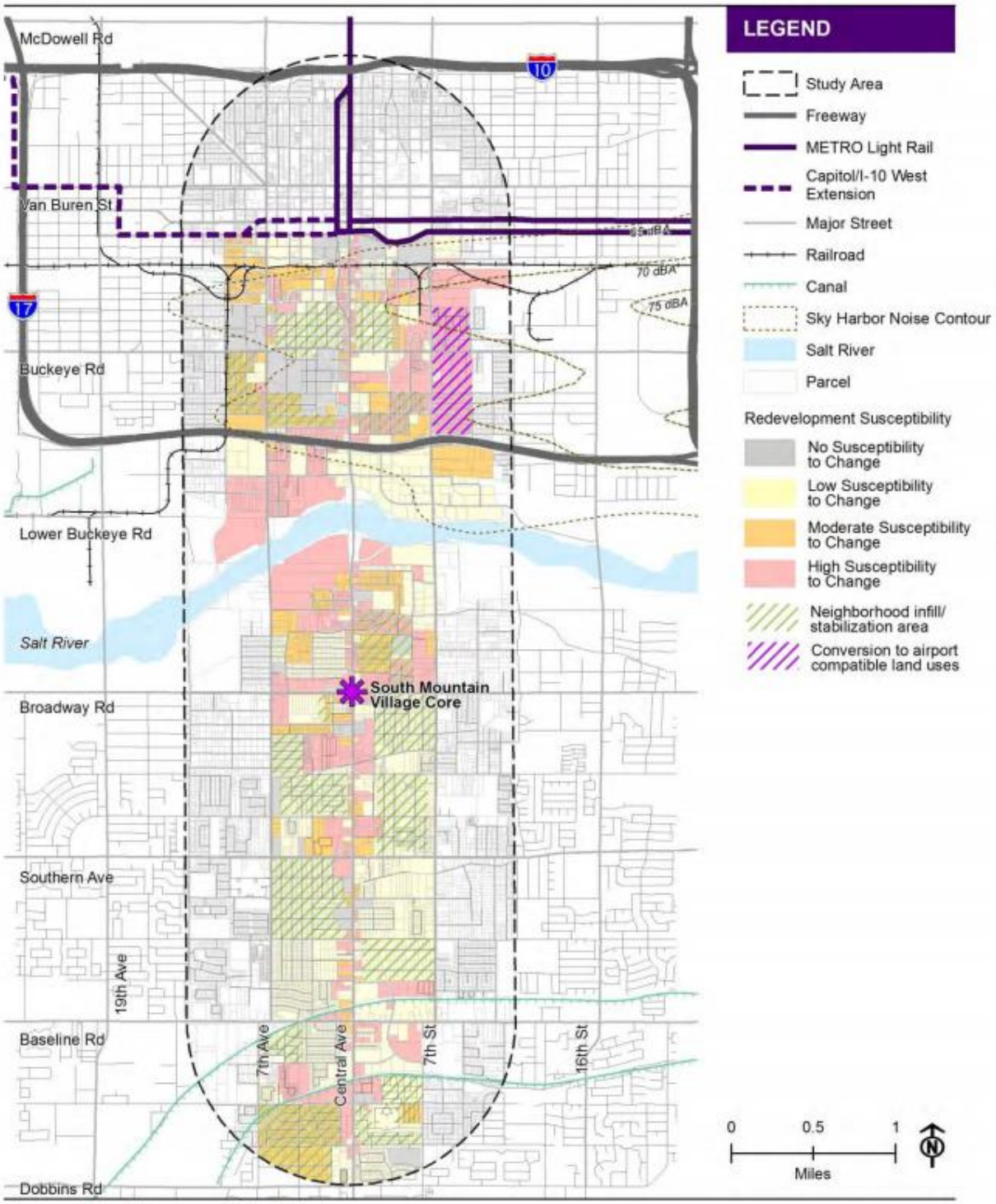


Figure 1: Proposed Light Rail Extension with Stations and Park & Rides (Valley Metro)



