Urban Infrastructure Design and Heat Vulnerability

Rethinking Infrastructure in Mesa, Arizona

A research project by Arizona State University's

Urban Infrastructure Anatomy and Sustainable Development

Spring 2015 Course

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1 Project Overview

In the Spring 2015 academic semester Arizona State University's Urban Infrastructure Anatomy and Sustainable Development class conducted a study to improve infrastructure in a Mesa, Arizona neighborhood to reduce heat vulnerability of users and inhabitants. The class split into four groups: i) Landscaping, Shading, and Exterior Environments, ii) Transportation, iii) Buildings and Neighborhoods, and iv) Institutional and Social Analysis. Each group developed recommendations for their topic and these recommendations are consolidated in this report.

2 Introduction

More frequent extreme heat events are expected for much of the Southwest U.S. and there is a pressing need to assess how the design of infrastructure can make people vulnerable, and ultimately solutions to reduce this vulnerability. The Phoenix, Arizona metropolitan area already experiences significant morbidity and mortality effects due to heat waves. Yet at the same time the region is considering strategies to reduce automobile use through more biking, walking, and public transit use which may necessitate exposure. The region's light rail line is an expanding system that currently serves Phoenix, Tempe, and Mesa. As of Spring 2015, construction was in progress to expand the line further East through Mesa. With increasing access to light rail, the city of Mesa has been considering redevelopment options around new stations. This course project focuses on a neighborhood historically known as Glenwood. The teams assessed strategies for upgrading infrastructure and community outreach to reduce vulnerability to heat. Findings are documented in the subsequent sections.

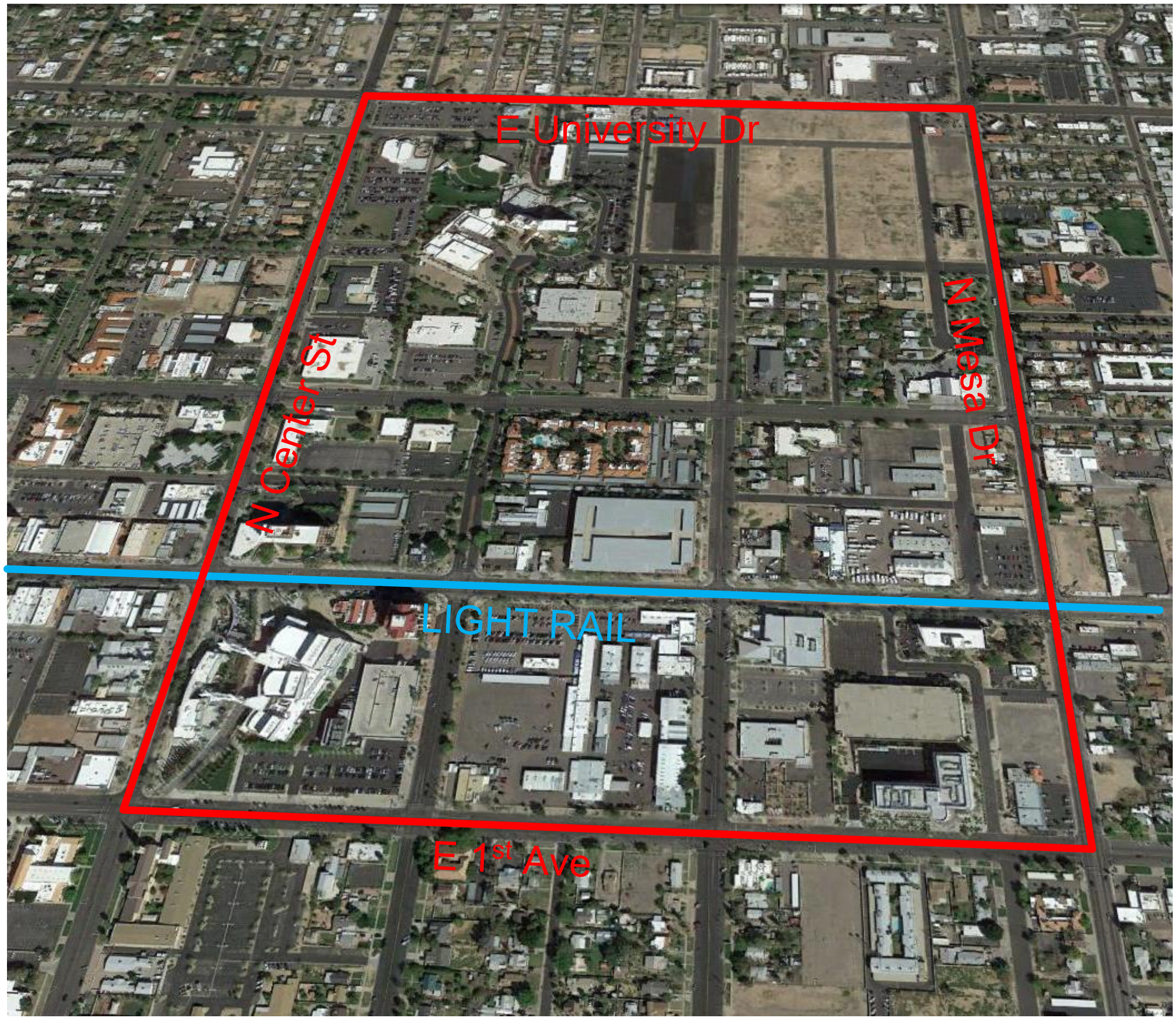


FIGURE 1: STUDY SITE IN MESA, ARIZONA

3 Landscaping, Shading, and Exterior Environments

This chapter details the methodology and results from the Exterior Environment team. As the Exterior Environment team, we concentrated on the specific design, composition, and placement of streetscape & landscape vegetation, structures, and materials around the target neighborhood. The chapter is divided into 5 topic sections: shading, surfaces, improvements for existing infrastructure, stormwater capture, and pedestrian corridors.

3.1 Shading

3.1.1 Methodology

Appropriate shading designs will be incorporated in this development, including natural shading, structure shading, and solar panel shading. These elements will not only reduce heat vulnerability, but will also enhance the beauty and aesthetics of the neighborhood and will provide clean solar energy to the city of Mesa. There are several points of interest in this regard. A combination of tree shading and street shade structures will be used to provide shading for pedestrian corridors and sidewalks. The Pedestrian Corridors will link several strategic locations in the area and many people are expected to use it, especially after the completion of the light rail. Thus, it is important to address how these people will be protected from the sun's heat during the summer. Various buildings such as the Mesa Main Library and the Mesa Arts Center already give appropriate building shades so this report is going to state a strategic way for placing the three shading elements in order to provide thermal comfort for people along un-shaded areas as well as beautifying the neighborhood.

Phoenix and its surrounded areas (Figure 2), are considered a low altitude desert where the average maximum temperature in the summer would be around 102 °F and the minimum temperature for winter would range between 36-37 °F (Davison, 2015). Thus, shading of the streets and pedestrian areas is an important consideration while planning the city and the urban transportation networks. It is both protection of inclement weather for buildings and the means to create and support 'walkability' of the city. It is of especial concern for city of Mesa, taking into account local climate conditions.

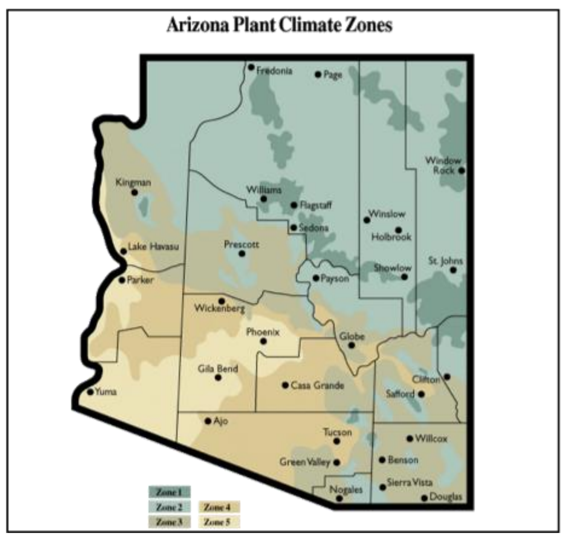


FIGURE 2: PHOENIX PLANT CLIMATE ZONES. IMAGE CREDIT: DAVISON (2015)

The city's transportation network should be developed as more pedestrian-oriented, and shading of the streets, bus stops and pedestrian corridors is the top priority to achieve this goal. Likewise, with imminent threat of global warming and high temperatures, urban engineers and planners have been compelled to adopt measures that guarantee movement of people, as well as ensuring their safety in the cities.

3.1.2 Shading Strategies

There are different strategies of approaches that can be used to shade a site. The type of shading to be used may be significantly influenced by the area that it is to be installed and economic factors. Tree and structures shading are the most likely strategy to be considered due to availability and the cost of acquiring them. Arizona is a dry state, and natural options are limited to hardy plants. Thus, hard choices have to be made between trees with positive environmental conservation advantages and shading structures with minimal cost. This Methodology will state three different strategies of shading which are Natural shading, Structure shading and Solar Panel shading.

3.1.3 Natural Shading (Tree Shading)

In different subtropical and tropical areas, there are various considerations to be made in selecting tree to plant in the area along sidewalks and pedestrian corridors. According to Donovan and Butry (2010) the trees need to be planted with reflection on the sun angles and location of shades. Knight, Anderson, McLaurin, and Coker (2006)also pointed out that street vegetation, particularly those planted to offer shade, need to be closely spaced. Because of the harsh environmental condition of urban cities, these trees should have the ability to flourish fast with less soil moisture (Sudha & Ravindranath, 2000). *Delonix regia, Muskogee Crape Myrtle Ficus Benjamina,and Tipu Tree* are the four types of trees that are going to be discussed in this plan based on their locations, height, width, amount of water consumption, and problems.

FIGURE 3: DELONIX REGALA TREE. PHOTO CREDIT: WALT (2015)

The first type of tree called *Delonix regia* (Figure 3). This type of tree can be planted to provide shades with a very nice colorful view. It grows to a maximum of 40ft tall and 16ft wide. These species are common in the dry deciduous forests of Madagascar (Knight et al., 2006). It has large flowers with orange petals spreading to about 8 cm (Macdonald, Harper, Williams, & Hayter, 2006). These large flowers are very crucial in offering shades along the sidewalks. Despite this vegetation requiring tropical climate, it can withstand salty and drought conditions, which makes it suitable for urban environment.

FIGURE 4. MUSKOGEE CREPE MYRTLE TREE

Second, *Muskogee Crape Myrtle* (Figure 4), which is appropriate vegetation for sidewalks. It grows extremely fast, attaining 15-25 feet in height (Knight et al., 2006). It gives an appropriate amount of shades with a beautiful view. Its lavender-smelling, purple flowers also give good ambience to cities. Besides growing tall, the tree also has long branches that offer shade to pedestrians. The growth rate of Muskogee Crape has been documented as 5 feet per year. Its high mildew resistance makes it desirable in the South (Knight et al., 2006). It does not consume a large amount of water, which makes it more appropriate for a semi-arid city like Mesa.

FIGURE 5. FICUS BENJAMINA. PHOTO CREDIT: STARR ENVIRONMENTAL

Another type of tree that seems suitable for the city is *Ficus Benjamina* (Figure 5). This tree has graceful dropping branches and oval leaves. This is a huge tree, growing to 60 feet tall and 60 to 70 feet wide (Gilman & Watson, 1993). It has fast growth rate and medium water consumption with a very low rate of maintenance. Its fruits are particularly delicious to fruit doves (Frith, Crome, & Wolfe, 1976). Also, the Ficus Benjamina tree suits most urban conditions especially parks and along Pedestrian corridors. Importantly, *Ficus Benjamina* can sustain extreme conditions whether its being sunny or in an area with lots of shade (Gilman, 1997). The tree takes up moderate amount of water during summer. Lastly, the roots of the above trees can be destructive to the point that they invade gardens.

FIGURE 6. TIPU TREE

The last type is *Tipu Tree* (Figure 6), which grows to a maximum of 98ft tall and 70ft wide. Its leaves are compound, and its flowers are bright yellow in color, which gives a fresh nice view. Its fruits produce seeds that can be used to grow other trees and it can withstand a wide range of climatic conditions. However this type of trees had destructive roots and can lift up concrete, for which our plan of replacing concrete sidewalks with Rubber sidewalks would solve this issue.

3.1.3.1 Structural Soil

FIGURE 7. STRUCTURAL SOIL. PHOTO CREDIT: SOIL SCIENCE FLICKR CC BY 2.0

The most significant problem that urban trees face, however, is the lack of useable soil volume for root growth, since trees are often an afterthought in city planning and streetscapes design (Bassuk, Grabosky, & Trowbridge, 2005). A structural soil (Figure 7) is a purposefully designed medium that is employed in the paved environment to establish trees and other forms of plants used for aesthetic purposes. The research and the ultimate development of structural soil were informed by the challenges that inhibit the growth of plant life on the paved surfaces. When building a concrete surface for instance sidewalks, the soils under such surfaces are subjected to high levels of compaction in order to achieve the stringent engineering standards and the load bearing requirements. As a result of the compaction, the roots of these trees are confined to small areas within the compacted natural soils with small pockets of air, inadequate nutrients and limited water (Bassuk, Grabosky, Trowbridge, & Urban, 1998). As such, the trees experience inhibited growth and have a shortened lifespan. Moreover, the roots of such trees will find regions of less resistance hence end up damaging drainage pipes, building foundations, and distorting the paved surfaces (Figure 8). In regard to the Bassuk et al. (1998) argument, the achievement of both the engineering and horticultural requirement by structural soil is due to its three principal components: crushed graded stone (with no fines), clay loam, and hydrogel (Bassuk et al., 1998). As illustrated above, when the natural soil is compacted, it becomes impermeable, and it inhibits root growth and tree development. On the other hand, compaction of the structural soil permits root growth and penetration while still providing the mechanical strength to support the paved surface. Ultimately, these properties of the structural soil enable trees to grow faster in it as compared to the regular soil.