Sources: City of Phoenix and Valley Metro team

Figure 2: Corridor Facilities of Potential Impact (Valley Metro)



Sources: City of Phoenix and Valley Metro team

Figure 3: Proposed Land Use Changes (Valley Metro)

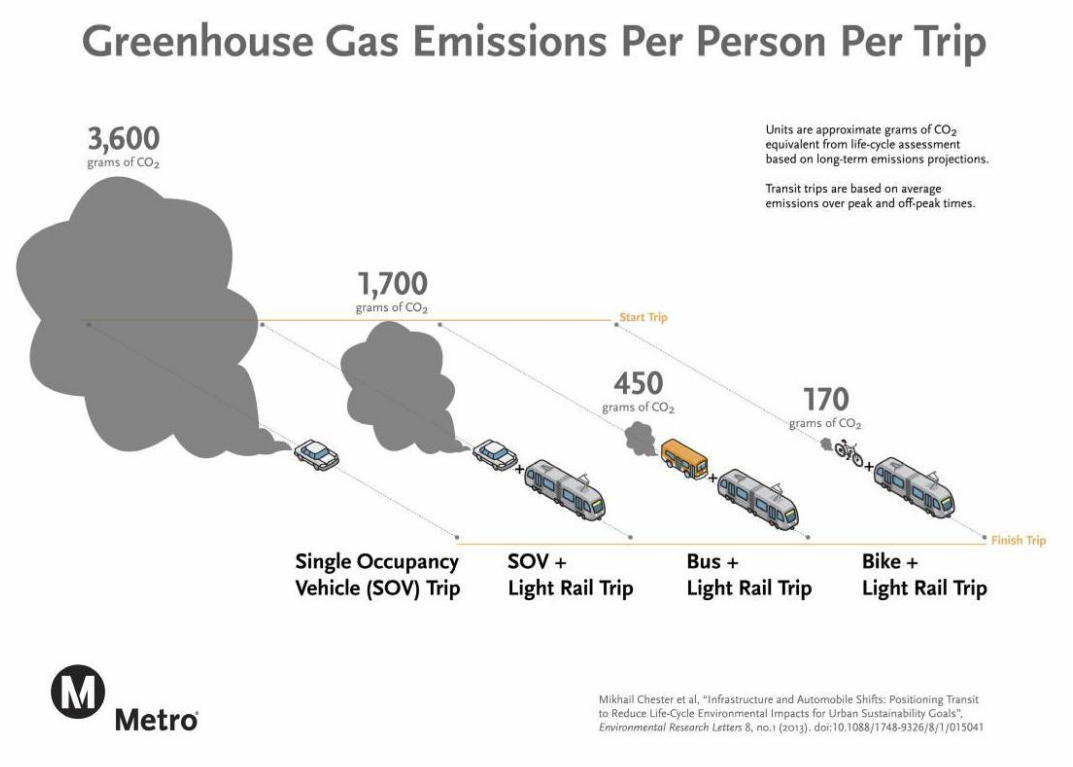


Figure 4: GHG Emissions Comparison ("Infrastructure and Automobile Shifts", Chester, 2013)