FIGURE 8. DESTROYED PAVED SURFACE BY TREE ROOTS. PHOTO CREDIT: IAN LOVETT

3.1.4 Structural Shading

The second shading strategy discussed in this methodology is structural shading. There are several best practices of developing sustainable structural shading solutions in hot arid areas among them Green roofing shaded bus stops, fabric canopies, and shaded Intersection stops.

3.1.4.1 Green Roofs

'Green roofing' practices have become widely applied in the municipal policies of many cities in Europe and Canada. Green roofs add measurable benefit to residents by tackling the loss of biodiversity and providing natural space valued for recreation and relaxation. However, green roofing for shade structures is not widely applied, and is more common for cities of the Gulf regions (Figure 9).

Two main types of 'green roofs' are extensive, which use a substrate depth from 5 to 15 cm, and intensive, which have deeper substrate and feature irrigation systems (Lawlor, Currie, Doshi, & Wieditz, 2006). Also, Biotextures are used in some practices of bus stops or gas stations design. Considering the peculiarities of climate in the case area, biotextures are more practicable. The installation of this type of roofing ensures that an open urban space is greened and the comprehensive municipal policy in increasing support of green roofing installation is important for improvement in urban micro-climate, particularly, urban heat effect, and air quality.

FIGURE 9.GREEN ROOF BUS STOP. PHOTO CREDIT: 100IDEAS.WORKPRESS.COM/ 2009/06/11/52-PUT-LIVING-ROOFS-ON-BUS-SHELTERS

3.1.4.2 Shaded Intersections

People frequently pause at intersections to make decisions about which route to take. Consequently, intersections are more likely to have more people waiting before deciding on which way to take (Macdonald et al., 2006). Because of the environmental legibility and pedestrian comfort roles played by sidewalks, it is impossible not to associate them from intersections. Because of high probability of presence of pedestrians at intersections, some of shading is important.

FIGURE 10. INTERSECTION PEDESTRIAN STOP SHADING STRUCTURE. PHOTO CREDIT: MAWDHAH ALHASHEMI

Canopy structures can be used to offer shading to the pedestrians waiting to cross the streets (Figure 10). The design of the canopies must not interfere with the visibility of both pedestrians and oncoming vehicles. It therefore implies that the canopy structures need not to be very high or very low. Highly placed canopy structures are likely not to provide shade at the desired location because of the changing angles of the sun. The span of the structure should not also extend to the road, as it might act as a protrusion. In addition, the material used in the construction of the canopy need to translucent in order to allow light while preventing the penetration of heat from the sun.

3.1.5 Solar Panel Shading

To increase energy efficiency while improving shading in the area, solar panel installation is a proper solution. The installation of solar panels as a shading structure has many advantages among them providing shade and being a source for a clean energy. Advances in technologies of construction materials brought up cost-efficient and more compact solutions, for example, *grid-tied solar roofs and roofs with integrated photovoltaic.*

FIGURE 11. SOLAR PANEL SHADED BUS STOP. PHOTO CREDIT: SPECIALISTAENERGIAVERDE.COM/ SDHCDA.PHP?ID=180

In addition, solar panels are being used as bus stops' shading structures (Figure 11). All over the world, cities are installing solar-powered bus shelters. In Tucson, Arizona, for example, Sun Tran transit bus shelters utilize solar powered lights to reduce the amount of energy used to provide safe and well-lit waiting areas for passengers. Solar bus shelters are part of the effort to "green" transportation, along with green buildings, around the globe in railways, buses and even on the high seas (Watt Watt, 2010).

3.1.6 Results

In the case area, which is delineated by Mesa Drive, East University Drive, East 1st Avenue, and North Center Street, there are located such buildings as Mesa Main Library, Northern Arizona university, Amphitheatre, Apostolic church, thus, there is intense pedestrian traffic. People have to get to such destinations from bus stops, and from main streets to inner-block zones.

There are also limited green zones, as the only park located at the north-east part of the block and lacks trees of high height. Instead, vacant zone occupies considerable zone between North Mesa Drive and East University Drive. This vacant zone impedes 'walkability' of the whole block and is likely to be rezoned as a park.

Therefore, based on the previous methodology, we as urban planners and engineers have to guarantee people's safety by providing well-shaded corridors and sidewalks that are less vulnerable to heat during the summer. Thus, we are stating in this report different shading strategies in order to increase shading and reduce heat vulnerability in the city of Mesa. These strategies confined between natural shading, structural shading, and solar panel shading.

3.1.6.1 Natural Shading

In the case area sidewalks and curbs lack trees. Even along the main streets, like East 1st street, there are no trees or verdure. This makes sidewalk environment open and thermally uncomfortable. The only place where shading from trees can be observed is the eastern part of North Pasadena Street, where the line of medium-height trees is present. Moreover, in the block, buildings are separated from the adjacent street by walls and lines for parking but with no shade trees.

3.1.6.2 Sidewalk shading

In regard to our methodology, natural shading section (Table 1), trees that have less height and width, such as *Delonix regia and Muskogee Crape Myrtle,* are more suitable to be planted along sidewalks where they give a very nice colorful view to streets as well as provide nice shades for pedestrians.

TABLE 1. SIDEWALKS TREE SHADING TYPES

LOCATION	TREE TYPE	GROWTH RATE	HEIGHT	WIDTH	LIGHT	WATER USAGE	MAINTENANCE
Sidewalks	Delonix regia (1)	Fast	16 - 40ft	11 - 16ft	Full Sun	Low	Evergreen
Sidewalks	Muskogee Crape Myrtle (2)	Moderate	15-25ft	8 - 10ft	Full Sun	Low	Low

3.1.6.3 Pedestrian Corridors Shading

Furthermore, pedestrian corridors connecting the University bus route with the Light Rail stop at Center Street and Main Street passing by the Mesa Arts Center, Mesa Main Library, Mesa Convention Center, and the Mesa Amphitheatre. Therefore, people should feel safe as well as comfortable walking from place to another and based on that there would be a need for larger, higher, and wider trees that give them bigger amount of shade. *Ficus Benjamina and Tipu Tree* (Table 2), are the 2 types of trees that we found more suitable to be planted along pedestrian corridors where they take in minimal water, suit hot conditions, give a big amount of shade, and are environment friendly compared to other trees.

TABLE 2. PEDESTRIAN COORIDORS TREE SHADING TYPES

LOCATION	TREE TYPE	GROWTH RATE	HEIGHT	WIDTH	LIGHT	WATER USAGE	MAINTENANCE	PROBLEMS
Pedestrian Corridor	Tipu Tree (3)	Very Fast	98ft	65ft	Full sun or partial shade	Medium	Medium	Roots can be invasive to sidewalks
Pedestrian Corridor	Ficus Benjamina (4)	Fast	60 ft	60-70ft	Full Sun	Medium	Low	The roots can be invasive to concrete

3.1.6.4 Structural Soil

This type of soil has been adequately developed to meet the load bearing requirements of the paved surfaces as well as the stringent engineering standards while supporting and allowing the growth of roots as compared to the natural soil. Thus, we planned to replace natural soil along sidewalks and pedestrian corridors with structural soil in order to have better long life plants.

3.1.6.5 Structural Shading

Another main concerns in the proposed recommendations for improving shading in the city of Mesa is the lack of shading structures in the parking lots and pedestrian areas. Thus, sustainable design of structures that provide shades is an important element of proposed strategy. Besides applying sustainable design practices it is important that such shaded bus stops along Mesa Dr. and Main St, and shaded intersections at East 1st Street, East Main Street, East 1st Avenue and East University Drive along Center Street are located so as not to impede walkability or any functioning of the area.

3.1.6.6 Solar Panel Shading Structures

Other areas that have particular requirements for shading are parking lots. There are four parking lots in the block, one near the amphitheater, one at the Eastern University drive, one at the Mesa Main Library, and one along the Northern Pasadena Street. All parking lots, with an exception of the last one, do not have any shading facilities and trees. In the parking lot at Northern Pasadena Street, there are 3 shade structures and two lines of medium-height trees. Solar panel shading structure is our final strategy of shading, which is going to be placed at parking lots (Figure 11) and which provide shading as well as providing a sustainable source of clean energy for the city Likewise, those solar panels light up in the dark and so they provide lighting at night and so ensure safety for pedestrians.

FIGURE 12. SOLAR PANEL SHADING STRUCTURE OVER PARKING LOTS. PHOTO CREDIT: CLEANTECHNICA.COM/1020/08/03/SOLAR-POWER-TRANSFORMS-PARKING-LOTS-INTO-GREEN-JOB-GENERATORS

3.2 Surfaces

The proposal also address the type of materials placed on different surfaces that generate a significant portion of the Urban Heat Island Effect in the neighborhood. The surface focus for the environment portion of this project will be on the materials type. When searching for material alternatives, one must consider the purpose of each surface to accurately narrow down these alternatives. The purpose therefore will provide an insight to the minimum material properties needed for the surface to functionally operate before excluding any more heat vulnerable options. Therefore, the approach will be to address two main groups, which are sidewalks and asphalt parking lots.

Sidewalks are outdoor corridors used by pedestrians that tend to be located next to roadways and vegetation. As a result, the main surface material property, which is compressive strength, can be kept significantly lower than the other two main groups. Therefore, the approach method to address heat vulnerability is to consider other materials, with less heat absorbance, that are able to carry pedestrians and light vehicles.

The proposed product is called Rubbersidewalks™ (Figure 13) using rubber mulch available in various colors instead of conventional concrete as the

FIGURE 13. RUBBERSIDEWALK™ EXAMPLE. PHOTO CREDIT: TERRECON.COM/PRODUCTS/RUBBERSIDEWALKS/)

building block (Terrecon, 2015). The sidewalk construction is done by placing preconstructed rubber mulch blocks over a well-compacted surface locked in a logo formation without any binding additive. Due to the elastic properties of rubber, the mulch blocks will be able to absorb dead and live loads without shifting or cracking.

Rubbersidewalks™ is primarily made from crumb rubber which has an average thermal conductivity of 0.15 compared to a concrete average value of 1.5. Therefore, by using Fourier's Law a supporting argument can be set to show how using rubber in sidewalks will absorb less heat than concrete during initial exposure to release it later on. In order words, by having rubber we are being proactive by choosing a material that is less thermally conductive.

EQUATION 1. FOURIER'S LAW

Fourier's law: $$q = \frac{k \cdot A \cdot (T_H - T_C)}{L}$$

where
q = heat transferred per unit time (W)
A = heat transfer area (m^2)
k = *thermal conductivity of the material* (W/m.K0
T_H = hot temperature (K)
T_C = cold temperature (K)
L = material thickness (m)

Based on the thermal conductivity

values discussed previously, the heat transfer capability of rubber is 10 times less than concrete. Using the estimated amount of Rubbersidewalks™ needed for building pedestrian corridors (which are discussed in more detail later on in this chapter) as a basis for calculation about 5.5 miles and width of 10 feet The total absorbed heat was calculated to be 39600 Watts per degrees Kelvin for concrete and 3960 Watts per degrees Kelvin for rubber. As a result, the rubber heat absorbance rate is calculated to be one tenth of concrete. Additionally, this argument can be set for various material choices in terms of heat vulnerability. For instance, the significance of placing colored coating over materials to minimize heat retention.

Additionally, it is estimated that 400 square feet of Rubbersidewalks™ will be responsible for keeping two tons of waste tire rubber from being disposed in landfills (Greenfieldboyce, 2006). Upfront investment to install Rubbersidewalks™ is higher by 30% in costs per unit area (Greenfieldboyce, 2006). However, lifecycle benefits outweigh the concrete since less maintenance will be required, and Rubbersidewalks™ service life is estimated to be two to three times longer than concrete. In case of repair, it is estimated that labor costs is approximately $1.5 per square foot compared to $8 per square foot for concrete (Greenfieldboyce, 2006). Assuming that one round of repair for the entire sample pedestrian corridor (5.5 miles) will occur throughout its service life, the maintenance savings will be the difference between 2.11 million dollars (concrete) to 396 thousand dollars (rubber).

Figure 14. Pedestrian corridors where Rubbersidewalks™ could be placed. Image Credit: Google (Modified by Authors)

Parking lots are open areas paved with asphalt used to park mainly lightweight vehicles. However, parking lots can also be used for secondary purposes such as stormwater management. Therefore, our approach method will be to implement permeable surface pavement in dedicated surface parking lots. Parking lots that could have permeable surfaces applied are shaded in orange in Figure 14. Additional information about permeable pavements can be found in the stormwater section and the Transportation chapter of this report. Permeable pavement is a feasible option if the parking lots were to be left as they are without any drastic alteration. On the other hand, since within the boundaries of the neighborhood there are vast amount of parking lots, another proposed initiative is to consolidate parking into multi-story parking structures so that existing paved surface lots can be reduced and converted to other uses. These multi-story structures can both serve the parking demand for the surrounding areas and generate funds for the City of Mesa. For illustration, one of the proposed locations for a multistory parking lot can be seen shaded in bright yellow in Figure 15. If constructed, a multistory parking lot will reduce the demand for all the surrounding surface parking lots on the west side of the neighborhood, allowing for the conversion of certain lots (shaded in green in Figure 15) to other uses, such as green space. Additional information about the proposal type of multistory parking lots and other locations can be found in the Building and Transportation portions of this report.

FIGURE 15. NEIGHBORHOOD PARKING LOTS TARGETED FOR MODIFICATION IMAGE CREDIT: GOOGLE (MODIFIED BY AUTHORS)

3.3 Improvements for Existing Infrastructure

Within our Mesa block there are historic single-family neighborhoods, apartment complexes, hotels, commercial buildings, parking garages, and public buildings. Extensive parking lots and wide roads with on-street parking surround the buildings. The buildings themselves have remained with traditional light color facade, gable or flat roofs, trees in the yard, and green grass for landscape. With new awareness of heat vulnerability, it is our goal to recommend sustainable improvements to residential houses and commercial properties to reduce energy consumption, reduce greenhouse gas emissions, and improve the heat vulnerability of the area.

3.3.1 Sustainable Improvements

In order to lower the heat vulnerability of the Mesa block, there are a few key sustainable improvements to recommend. Upgrading roofs, green roofs, xeriscaping, shade structures, and green walls. There are numerous benefits to sustainable infrastructure. The most important is the impact it has on heat vulnerability. By reducing the amount of heat that can be absorbed into materials and later released, reduces the air and surface temperatures, allowing for more comfort outdoors and more people choosing to walk and bike instead of rely on automobile transportation. These sustainable improvements also lowers energy use, reduces air pollution, reduces greenhouse gas emissions, protects harmful exposure to ultraviolet rays, reduces pavement maintenance, and improves the quality of life.

3.3.2 Roofing

During the summer, the temperature of a standard or dark roof reaches over 150 degrees Fahrenheit while cool roofs will remain more than 50 degrees cooler. Updating roofs to cool roofs includes reflective painted roofs, reflective tiles or shingles, sheet covering, and green roofs. These additions when done in a heat intensive area, reduces air conditioning needs which will reduce energy bills, improves indoor comfort for non-air conditioned spaces, and reduces the roof temperature. Benefits to the environment include reducing local air temperatures, lower peak electricity demand, and reduced power plant emissions. ("Cool Roofs," 2013).

There are three basic options for converting an existing roof into a cool roof; coat the roof, re-cover it with a new waterproofing surface, or replace roof with a new one. If a roof is in poor condition or near the end of its life, the owner should re-cover, replace, or retrofit the roof. Cool roofs do not necessarily cost more than non-cool roofs if you are installing a new roof or replacing the roof, however converting a standard roof that is in good condition into a cool roof can be expensive. Major roof costs include upfront installation and ongoing maintenance. Yet looking at the long run, installing a cool roof can save the owner money in the long run with energy savings, possible rebates and incentives, HVAC equipment downsizing, and extended lifetime of the roof ("Cool Roofs," 2013).

Another option of roofing is the green roof. Green roofs are roofs with a vegetative layer grown which works as a barrier between the roof and sun. During the summer months, the surface temperature of a green roof can be cooler than the air temperature when traditional rooftops will be up to 90 degrees Fahrenheit warmer ("Green Roofs," 2013). Green roofs have the same benefits as the cool roof but with the added benefit of having a garden. Recommending green roofs to property owners that wish to keep a green yard could convince them to switch their yard to xeriscape and add a green roof. Although green roofs are expensive, simply promoting residents to paint reflective white surface on their roofs can dramatically reduce heat emitted from roofs.

3.3.3 Xeriscaping

The majority of the lots within the Mesa block are grass landscaped with trees. The Mesa block is considered within SRPs flood irrigation, although it is unclear which lots choose that form of irrigation. With these houses and commercial buildings having water rights, it is imperative to work with the residents to show them the cost-benefit of xeriscape to conserve water and reduce water bills ("Drought Tolerant/Low Water Use Plant Lists," 2014).

Xeriscaping is a water conservation concept designed to reduce water use by 50 or 75 percent or eliminate the need for irrigation altogether. The most important environmental aspect of xeriscaping is choosing vegetation that is appropriate for the climate and in Mesa, Arizona’s case drought tolerant vegetation such as ocotillo. Another important component of xeriscaping is installing efficient irrigation methods such as drips and soaker hoses that directs water to the base of the plant and prevents water evaporation. The Novato, California city's water department estimated that houses that converted to xeriscaping saved 120 gallons of water a day (National Geographic Society, 1996-2015).

Trees are an important part of xeriscaping and reducing the heat impact of the area. Trees planted in the Mesa area should be drought tolerant and should be planted near housing and commercial structures to cast shade on the buildings to reduce the surface temperature of the building. A study conducted by the Center of Integrated Solutions to Climate Challenges found that increasing tree shade in a neighborhood from 10 percent to 29 percent can lower temperatures by 4.3 degrees Fahrenheit (Phillips, 2014). Richard Adkins, the Forestry Director for the City of Phoenix, even stated that "trees are the key to combating the urban heat island effect" (Phillips, 2014).For trees to be the most effective, planting them 10 to 15 feet away from building walls on the east and west sides' blocks direct sun at its low angle (Climate Protection Partnership Division).

3.3.4 Green Walls

The Mesa block also has the potential for green walls. There are carports on residential lots, parking garages, large commercial buildings, and parking shade structures that are currently collecting heat and releasing it back out into the atmosphere making the surface temperature warmer. Residents with carports can create green walls by repainting the shade structures, replacing them with heat friendly material, and growing vines such as bougainvillea along the walls and top surface will create more shade and lower the temperature around the area. Buildings with large wall such as parking structures and commercial buildings should consider growing a large scale green wall on walls facing east or west and where pedestrians walk.

There are two main categories of green walls; green facades and living walls. Green facades are wall systems where climbing plants cover specially designed supporting structures. Green facades can be attached to existing walls or built as freestanding structures. Living walls are composed of pre-vegetated panels or integrated fabric systems that are affixed to a structural wall or frame. This system will support a great diversity of plant species including ferns, low shrubs, perennial flowers, and edible plants. As the living wall is more diverse in plant life, its maintenance is more intensive including regular water, nutrients, and fertilizer (Sharp, 2007).

As identified by the Green Roofs for Healthy Cities, public benefits to green walls are the aesthetic improvements, reduction of the urban heat island effect, improved exterior air quality, and local job creation. Improved private benefits are improved energy efficiency, building structure protection, improved indoor air quality, noise reduction, and marketing potential ("Green Walls Benefits," 2014). Aesthetically, the green walls could be built on primary pedestrian corridors to attract people to the area. Like green roofs, green walls provides thermal insulation for buildings which reduces the demand on power and decreases the amount of pollution pumped into the air.

3.3.5 Incentives

Incentives will be needed to encourage enough people to make the improvements to their lots to make a change in the heat vulnerability.

3.3.5.1 Xeriscape

Mesa currently has two rebate programs for removing grass on property and converting to xeriscape. Residential land owners that remove 500 square feet or more of grass can apply and receive a $500 rebate (City of Mesa, 2015a).

Mesa's non-residential property owners that remove 10,000 square feet or more grass can apply and receive a $5,000 rebate. However the non-residential rebate is through a federal grant and the city can only accept up to 10 non-residential water consumers a year. This non-residential rebate is overall successful and currently has a waiting list of 23 non-residential customers (City of Mesa, 2015b)

Comparing Mesa's rebate program with other local xeriscape rebates Mesa could increase its rebate prices and offer more rebates to conserve water. The City of Chandler offers a new landscape $200 rebate for landscaping 1,000 square feet or more with at least 500 square feet non-grass. The city also provides a turf removal rebate between $200 and $3,000 for removing 1,000 square feet or more of turf to convert to xeriscaping. To also increase water conservation, the city provides a rebate up to $250 for installing a weather based 'smart' irrigation controller (City of Chandler, 2015). In Novato, California residents were offered conservation incentives through reductions in their water bills if residents converted their lawns to xeriscaping (National Geographic Society, 1996-2015).

The City of Mesa should strongly consider remodeling their residential rebate to encourage more residents to convert their lawns to xeriscape to save money and use less water. The rebate should be tiered to make it more appealing to remove more grass.

For example:

500 sq- $1,000

750 sq- $1,500

1,000 sq- $2,000

1,250 sq +- $3,000

3.3.5.2 Green Walls

There are several LEED credits available when used in combination with other sustainable building elements including; Landscape Design that Reduces Urban Heat Island non-roof, Water Efficient Landscaping, Innovative Wastewater Technologies, Optimize Energy Performance, and Innovation in Design. LEED credits are great incentives for companies looking to upgrade their building to become LEED certified.

3.3.5.3 Education and Encouragement

Since current incentive information is not widely known, it is important to reach the residents in an effective manner. A few methods could be posting flyers on doors, mailing flyers with the information and how to's, providing flyers at events, and providing the information at all public meetings or public classes.

3.4 Stormwater

In order to successfully implement an Earth system in dealing with the City of Mesa's stormwater plan, an analysis of opportunities and constraints had to be examined as well as the underlying economic, political, structural, and environmental factors which are at play. Attempting to overthrow the current system of things through a political or cultural ideology as well as presenting simple-minded solutions will only cause failure in adopting an Earth system.

In reviewing other city's stormwater management plans, such as through Tucson, they attempt to use planning ethics as a means to educate individuals over issues pertaining to stormwater. Through children's books, community meetings, or other practicums. While reaching the wide spectrum of knowledge base is present, achieving popularity is not evident. Without an interest among community members, increasing awareness with regards to managing stormwater would be futile.

Instead a dialogue should occur between community members and the city. Unlike most dialogues, which only present radical-minded "solutions", achieving common ground with community residents is crucial. More specifically when dealing with a capitalist structure, an incentive should be given towards businesses and residents when they abide by the stormwater management plan. This in the end will only be a small tradeoff for the city financially while achieving economic, social, and environmental benefits. In Tucson's stormwater management plan they encourage citizens to properly recycle hazardous materials such as pharmaceutical pills or oil in an attempt to protect the natural water ecosystems. While businesses might be required to properly dispose of toxic materials, homeowners are often given no regulations. It is questionable how dangerous these household pollutants can be in relation to stormwater. In order to combat this issue, the City of Mesa should encourage an incentive program that financially rewards residents who bring in their toxic materials to a fire station or other community-gathering place.

The outreach program should not be implemented through traditional methods such as community meetings; but rather through signage among surrounding businesses, schools, mailed flyers, and Mesa Community College.

With regards to the physical constraints that are existent, currently there are two drainage basins near Mesa, Salt River at Priest as well as the Indian Bend Wash at Curry Road. These drainage basins are surrounded by unnatural physical constraints. Attempting to use these basins as a tool for water delivery to the City of Mesa along Main Street would almost impossible due to zoning, planning law issues, financial, and physical constraints. However their location provides an insight with the way this dynamic resource is managed. In reviewing a topographic map for the City of Mesa, the geographic forms appear to be flowing downward in a southwest direction. Controlling this resource from a macro scale would be challenging, therefore focus would be along Main Street where a large amount of pedestrian activity is present making this area much more vulnerable compared to other zones of Mesa.

While consulting with the building's group, a follow-up dialogue would be needed to implement their proposed pedestrian corridor. Because Main Street will essentially be the central hub of Mesa, constructing the pedestrian corridor along this area would be the most useful. In an attempt to get people out into the community, implementing the pedestrian corridor along Main Street as well as between neighborhoods where north south thoroughfares are present would be ideal.

FIGURE 16. STREETSIDE BIOSWALE. PHOTO CREDIT: LOS ANGELES AND SAN GABRIEL RIVERS WATERSHED COUNCIL

When elaborating with the transportation group, it was mentioned that using a porous material wouldn't be useful; instead an asphalt-like material should be used. Because of this Main Street should be given a slight incline following both directions to allow stormwater to drain into vegetative corridors where the vegetative median and pedestrian corridors are present in a street side bioswlae as shown in Figure 16. This will decrease the UHI effect along one of Mesa's most vulnerable areas as well as provide a "sense of place" for the City of Mesa. Natural vegetation such as desert fountain grass will be used to help filter the pollutants from the stormwater runoff and help to recharge the groundwater supply. Where pedestrians are present, a roadway buffer with a bioretention system will also help to naturally absorb and filter runoff.

3.5 Pedestrian Corridors

The project neighborhood possesses several characteristics that will potentially lead it to become an area of increasing pedestrian activity. First, it overlaps with the eastern part of Downtown Mesa, placing it close to many economic and social activities. Second, several major locations of interest are located within the neighborhood, including the Mesa Main Library, the Mesa Amphitheatre, and the Mesa Arts Center. Third, the Valley Metro Light Rail Central Mesa Extension (due to be completed late 2015) will pass through the neighborhood, with two Light Rail stops being placed within the neighborhood. Fourth, the neighborhood is considered by the City of Mesa to be a major target area for future development and redevelopment projects. The combination of these characteristics, along with the City of Mesa's efforts to reduce car use around the Downtown Mesa area, makes it very likely that neighborhood pedestrian and bicycle travel activity will significantly increase into the future (McVay).

This probable increase in neighborhood pedestrian and bicycle travel will subsequently result in more people being exposed to heat, increasing their heat vulnerability. As discouraging pedestrian and bicycle travel is not a viable option for the City of Mesa (for economic and social reasons), other options to manage the heat exposure of these pedestrians and bicyclists must be considered instead. Therefore in this section, working in conjunction with the Transportation team members, the Exterior Environment team proposes a design and implementation outline for neighborhood "pedestrian corridors" and supplementary infrastructure that will perform the dual function of providing safe, comfortable neighborhood transit pathways as well as actively reducing the heat exposure of travelers.