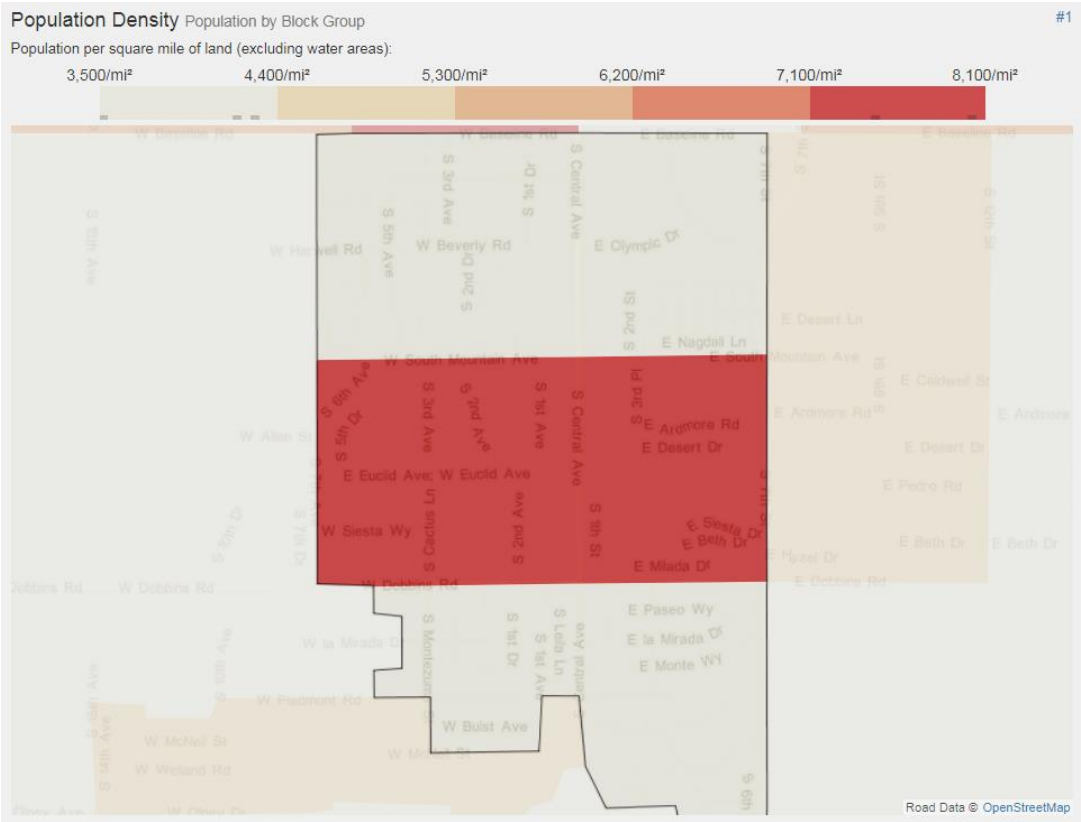
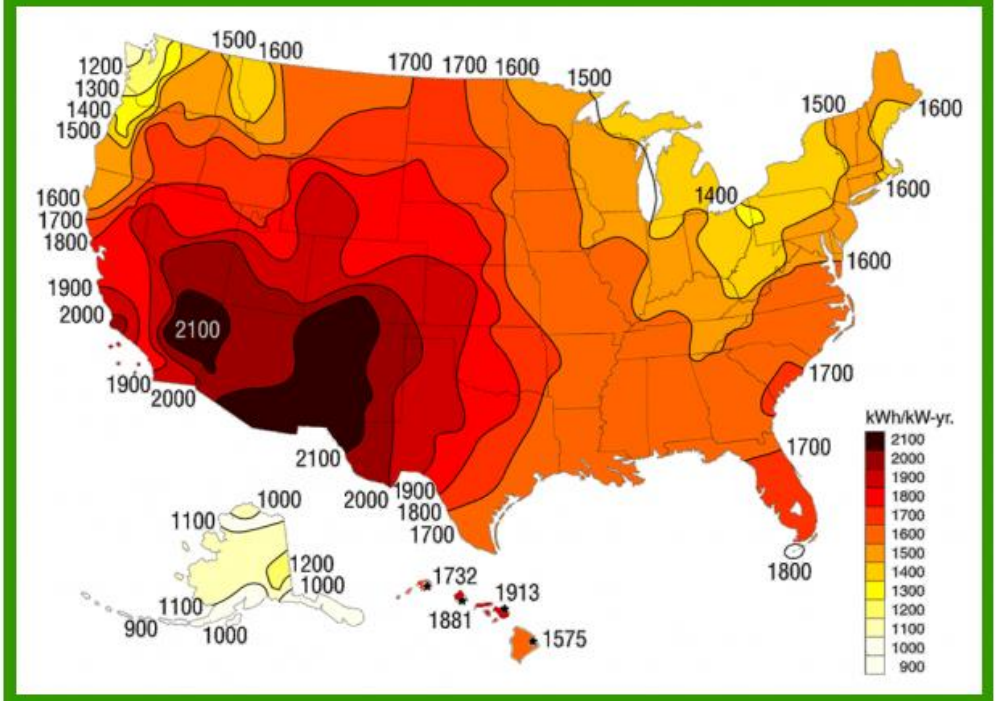