The procedure for developing the outline for pedestrian corridor design, implementation, and supporting infrastructure was as follows. A set of design principles was compiled through a literature review of identified documents and research related to pedestrian corridor design. Along with the above resources, design principles for heat mitigation elements were drawn from pertinent heat mitigation research, as well as including specific material and design suggestions provided by the Exterior Environment team members focusing on shading, surfaces, stormwater, and improvements to current infrastructure. After developing the design principles, analysis using a combination of Google map data, site visits of the neighborhood, and discussions with Jeff Mcvay (a City of Mesa employee) was conducted to identify potential locations for the corridors placement. Next, a corridor placement and implementation scenario was developed via a collaborative process utilizing project data and critical input from the Environment team, Transportation team, Jeff Mcvay, and Dr. Mikhail

Chester. Finally, the design scenario was visually represented by using Google map images and graphic editing tools to model the scenario.

3.5.1 Overall Pedestrian Corridor Design

The pedestrian corridors proposed for the target neighborhood have two primary design objectives. First, the corridors need to be sufficiently attractive to pedestrians so that they will choose to use the pedestrian corridors over their other transit path options. Second, corridors need to protect pedestrians from heat exposure as much as possible. Luckily, these two objectives are quite complementary. With careful planning, standard design elements that attract pedestrians can be modified to minimize heat exposure, and elements that mitigate heat exposure can actually attract pedestrians.

When reviewing existing pedestrian corridor or pathway design guidelines from other localities or organizations, an extensive variety of potential design elements to attract pedestrians were identified (City of Bellevue, 2000; City of Mesa, 2015c; Crankshaw, 2012; U.S. Department of Transportation - Federal Highway Administration, 2014). By cross-referencing these guidelines, as well as reviewing studies which attempt to quantitatively examine what pedestrian design elements most influence pedestrian path choice (Guo, 2009; Guo & Loo, 2013; Rodríguez, Brisson, & Estupiñán, 2009), a streamlined list of important design considerations to incorporate into the proposed corridors was identified. These are width and quality of sidewalks, intersection crossing aids, way-finding features, vegetation variety, aesthetic variety, frequency and types of pedestrian amenities, and availability of useable open space.

As for heat mitigation design elements, current heat research focuses on three main "passive" design strategies for reducing pedestrian heat exposure outdoors: shading, maximizing surface albedo, and "passive" evaporative cooling (i.e. evaporation from a body of water). While research shows that all three of these strategies are effective at reducing heat impacts, there is also a significant performance difference between these strategies. During the daytime, shading has the highest cooling effect by a significant margin, followed by surface albedo, and evaporative cooling being the least effective. During the nighttime, evaporative cooling is the most effective, with shading and surface albedo being ineffective after sunset (Saneinejad, Moonen, & Carmeliet, 2014). Additionally, shading can actually increase nighttime temperatures by reducing sky-view factor and trapping heat (Rosheidat, 2014). However, besides "passive" heat mitigation methods, there are also "active" outdoor heat mitigation methods using cooling devices such as misting lines, misting fans, evaporative coolers, etc. Among these "active" methods, reviewing available research and online price listings suggests that misting fans might be the most cost effective outdoor cooling strategy (Farnham, Emura, & Mizuno, 2015). Taking the above information into account, proposed corridor design should attempt to maximize daytime and nighttime heat mitigation by combining and balancing the strengths and limitations of these various heat mitigation strategies.

3.5.2 Specific Pedestrian Corridor Design Elements

To provide a clearer picture of how we envision the design of the pedestrian corridor, we provide below more detailed descriptions of specific corridor design elements.

3.5.3 Pedestrian Movement and Way-finding Elements

Currently the majority of sidewalks in the neighborhood are rather narrow, appearing to have an average width of approximately 5-6 ft., close to the minimum sidewalk width allowed by federal standards for accessible sidewalks (U.S. Department of Transportation - Federal Highway Administration, 2014). For the proposed pedestrian corridors, the width of the sidewalks should be at least 10-14 ft. to allow for increased pedestrian traffic and accessibility. For the sidewalk composition, the sidewalk material(s) recommended in the Surface section of this report should be used. Additionally, the pedestrian corridor sidewalks should be imprinted and colored in a distinctive style from "normal" sidewalks to enhance aesthetic appearance and pedestrian way finding, as well as acting to increase sidewalk albedo. At points where the pedestrian corridors cross streets or intersections, curb extensions or pedestrian crossing islands should be implemented to improve crossing safety. Way finding features should include entry and distance markers throughout the pedestrian corridor, as well as location displays at major intersections that could also act as neighborhood maps and advertising boards for local events.

3.5.4 Vegetation, Shading, and Aesthetic Features

The pedestrian corridors should primarily utilize the trees varieties and shade structures recommended in the *Shading* section of this report. However, landscaping and planters along the pedestrian corridors can feature a greater density and variety of vegetation and shading structure types than along standard sidewalks. This variety can include trees with high and low leaf area density as well as full and partial shade structures to provide pedestrians contiguous access to shade while still providing areas of sunlight for comfort during cooler months. Shade structures should also be designed to have ventilation openings or angled in a manner to prevent heat being trapped at night. Ornamental vegetation (such as shrubs and bushes) should be selected and placed to also act as heat barriers between pedestrians and heat retentive surfaces such as building walls and granite mulch ground cover. Any aesthetic features (such as statues, artistic displays, utility or architecture screens, etc.) should be made of or coated with materials that will not absorb and retain heat.

3.5.5 Pedestrian Amenities and Open Space

Throughout the pedestrian corridor should be strategic distributions of various pedestrian amenities, including seating, trash/recycling bins, drinking fountains, nighttime lighting, vendors or vending machines, and public bathroom access. In most cases, these amenities should be placed under or near fully shaded areas; however, some seating should be available in sunlight areas for comfort in cooler months and lighting should be evenly distributed to provide sufficient nighttime illumination for safety reasons. Additionally, whenever possible, areas of useable open space and clear sight lines around the pedestrian corridors should be preserved or added, both to be attractive to pedestrians and for safety reasons (collision and accost prevention).

3.5.6 Heat Refuges & Cooling Centers

Besides the elements mentioned above, we also propose that the pedestrian corridor should be supported by strategically placed "heat refuge" structures or designated "cooling center" locations. "Heat refuges" would be structures similar to shaded bus stops, but would have a distinct color scheme to distinguish them from normal bus stops and avoid misidentification by

FIGURE 17. TEMPE TRANSIT CENTER BUS STOP (PHOTO BY CHRISTOPHER ROBINSON)

pedestrians (although, these heat refuges could also act as bus stops if they are placed along bus routes, and existing bus stops could be upgraded into heat refuges). Additionally, the heat refuges would possess additional heat mitigation amenities, such as drinking fountains and possibly even a cooling device such as a misting fan. If a cooling device was placed at these heat refuges, they should be equipped with timed activation switches that would automatically shut-off (similar to a Jacuzzi timer) to avoid unnecessary energy/water waste. These cooling devices could also be temporary, only being placed at the heat refuges as needed for particularly hot days/months or in conjunction with local events. As for basic heat refuge design, we recommend a design template similar to the bus stops found at the Tempe Transit Center, as the double-sided shade cover and seating arrangement provides good shade coverage as the sun position changes throughout the day/year (Figure 17). “Cooling centers” would be buildings or businesses that have been specially designated or contracted to provide pedestrians free heat relief amenities. These amenities would at minimum include access to drinking water and cooling devices. Additional information regarding the implementation of cooling centers can be found in the Social chapter of this report. Locations of heat refuges and cooling centers should be coordinated to ensure maximum coverage while avoiding unnecessary overlap.

3.5.7 Pedestrian Corridor Placement and Implementation Phases

We recognize that budget and time constraints will limit the when and where pedestrian corridors and supporting infrastructure can be implemented. Therefore, we provide below our recommendations for corridor placement and implementation priority according to 3 “phases”.

Phase 1

This initial phase runs north/south and connects the soon to be completed Light Rail stop at Center St and Main St with the University bus route, as well as passing by the Mesa Arts Center, Mesa Main Library, Mesa Convention Center, and the Mesa Amphitheatre, covering almost all the existing locations of interest in the target neighborhood. The majority of the proposed corridor also aligns with an already existing walking/bike path, which already possesses considerable shading and pedestrian amenities, and would only require moderate investment to be upgraded to meet design criteria for the pedestrian corridors. These characteristics make this the optimum first phase of the pedestrian corridors, and could be feasibly implemented immediately.

Phase 2

The next phase is more ambitious, requiring more extensive investment and having three sub-phases. Phase 2A extends east/west along 1st St from Center St until Lesueur. Phase 2B runs north/south along Hibbert from University Dr. until reaching 1st Ave. Phase 2C begins at the Mesa Convention Center, goes east crossing and following Centennial Way until reaching 2nd St, runs east along 2nd St until reaching and going south on Lesueur until reaching 1st Ave. Phase 2A could be implemented in the near future (1-2 years), as it would connect current neighborhood residents and pedestrians coming from Mesa Downtown to Pioneer Park. Phase 2B and 2C would be best implemented after the barren northeast corner of the neighborhood has been fully redeveloped, which could take several years (3-5 years).

Phase 3

This phase is would be the last phase, having two sub-phases and acting as a perimeter around the target neighborhood, only being implemented after the other phases have been completed and if sufficient funding is available. Phase 3A would run east/west on 1st Ave from Center Drive to Lesueur. Phase 3B would enclose the perimeter by running north/south along Center St from 1st Ave to University Dr., east/west along University Drive from Center Drive to Mesa Drive, and north/south along Mesa Drive from University Drive to 1st Ave. This phase would most likely not be implemented anytime soon (5-10 years).

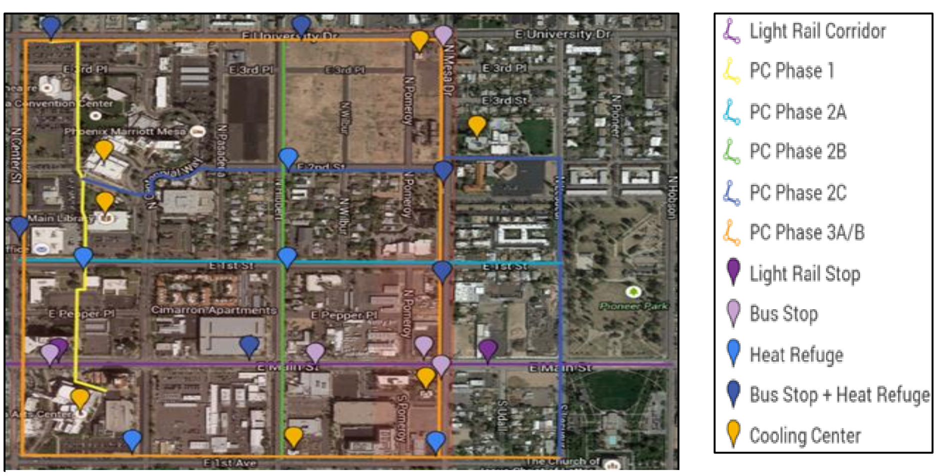


FIGURE 18. SCENARIO FOR PEDESTRIAN CORRIDOR AND HEAT REFUGE. IMAGE CREDIT: GOOGLE (MODIFIED BY AUTHORS)

3.5.8 Pedestrian Corridor Scenario

Figure 18 displays a visual representation of a pedestrian corridor scenario according to the aforementioned placement and implementation phases, along with possible locations for heat refuges, integrated bus stops/heat refuges, and cooling centers. Also indicated for reference purposes are the locations of the Light Rail corridor, Light Rail stops, and unmodified bus stops.

4 Transportation

The project motivation is to improve the desirability of visiting and residing in Downtown Mesa. Focus has been placed on efforts to reduce reliance on vehicle travel and promote a vibrant downtown accessible through multiple modes. The introduction of light-rail into the Downtown Mesa area will necessarily increase the attraction to walking, connecting bus routes, and biking. The project attempts to accommodate the projected increase in multimodal traffic and to enhance the neighborhood infrastructure to further promote this increased mobility.

Multimodal travel is a double-edged sword when it comes to addressing the heat-related impacts of the overall nature of the area's transportation infrastructure. On one hand, vehicular travel requires large areas of asphalt and wide stretches of road that push destinations further away from each other. Generally, the entire project team desires to reduce these distances and draw residential areas closer to each other in terms of time or space. Unfortunately, in the current built environment time spent walking translates to greater exposure to ambient heat as well as the energy retained through the heat island effect.

A personal vehicle offers a unique layer of protection against this heat exposure as it essentially serves as a personalized air-conditioned travel module. For all of the attempts to mitigate exposure risks, it is not realistic to offer a better system of protection for other travelers. There are many strategies to improve the protection systems for non-motorists and the following recommendations incorporate those whenever possible.

4.1 Preliminary Design of Improved Corridors

Many of the street pathways through the Downtown Mesa area are recommended for a redesign of their travelled way. These are streets that are overly focused on motor vehicle traffic, inefficient in their use of public right-of-way, and unaccommodating towards multimodal purposes. In some cases, these street sections overemphasize parking or offer an inefficient parking layout.

In all cases, multimodal considerations are required to more effectively promote transit-centric vibrancy.

The recommendations in this section have not been vetted by a comprehensive transportation study. The reconfiguration of these road segments will affect street capacities and create changes to dynamics of vehicle flow through the Downtown area. While this is largely the intended purpose, a thorough traffic analysis is recommended to ensure that vehicle flow continues to function as intended.

4.1.1 Main Street

As the primary point of access to the light rail, Main Street must be considered as a center of multimodal movement. The addition of bicycle lanes on Main Street and the reducing the availability of on-street parking are proposed. Figure 19 provides a visual representation of this concept.

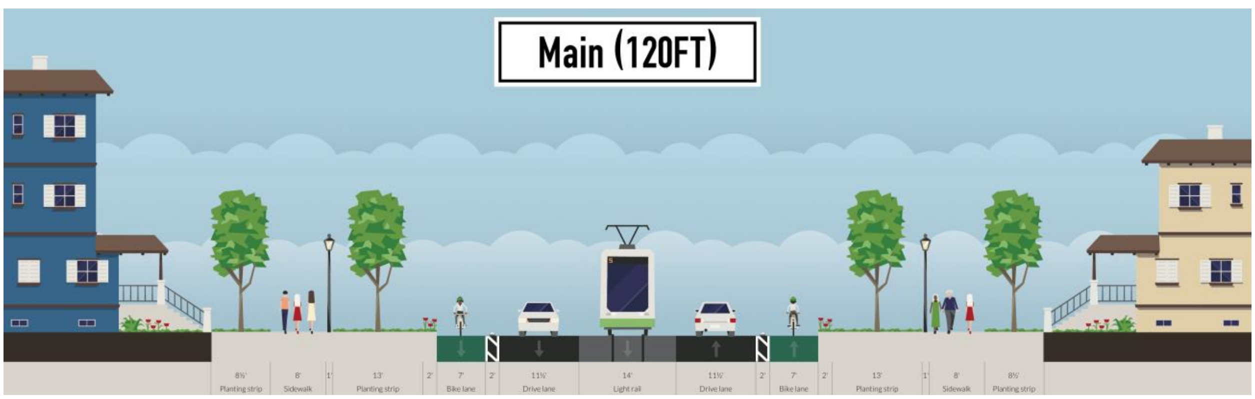


FIGURE 19. MAIN STREET

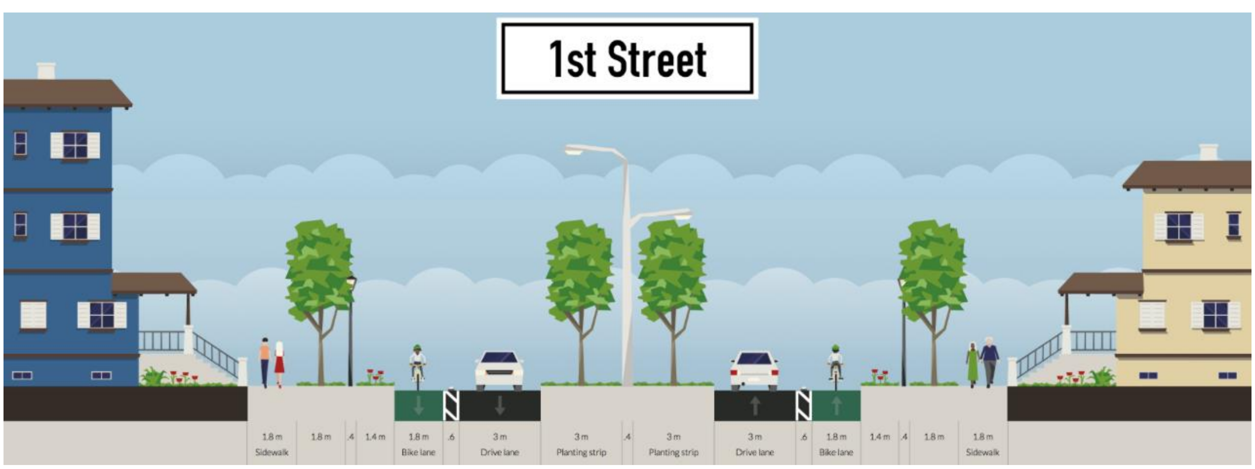


FIGURE 20. FIRST STREET, FROM CENTER STREET TO MESA DRIVE

The current design of First Street devotes more than forty feet of width to parking. This alignment necessitates a crossing distance of over eighty feet for pedestrians. Portions of the road may maintain on-street parking near Centennial Way due to the parking demands of the nearby apartment complex. Figure 20 shows the recommended revised street cross-section.

In a manner similar to First Street, Hibbert devotes significant width to the service of motor vehicles. This alignment necessitates a crossing distance of over eighty feet for pedestrians. Similar to the proposal for First Street, this design preserves vehicle access while redesigning for improved pedestrian and bicycle facilities. The sidewalk-to-sidewalk right-of-way is 120 feet, where only roughly forty feet is required for vehicle travel and parking. Even while preserving vehicle access, this street can be drastically redesigned to allow comfortable multimodal usage while offering aesthetic green areas and vegetation. To promote use of this corridor by pedestrians and bicyclists, a traffic signal should be considered for the intersection with University Drive.

The upgrades proposed for this street are best realized in comparison to the

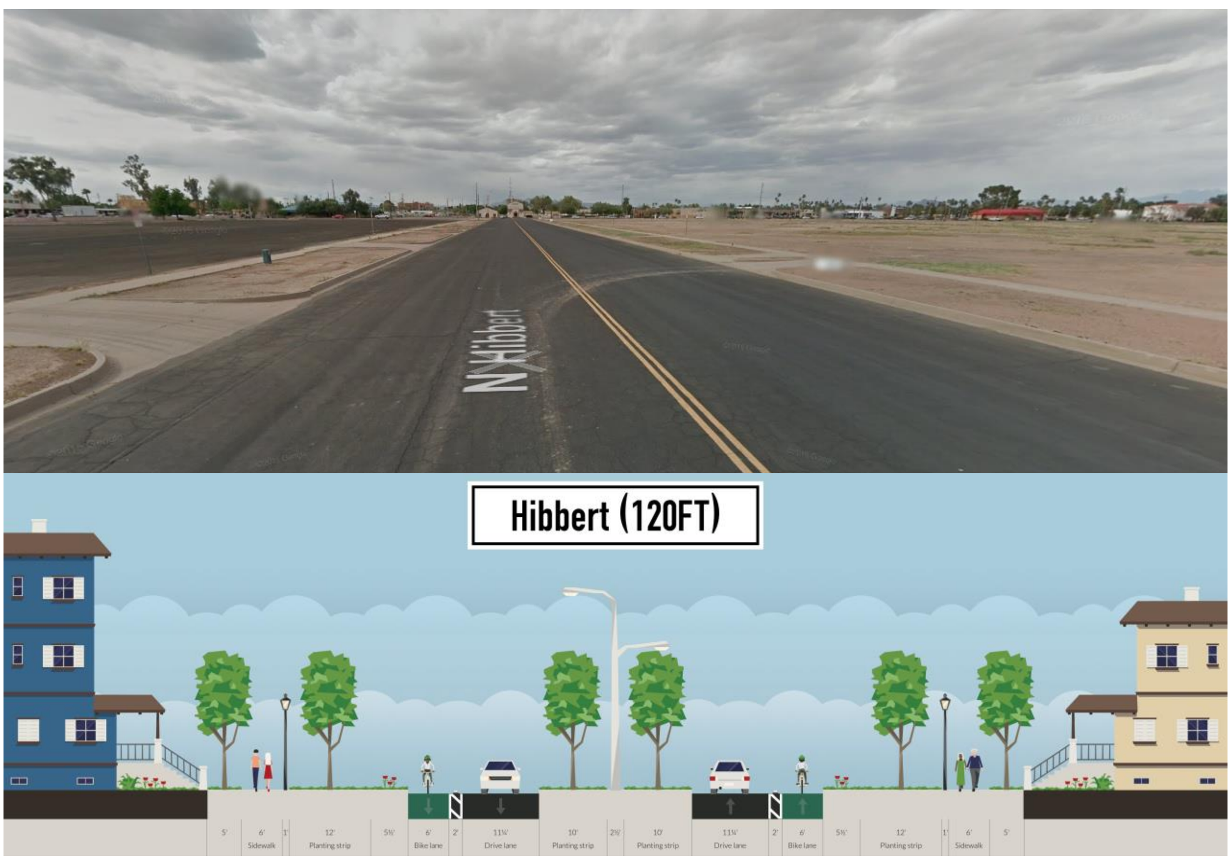


FIGURE 21. HIBBERT, FROM MAIN STREET TO UNIVERSITY DRIVE

existing condition at the site. Figure 21 shows the proposed cross-section for Hibbert below the current existing configuration.

4.1.2 Center Street

The current alignment does not include a bicycle lane and the presence of on-street parking limits the ability of its addition. There is ample parking available in the vicinity and as such the parking lane should be removed. The addition of a center-lane median with xeriscaping is suggested as a means to improve the aesthetic quality of the street and to remove as much asphalt as possible.

4.1.3 Pepper Place

Extending Pepper east from Pomeroy would create an additional point of access to the residential area of the neighborhood and reduce the vehicle demand at Main Street. The shortening of this block would also increase the walkable area, thus further reducing exposure to extreme heat.

4.1.4 Pedestrian upgrades for access to Pioneer Park

Pioneer Park is an attractive facility for the overall utilization of the downtown area. The improvements to pedestrian access described above will offer improved access to the park. The intersection First Street and Mesa Drive is an ideal location for aesthetic upgrades and improved pedestrian access. The street improvements recently completed in the Fiesta District along Southern Avenue is a good reference for stylistic upgrades that could promote the attraction of non-vehicular access to Pioneer Park.

4.2 Increased Mobility for Pedestrians and Bicyclists

4.2.1 Bicycle Striping

In concurrence with these street reconfiguration projects, the targeted streets should receive updated bicycle signing and striping. There is controversy in the bicycle advocacy community and among traffic engineers regarding the proper treatment of on-road demarcation for cyclists. Some municipalities have been experimenting with green-painted bicycle lanes for higher visibility. If the City of Mesa is interested in pursuing these types of demarcation techniques, this area is an ideal place for initial deployment. One additional technique that the project team suggests is the “bicycle box” which features a painted area at signalized intersections that offers higher visibility of cyclists, as shown in Figure 22.

The purpose of this striping configuration is to separate vehicles from bicyclists and pedestrians at signalized intersections. In a case study conducted in Eugene, Oregon vehicle stopping distance increased from four to eight feet from the crosswalk area. The estimated cost for each installation is $1,600 (Loskorn, Mills, Brady, Duthie, & Machemehl, 2013).

Additionally, the City can place pavement marking on unimproved road sections that indicate bicycle and vehicles must share the lane. Placement of these markers will help draw attention to the increased bicycle traffic and promote awareness for road areas that will net yet offer separated bicycle lanes. These markings are commonly known as "sharrows" and an example is shown in Figure 23.

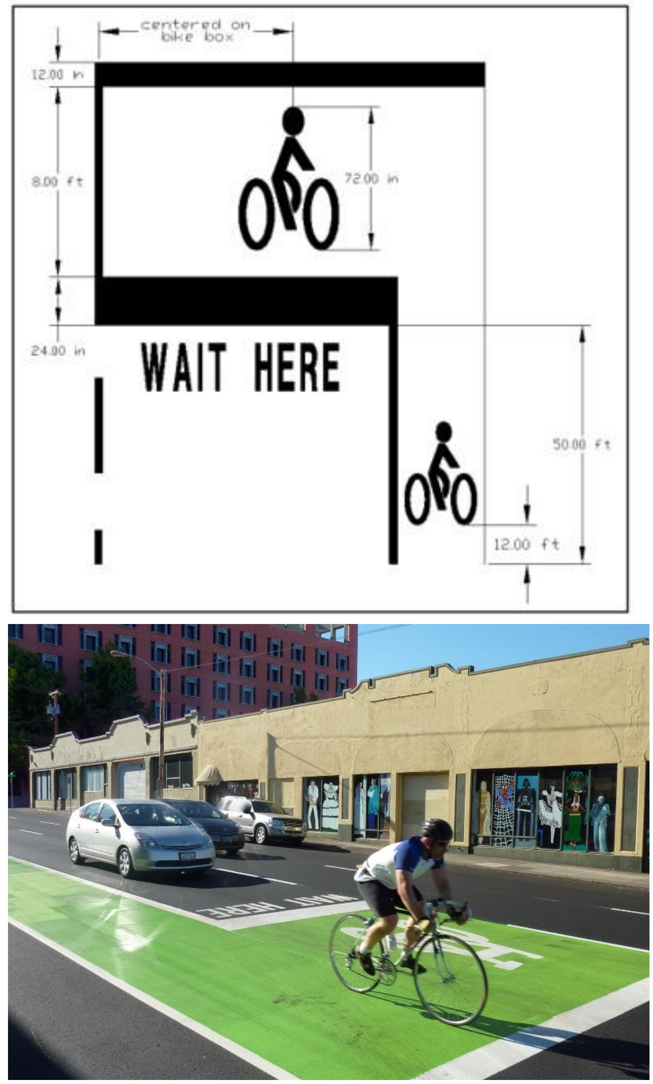


FIGURE 22. BICYCLE BOX, DEMARCATION THAT FEATURES A PAINTED AREA AT SIGNALIZED INTERSECTIONS FOR VISIBILITY OF BICYCLISTS

4.2.2 Rethinking Paved Areas

The preliminary roadway design cross-sections above include visual depictions of sidewalk placement and general characteristics; however, there are significant elements that constitute desirable pedestrian facilities that require more detail. The theory guiding the separation of people from the roadway is based on the perception of safety and comfort (Litman, 2008; Ratner & Goetz, 2013).

FIGURE 23. SHARROWS, INDICATING BICYCLES AND VEHICLES MUST SHARE THE LANE

People are more willing and to use sidewalks that feel safer and provide more aesthetically pleasing surroundings.