Figure 5: Population Density from Baseline to Dobbins (Statistics Atlas)

How much you could save with solar:

In **Arizona**, we estimate you live in the **2050** area of the map below, and you pay **$0.12** per kWh for electricity.



Your roof can hold up to **54** solar panels, which equals **14.3-kW** of generating power.

Here's the best part: In one year, the panels can produce enough to reduce your energy bills by **$2,744**!

Figure 6: Solar Power Production and Savings for 1 Light Rail Station (Solar Power Rocks)

Table 1: Existing Roadway Conditions

Roadway	Direction of Travel	No. Lanes	Limits	Functional Classification	Annual Average Weekday Traffic
27th Avenue	North/South	3-5	Broadway Rd -South Mountain (Major Roadway ends at Dobbins Rd)	Arterial (Broadway Rd -Dobbins Rd)	N/A
19th Avenue	North/South	5-6	Outside Study Area -South Mountain (Major Roadway ends at Dobbins Rd)	Major Arterial (Broadway Rd - Baseline Rd) Arterial (Baseline Rd - Dobbins Rd)	22,400
7th Avenue	North/South	5	Outside Study Area -South Mountain (Major Roadway ends at Baseline Rd)	Arterial (Elwood St - Baseline Rd)	29,100
Central Avenue	North/South	4-5	Outside Study Area -South Mountain (Major Roadway ends at Dobbins Rd)	Arterial (Elwood St - Dobbins Rd)	23,700
7th Street	North/South	5	Outside Study Area - South Mountain (Major Roadway ends at Baseline Rd)	Major Arterial (Elwood St - Baseline Rd)	23,300
16th Street	North/South	6	Outside Study Area -South Mountain (Major Roadway ends at Dobbins Rd)	Arterial (Elwood St - Dobbins Rd)	25,500
24th Street	North/South	5	Outside Study Area - South Mountain (Major Roadway ends at Baseline Rd)	Arterial (Elwood St - Baseline Rd)	21,400
Broadway Road	East/West	6-7	Outside Study Area -Outside Study Area	Arterial (27th Ave -24th St)	22,100
Southern Avenue	East/West	5	Outside Study Area -Outside Study Area	Arterial (27th Ave -24th St)	28,300
Baseline Road	East/West	4-6	Outside Study Area -Outside Study Area	Major Arterial (27th Ave -24th St)	35,600
Dobbins Road	East/West	2-3	Outside Study Area -20th St (Major Roadway Ends at Central Ave)	Arterial (27th Ave -Central Ave) Minor Collector (Central Ave - 20th St)	8,300

Table 2: LOS Descriptions

LOS	Description
A	free flow, with low volumes and high speeds
B	reasonably free flow, speeds beginning to be restricted by traffic conditions
C	stable flow zone, most drivers restricted in freedom to select their own speed
D	approaching unstable flow, drivers have little freedom to maneuver
E	unstable flow, may be short stoppages
F	forced or breakdown flow