The current road configurations in Downtown Mesa are overly devoted to the area used for driving or parking. Narrowing the roadway and expanding the sidewalk widths and space used for planting of trees or placement of art utilize the entire public right-of-way utilized for a more equitable distribution of travel modes. In addition to promoting walking on psychological level, the presence of trees or structural shade in these buffer areas also limit exposure to sunlight and heat. Specific suggestions regarding vegetation for these purposes are revisited later in this report and are presented in much greater detail by the Landscaping and Exterior Environment group.

Research into the role that pavement and vegetation play in the urban heat island effect has expanded rapidly in recent years as recognition of the role that infrastructure plays in sustainable design has increased. The best data will be increasingly available in coming years as municipalities deploy heat mitigation strategies using alternative paving materials and strategically placing structural and vegetative shading. Preliminary results and research indicate favorable results from these efforts.

Ambient air temperatures in Arizona during the summer months can reach as high as 120°F during the day. Surface temperatures of roads and sidewalks exceed 150°F as concrete and asphalt materials absorb higher percentages of the sun's radiant energy. There are three directly applicable strategies that reduce this effect: materials that absorb less of this energy, reducing the surface area of materials that absorb greater energy, and placement of vegetative or structural shading.

The benefits of reducing the area of paved roads are significant but not high enough that projects should be developed that solely aim to remove asphalt. Instead, any future project should attempt to incorporate the philosophy that less asphalt and more unpaved or vegetated areas are preferable.

With the road configurations suggested above, the City of Mesa will reduce paved area in favor of unpaved or vegetated areas by the following amounts 39,600 ft^2 (Main St), 75,500 ft^2 (Hibbert), and 58,000 ft^2 (1st Street). The benefits of these changes are substantial. The surface temperature reductions due to paved surfaces designed for UHI mitigation lower ambient air temperature by roughly 5°F (Santamouris et al., 2012). Adjacent vegetation has an even more dramatic effect; ambient air temperature for pedestrians is reduced by 10°F (Rosheidat, 2014). These effects are separate and can be compounded. These reductions significantly reduce the exposure risk for pedestrians and bicyclists while simultaneously increasing the desirability of multimodal travel.

In order to distill some of the important facts for ground surface characteristics, the relevant UHI considerations are the material's properties for heat capacity and the flux of that energy back into the atmosphere. Xeriscaping and vegetated areas have both higher capacity for heat storage than paved materials, and more importantly, have a much lower rate of heat flux of that energy back into the surrounding environment. Standard concrete and asphalt have a sensible heat flux of between 350 and 500 W/m^2. Reflective and "cool" pavements can lower this range to about 160 to 275 W/m^2. Vegetated and xeriscaped areas measure approximately 90 and 170 W/m^2, respectively (Takebayashi & Moriyama, 2012). Maximizing the replacement of traditional asphalt and concrete with engineered materials and vegetated cover reduce or spread out the heat transferred back to the surrounding atmosphere resulting in lower ambient temperatures.

This heat flux from ground materials to the atmosphere is not the singular measure of the urban heat island effect. The building components of the area also have an impact on the local heat envelope. Increasingly reflected solar radiation from a treated asphalt surface can be absorbed by buildings at a higher rate than prior to the treatment. More comprehensive methods and measurements of the overall urban heat island effect will emerge from the ongoing research into this concept.

4.2.3 Pedestrian Route Assessment and Revitalization

As one of the project team's primary goals is to increase the viability of walking and bicycling throughout the downtown area, it is important that the team ensures safe walking routes and has prepared an assessment of possible walking durations with heat mitigation strategies as needed. The fundamental approach to this assessment is that the assumption that any two locations in the area are a possible walking origin or destination. There is a current mix of land uses and this diversity is expected to grow following the installation of increased transit services.

This pedestrian route assessment is a survey of available walking routes through the boundaries of the study area with an associated estimate of maximum walking travel time. For an individual exposed to the heat island effect, travel time is the essential measure of vulnerability to temperature impacts. The value of assessing walking times is to deploy potential countermeasures such as: improving walking routes, placing safer pedestrian crossings, locating heat refuges or water facilities, and placement of bus stops. This topic will be revisited within the *Protecting Pedestrians and Bicyclists from Heat Exposure* section below.

The configuration of the road network in the downtown area requires that pedestrians travel in one of the cardinal directions. Fortunately, this provides an easy translation to a radial, or "as the crow flies," estimation. The maximum distance that can traverse with cardinal travel occurs when travel directs are equidistant. Applying the Pythagorean theorem with the radial distance as hypotenuse allows the overlay of a circle to the map with a maximum travel distance from each point. Through an iterative process of overlaying these circles across points of interest throughout the neighborhood, connecting points that exceed safe exposure limits can be addressed.

4.3 Enhanced Transit Connectivity

The most obvious example of expanded transit services to Downtown Mesa is the extension of the Valley Metro Light Rail. There is an expected influx of travelers around the neighborhood that will be increasingly reliant on transit. The prime consideration in evaluating and improving the area's overall transit system then is to increase mobility between the new light rail stations throughout the neighborhood business and residential areas. In addition to protecting this increased pedestrian volume from temperature impacts, the overall reliability and convenience of the neighborhood transportation network must be enhanced.

To further this goal, a neighborhood bus circulator route is proposed for the project area. The proposed route would run from the Main Street/Mesa Drive light rail station to the north corner of downtown. It would then proceed to the

Main Street/Center Street light rail station and then to the northwest corner where the library and other attractions are located. This route, as shown in Figure 24, connects the major areas of interest in a time-efficient manner.

FIGURE 24. EXISTING BUS STOPS AND THE PROPOSED ROUTE FOR THE NEIGHBORHOOD CIRCULATOR. IMAGE CREDIT: GOOGLE (MODIFIED BY AUTHORS)

Transit vehicles can serve a secondary role in limiting heat exposure beyond a faster means of transportation. The interiors of these vehicles are air-conditioned. A pedestrian in need of relief from heat might ride the light rail or circulator bus to obtain access to a cooled environment. Such a rider might even wish to return to the same point only to have gained some period of respite.

The specific locations of stops is to both serve this neighborhood route, but also to ensure that there are stops located within the radii described for protection against heat vulnerability. These bus stops all have the potential to serve as some type of protection and respite from the temperatures through the inclusion of shade, and can be expanded to include water or ventilation as appropriate. The Landscaping and Exterior Environments group has proposed specific designs for bus stations that can be upgraded to provide cooling services.

New technologies can also be leveraged to provide greater information to riders regarding the times until the next bus arrives, the current temperature and recommended rest times, and information about obtaining emergency services or more thorough heat relief needs such as an indoor cooling center. Real-time tracking information can be incorporated from the neighborhood route, the light rail, and the adjacent Valley Metro lines to help riders make informed choices about their exposure times and personal safety.

4.3.1 Protecting Pedestrians and Bicyclists from Heat Exposure

As mentioned above, moving people out of cars and onto the street is beneficial in many ways but increases the exposure that individuals will face to extreme heat. In the methodology section, information related to the Occupational Health and Safety Administration (Occupational Safety & Health Administration, 1999) was provided that detailed maximum exposure times to high temperatures. These OSHA guidelines have been developed for working conditions that are likely more strenuous than the activity level of walking in direct sun exposure. The OSHA guidelines advise a maximum working duration of fifteen minutes at 90 degrees Fahrenheit. Summer temperatures in Mesa regularly exceed 100 degrees; this extra stress on pedestrians would likely mean that the OSHA guidelines are appropriate for this application.

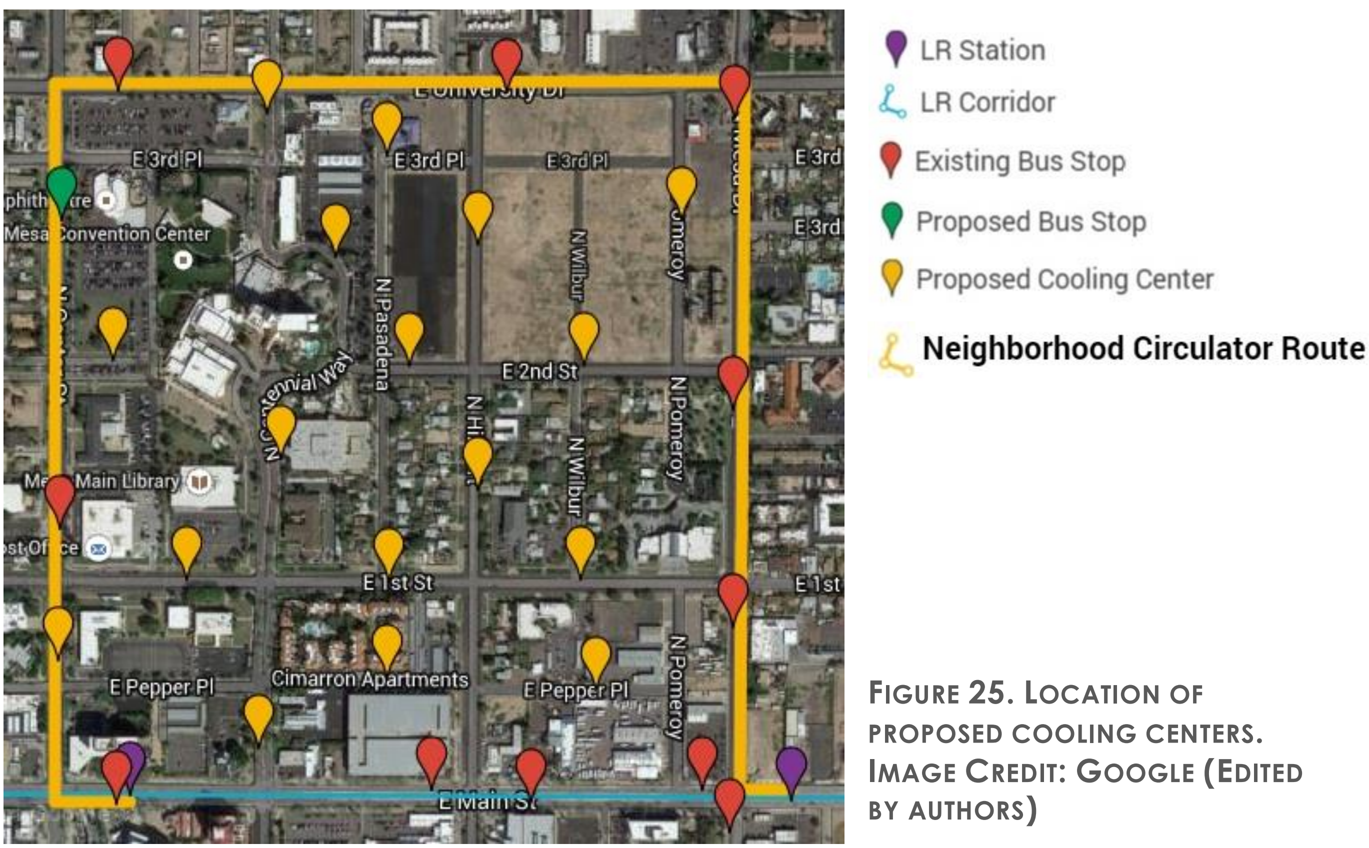


Figure 25. Location of proposed cooling centers. Image Credit: Google (Edited by authors)

The OSHA regulations are intended for workers that are likely more physically adjusted to working in outdoor conditions. The considerations needed for Downtown Mesa include the population-at-large, many of whom are more vulnerable than a typical worker. To be conservative, the project team has selected a five-minute baseline for walking travel. At a typical walking speed of 3.5 feet per second, the corresponding linear distance (cardinal directions) is 1,050 feet. Converting this linear distance to a radial distance as described above, provides a design radius of roughly 750 feet. The resulting placement of cooling centers is presented in Figure 25.

The fundamental approach of the project team then is to ensure that any necessary facilities for cooling, sheltered rest, or water supplies are available to any pedestrian at any point in Downtown Mesa within that distance. This radial distance analysis has been used to place an additional transit stop on Center Street (shown in green in the figure above), which would essentially offer pedestrians a shaded location and an alternate means of transportation. The proposed cooling centers have been placed strategically using the radial distance analysis such that from any given point in the downtown area, there will always be a cooling center available at a 750 feet walking radius.

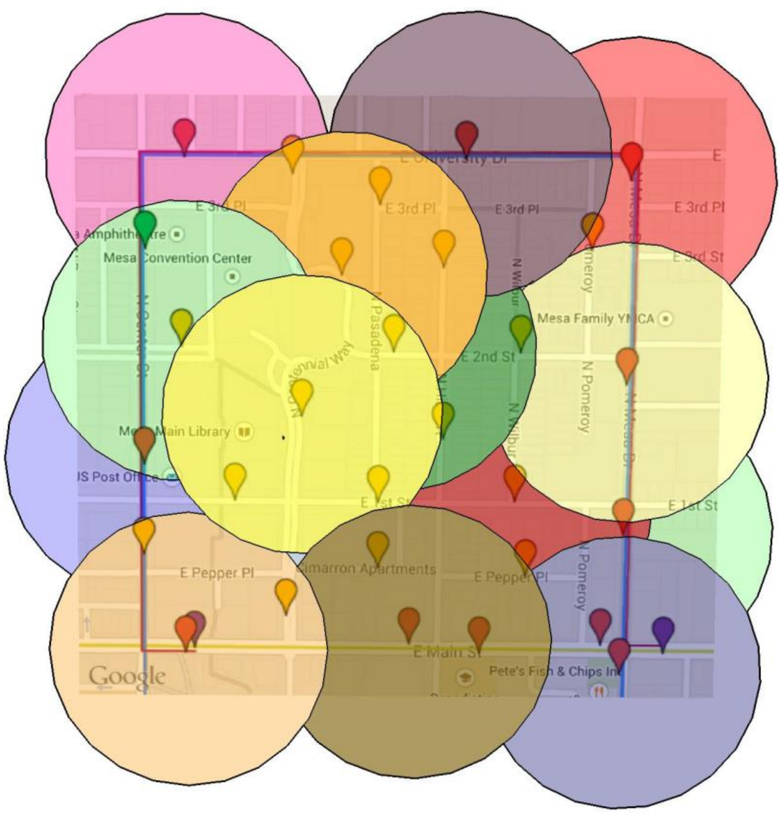


FIGURE 26. DISTANCE BASED APPROACH TO EVALUATE REFUGE LOCATIONS. IMAGE CREDIT: GOOGLE (EDITED BY AUTHORS)

The specific distance of placement for these heat refuges should ultimately be made in consultation with local public health officials. There is no certain measurement that can be provided and there is a natural tension to increase these walking intervals to the maximum allowable time to reduce costs. However, protection of the public is the ultimate priority. It is also important that the refuge locations remain uniformly dispersed throughout the neighborhood in order to promote walking. The reliable spacing of refuges will reduce the anxiety of potential pedestrians and increase the likelihood that walking will be the selected mode.

This distance-based approach is also used by the other teams to evaluate refuge locations and expand their availability as needed. The Social group has also considered existing facilities that are available to provide heat relief such as business, charities, or municipal buildings. The City can revise these locations in conjunction with other initiatives that provide heat-relief services with the potential to scale back certain facilities specified in this analysis.

4.4 Conclusions and Recommendations

The Transportation group has presented a series of design elements and specific suggestions that, taken together, provide significant improvements to the accessibility and mobility of all visitors to Downtown Mesa while detailing measures to mitigate heat accumulation and exposure threats. As a whole, these proposals are unlikely to be practical for immediate installation. The following summary list of initiatives is provided with suggestions on how to prepare each element to incorporate projects that occur further into the future.

4.4.1 Road Reconfigurations

The list of road improvements suggested represent projects that can be individually planned, financed, and issued to the engineering and construction community. These projects will place the physical infrastructure and require careful selection of materials. However, areas to be vegetated can be left as xeriscaping and bus stops/heat refuges can be installed at other times. We recommend that Hibbert be considered as the primary improvement project as the resulting increase in accessibility to the downtown area would be significant in reshaping the overall character of travel in the neighborhood.

4.4.2 Transit

The City of Mesa currently operates only a single, small-scale bus circulator route and it might be impractical to deploy a new route in advance of significant demand. This proposed service likely requires a realized increase in pedestrian traffic to justify the expense. The bus stops can be deployed as heat refuges in advance of the transit operations to serve the present need of providing protection to the community.

4.4.3 Heat Refuges

The City may wish to wait on installation of heat refuges until there is a demonstrable demand for such facilities. The installation of attractions in the public right-of-way is likely to be a controversial choice among area residents. Of all of the suggestions proposed by the Transportation group, these facilities are the most untested and unfamiliar to the public. However, the City must also take caution to ensure that the public is protected from heat exposure. Whether installation occurs immediately, or after some time, the City is encouraged to collect data and actively monitor the rates of pedestrian travel and the corresponding temperature. The revitalization of the Downtown Mesa area depends on active multimodal travel.

Combining these suggestions with ongoing transit development currently in progress creates an important opportunity to expand commerce and vibrancy in Downtown Mesa. It is our hope that the project team has provided a roadmap for the City of Mesa to create future redevelopment projects aimed at increasing multimodal travel and that foster strong urban communities. Downtown Mesa is an ideal location for an initial foray into sustainability-focused development. There are numerous attractions and a transit apparatus that will deliver visitors ready to contribute to the commerce of the area. We fully encourage the City of Mesa to embrace this opportunity to deliver a comprehensive and innovate design concept to its residents.

5 Buildings and Neighborhoods

The scope of work for neighborhoods and buildings has a large range of results. The document has been organized for ease of reading and absorption by sequencing our results from macro to micro, beginning with neighborhoods and ending with buildings. Furthermore moving within each category from the general results and recommendations to specific tactics or strategies we feel can make a significant advancement in the short medium and long terms. Ideally we aim to make it clear for both the public and private sectors to understand their roles and levels of opportunity.

Beginning with neighborhoods, upon first glance we can confirm that the area within the projects context is in need of revitalization. Currently the most significant transformation is occurring within the Main Street corridor as the Light rail is being extended within the center of the right of way. This level of investment has the potential of triggering a variety of possibilities that could provide transformative results in the immediate vicinity as well as in the areas surrounding the Main Street district such as its historic neighborhoods, civic institutions, vacant lands and variety of commercial enterprises.

From the perspective of planning, the area adjacent to light rail or the Transit Orientated Development (TOD) zone is ripe for zoning changes and city backed incentives for alteration of use and redevelopment. For example a large super block south of Main Street, a former commercial center for automobiles is a grand opportunity for a new mixed use building typologies for public transit oriented development. Providing a blend of uses with a super block can significantly enhance the quality, and desirability of an area by providing local shops and venues such as entertainment and employment. It is our recommendation that the city encourage this type of transformation directly adjacent to the light rail. Similarly there are smaller and equally adjacent parcels available to the rail line that speaks to the same kind of mixed-use developments although on smaller scales.

There are many benefits to this kind of development including safety and security, increased access to public and private services. In addition to the transit oriented development areas adjacent to the light rail, within our project boundaries a substantial vacancy of land is available for development using similar strategies. At nearly twenty acres cleared along the south side of university there exist a dramatic opportunity to speak to the automobile as this corridor is much different than main street. High volumes of multi lane traffic dominate university Drive. With these two factors, large vacant lands and a busy thoroughfare of vehicle travel there exists an opportunity to speak to windshield if you will, and develop the site to show how the future of neighborhoods could look like. Developed as medium to high density residential housing perhaps with a mix of commercial/retail the area could become an iconic destination for people to build a life. With element such Walpole pathways well lit by solar powered led streetlights and vegetated corridors, the environment could benefit both people and place.

Whether speaking of the vacant parcels or those that are primed for redevelopment we can implement ideas on climate at many scales and stages of redevelopment. From a class perspective its has been productive to work with other groups focusing on social, environmental, and transportation aspects all of which integrate themselves fundamentally into the urban fabric. Using ideas such as social centers where the public can receive basic services such as food and water are potential ideas for supporting current demographic of the area. Additionally such ideas as water stations at bus and transit facilities could significantly contribute to the health and welfare of the public. With temperatures in our region at significant levels we need to make an effort to provide infrastructure such as shaded areas of refuge and vegetated corridors that make movement through the area joy.

5.1 Mixed Development and Neighborhood Planning

Specifically speaking, we propose strategies such as traffic calming, pedestrian specific corridor moving north-south through the civic area, this area in particular can provide new opportunities for public and private partnerships in

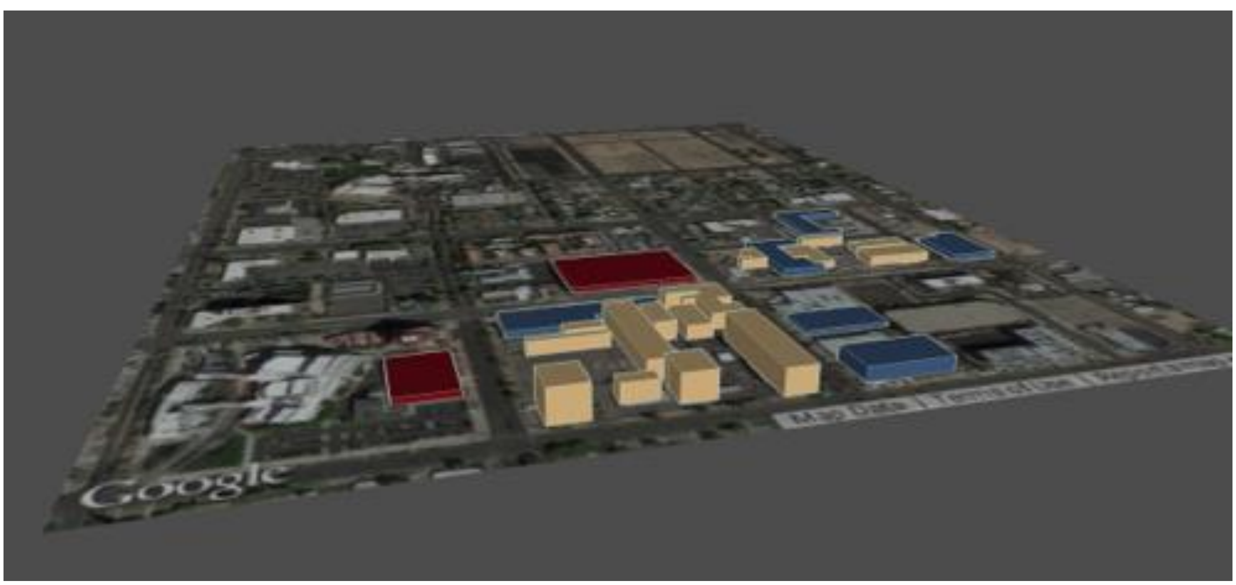


Figure 27: Current land use in project area stretching from Center Street to Mesa Drive and North from 1st Avenue to University.

Red indicates current parking structures recommended to be maintained because of their multi-story architecture.

Blue indicates parking lots, which are envisioned to become future development.

Beige indicates buildings, which are run-down or have limited pupose for the future of Mesa.

the form commercial buildings utilized for uses such as parking, events and small business startups. This area in particular can also function as an area of refugee and provide complementary civic meeting destinations by providing shade through solar canopies reducing heat on a meso scale and providing energy for events reducing the demand on the primary electrical system. We have taken the position as a group that if the city is going to maintain surface level parking to do so by utilizing a solar canopy over the area thereby serving more than one function.

The proposed land use map is shown in Figure 28, which has limited open parking lots and more high-density development. The vacant lots along University Drve were the portions we wanted to focus on for this deliverable. With

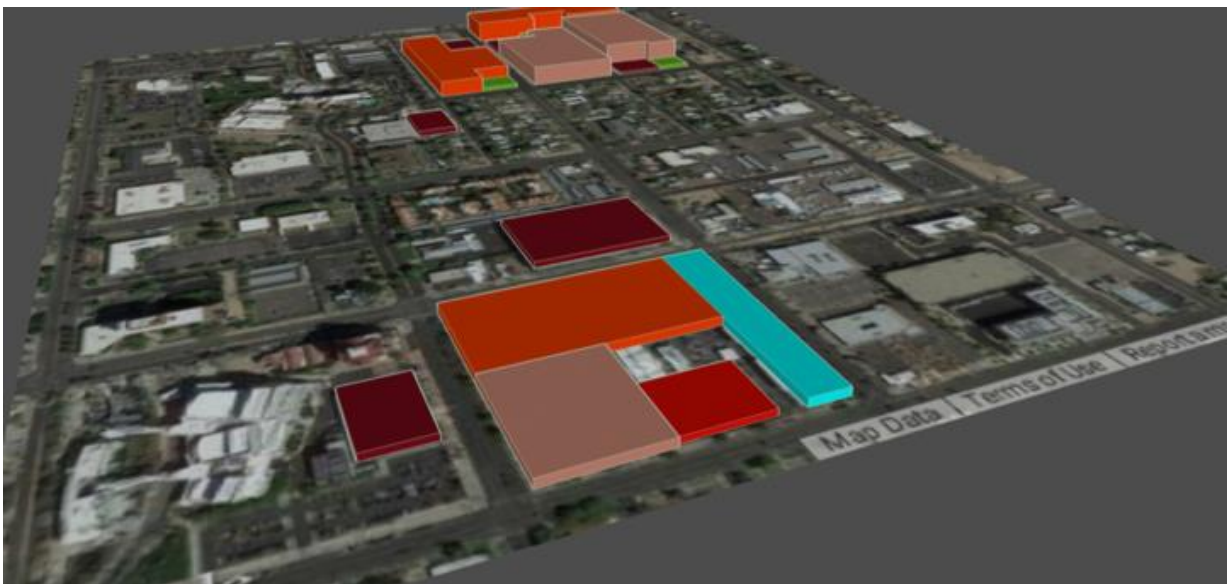


FIGURE 28. PROPOSED SITE ANALYSIS.

RED INDICATES CURRENT PARKING STRUCTURES RECOMMENDED TO BE MAINTAINED BECAUSE OF THEIR MULTI-STORY ARCHITECTURE.

ORANGE REFLECTS HIGH-DENSITY MULTI-STORY APARTMENT COMPLEXES.

PINK REPRESENTS LOWER-DENSITY TOWNHOME STYLE LIVING.

GREEN INDICATES URBAN PARKS AND GREEN SPACE.

LIGHT BLUE INDICATES PROPOSED COMMERCIAL SPACE.

the land shovel ready we envision a mixed housing parcel, from high density to mid density living. As you can see from Figure 28, we've labeled lower density residential in pink, which can be seen in the building design in Figure 29. We envision a community style development connected by green space and public uses. Residents living along Wilbur will use the center lane along Wilbur as a bike only lane, which is only accessible. The parking lots are located at the

FIGURE 29. LOW DENSITY RESIDENTIAL, AS INDICATED BY PINK IN FIGURE 27. THE FIGURE SHOWN IS FROM NORTH HIBBERT TO NORTH POMEROY.