Table 3: South Mountain Village Public Transit Ridership Data

Route	**Description**	**2017 FY total Boarding's**	**Boarding's per mile**
19	Along 19th Ave	1663392	2.2
8	Along 7th Ave	528629	1.7
0	Along Central, portion down Dobbins Rd	1023735	2
7	Along 7th St	998962	1.6
16	Along 16th St	910027	1.8
70	Along 24th St	1195075	2.5
30	Along 32nd St and east along University Dr	91005	0.7
48	Along 48th St, and then 52nd St north of Broadway Rd	203613	1.1
77	Along Baseline Rd	462066	1.6
61	Along Southern Ave	436335	1.7
52	Along Roser Rd	132128	0.8
45	Along Broadway Rd	312680	1.7
RAPID - CSMW Central south mountain west	Along Baseline Rd from 27th Ave to Central, then along Central from Baseline Rd northward	22489	9.0
RAPID - CSME Central south mountain east	Along Central down towards Baseline Rd, then from Central to 24th St along Baseline Rd	13988	5.6
LIGHT RAIL -TOTAL		12552137	5.1

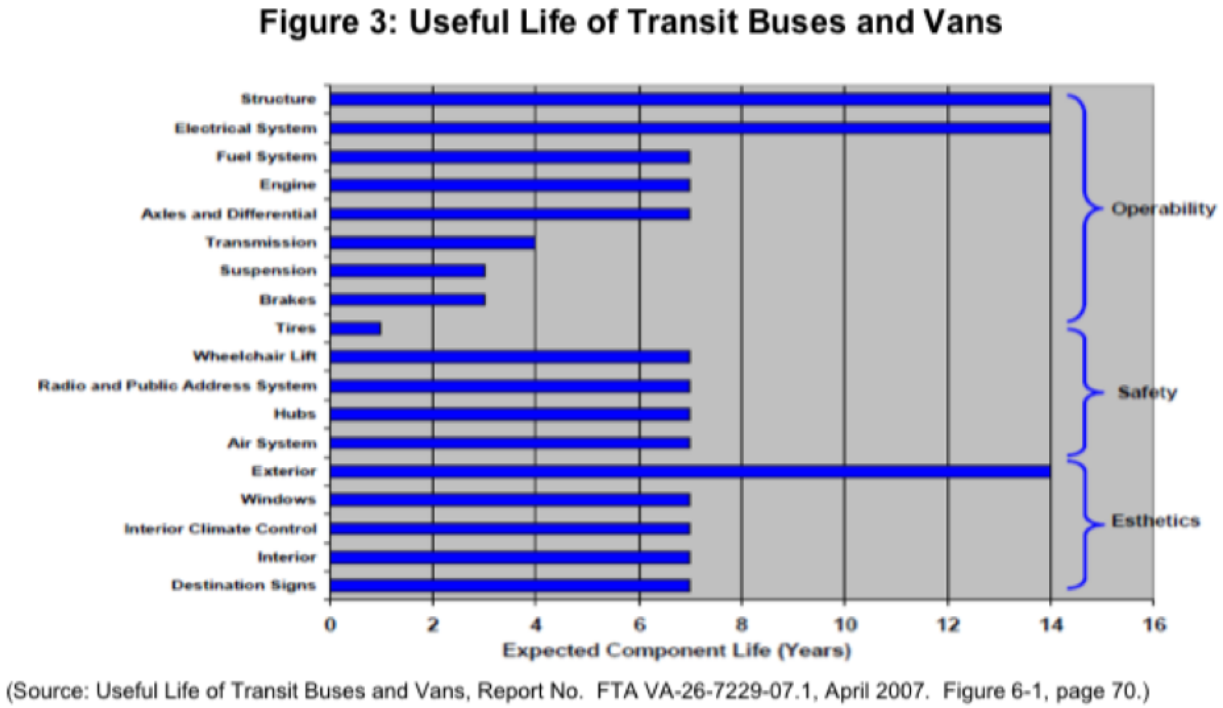


Figure 7 Bus Component Lifespans