North end of each parcel to reduce traffic flow south on those streets through the neighborhood. The main principle behind the design of these parcels is having your door face the street. We want a community, which thrives and talks to one another and having a walk able/interactive area can bring a sense of place into a community.

In **Error! Reference source not found.** you see a much more dense development. With such a wide demographic around the valley and Mesa being the second largest city in the State of Arizona, we want to cater to low income, high income, students or professionals. By having a range of housing choices you allow for a more diverse mix of people, which can ring more culture into a city. However, above all else we want the housing to be aesthetically attractive to bring people in from other parts of the valley. By having the convention center just east of this development, this provides a great deal of potential for creating an area where people WANT to live.

In investigating specific ways to reduce heat vulnerability in the neighborhood scale we have found a number of technologies and systems such as solar chimneys, energy panels, roofing design among others.

5.2 Materials and Building Systems

Buildings retain heat stored during the day and it takes much more time to cool down as compared to the rural areas resulting in Urban Heat Island Effect. Materials plays significant role in energy transmittance, R-Value can measure the thermal transmittance through these materials. The higher the R-Value of the material the more effective the material is for insulation.

Therefore using the right kind of materials with sustainable R-values help reduces the loss of energy/heat through dissipation and thereby increasing the energy efficiency and reducing the heat vulnerability of the buildings.

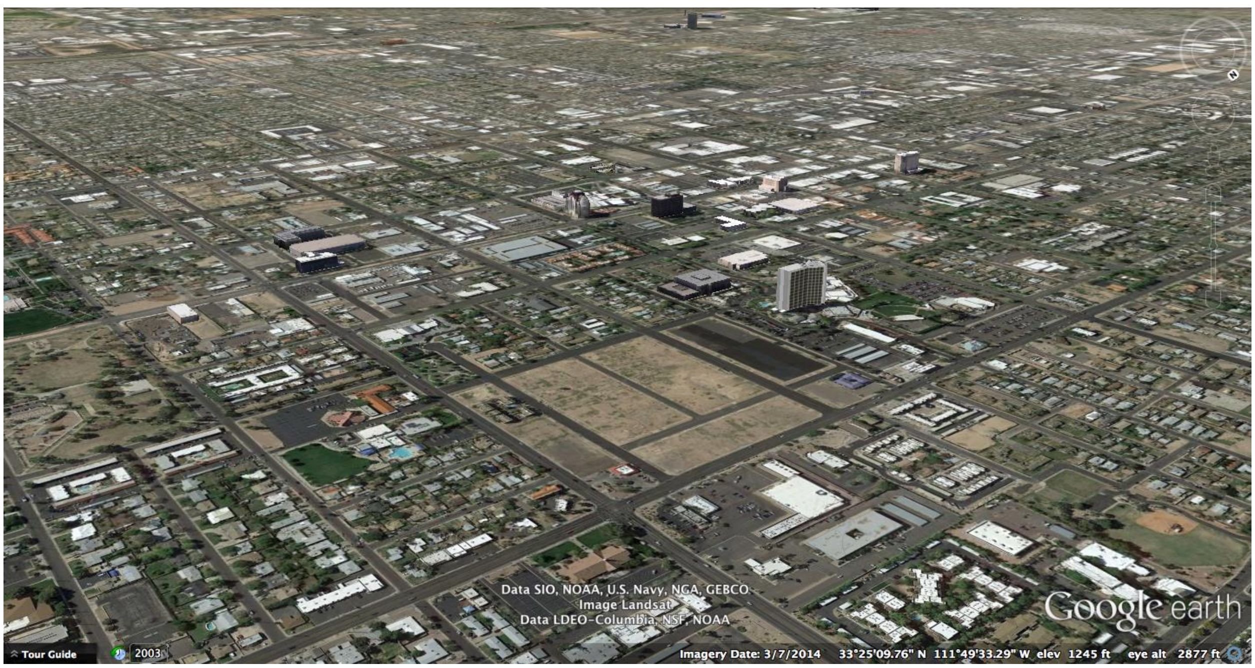


FIGURE 30. PERSPECTIVE EMPHASIZING ADAPTIVE AND NEW DEVELOPMENT ALONG THE LIGHT RAIL CORRIDOR.

5.2.1 Codes

Mesa and Maricopa County are under Climate Zone 2; Table 1 lists the values for Insulation and Fenestration requirements for the components.

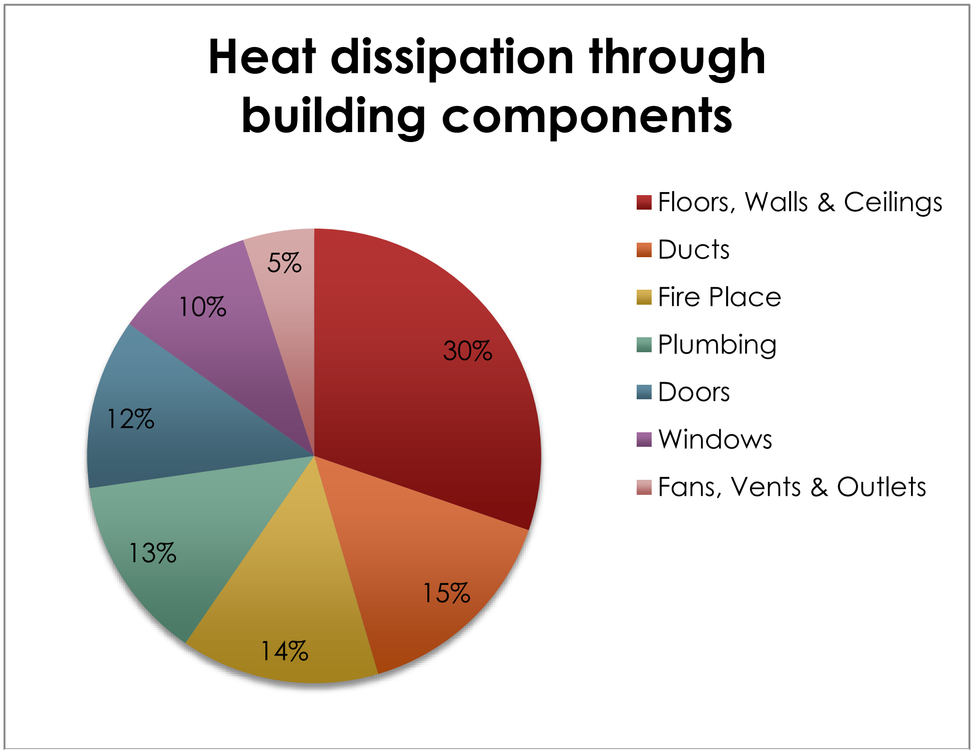


Figure 31. Representation of heat lost through different components of the building. Approximately 40% of heat loss occurs through the envelope. Image Credit: US Home Builders Association and US Department of Energy

The Energy Code of Mesa is based on International Building Code (IBC). The directions for energy efficiency of Building envelope system in IBC needs to be in compliance with International Energy Conservation Code (IECC).

ASHRAE allows the building thermal envelope requirements to exceed IECC requirements by not less than 10 percent. That is U-factor, C-factor, F-factor and SHGC in the specified tables shall be reduced by 10%.

Table 3. Insulation and fenestration requirements by component

Factors	IECC	ASHRAE 189.1
FENESTRATION *U*-FACTOR	0.40	0.40-0.77
SKYLIGHT *U*-FACTOR	0.65	0.65
GLAZED FENESTRATION SHGC	0.25	0.25
CEILING *R*-VALUE	38	38
WOOD FRAME WALL *R*-VALUE	13	13
MASS WALL *R*-VALUE	4/6	7.6ci

FLOOR *R*-VALUE	13	30
BASEMENT WALL *R*-VALUE	0	NR
SLAB *R*-VALUE & DEPTH	0	NR
CRAWL SPACE WALL *R*-VALUE	0	NR

Apart from the requirements shown in Table 3, the City of Mesa energy code specifies that supply ducts may be insulated to a minimum of R-6 when one or more of the following conditions are met:

1. Minimum SEER rating of space heating/cooling system is 14.

2. Maximum U-factor is 0.60 and maximum SHGC is 0.27 for all fenestration products.

3. Wall insulation minimum R-value is R-19.

5.2.2 Proposed Systems

Following are the alternative systems and materials the team is proposing in order to address the heat vulnerability:

SYSTEMS

Cool Roofs

Solar Paneling

Solar Chimneys

Solar light tubes

Static and dynamic facades

Vegetative Facades

MATERIALS

Elastomeric Foam Coating/ Low emitting paint

CMU and Concrete cast in situ

5.2.2.1 Solar Panels

Solar panels installed on the roof, protect it from direct sunlight and also forms the

FIGURE 32. SOLAR PANELS ON A GABLE ROOF

source of power generation. Solar shading is discussed in detail in section 5.3 'Solar Shading and Parking Structure'.

5.2.2.2 Cool Roofs

Cool roofs are roofing materials with high solar reflectance. Painting the surface with high albedo materials or lighter color paint achieves this. This coating also increases the durability of the roof. The cool roofs can be very efficient on large industrial and commercial structures.

FIGURE 33. THE UTAH OLYMPIC OVAL USED COOL ROOF TECHNOLOGY

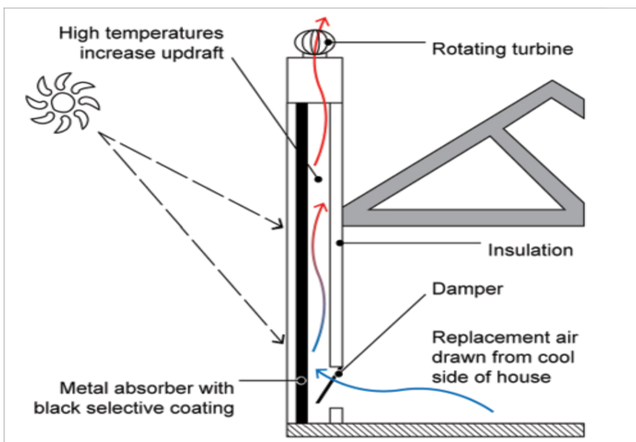


FIGURE 34. SOLAR CHIMNEY OPERATION

5.2.2.3 Solar Chimneys

Solar chimney can be used for improving the natural ventilation. Figure 36 explains the concept of the solar chimneys. It is the method of passive ventilation that can be used in commercial spaces, malls and plazas.

5.2.2.4 Solar Light Tubes

The solar light tubes work similar to the traditional skylights, but these solar tubes have few more advanced features such as infrared and UV filters that allows only visible light to pass through them there by not heating the interiors. Also, they reduce glare and inconsistent light pattern.


FIGURE 35. SOLAR LIGHT TUBE INSTALLED IN THE INTERNATIONAL LAW OFFICE OF MORGAN LEWIS, WASHINGTON, DC

These fixtures can be custom designed to combine with LED lightings to provide illumination during the night.

5.2.2.5 Static & Dynamic Facades

FIGURE 36. EXAMPLE OF MECHANICAL FACADE

The heat transmission here is avoided by the air gap in between the façade and the building envelope.

5.2.2.6 Vegetative Facades

Vegetative facades follow the same principle as mechanical facades. The evapotranspiration of the vegetation accelerates the cooling of the surroundings in this case.

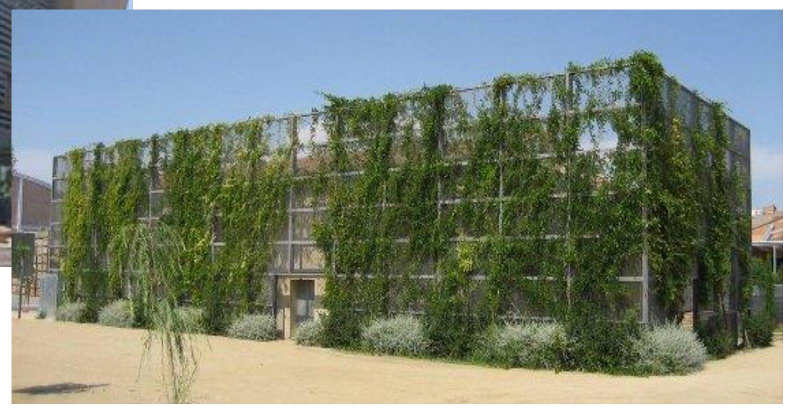


FIGURE 37. EXAMPLE OF VEGETATIVE FACADES

5.2.2.7 Elastomeric Foam Coating

Elastomeric coatings applied to roofs and walls cover the hairline cracks caused by temperature variations. It also provides UV resistance and avoids absorption of water into the building envelope.

5.2.2.8 CMU and Concrete Cast In Situ

Concrete generally has high thermal resistivity as compared to bricks. Special concretes designed using fly ash can increase its resistivity further. Fly ash and slag based cement and concrete are durable and less expensive as compared to the Portland cement.

5.2.2.9 Material Recommendations

When cost is the major driving factor, several research and case studies show that integration is the key to succeed in sustainable construction practices. In integrated design, the sustainable materials, systems and equipment are installed with the conventional electrical, HVAC and other mechanical systems, there by downsizing the primary conventional systems. Also, the efficiency of HVAC systems can also be improved by investing on good building envelope materials. Alternative sustainable materials are durable and are less vulnerable to heat. Most of these materials have lesser pay back period, and hence is economical.

TABLE 4. SUMMARY OF MATERIAL RECOMMENDATIONS

EXISTING/ CONVENTIONAL	UPGRADE/ SUSTAINABLE
Bricks Walls $40/sft	CMU with Brick veneer $23 per sft
Concrete - Based of Portland Cement	Fly ash/Slag based concrete - More Durable and slightly less expensive by 0.5-1$ per ton
Paint	Low-emitting & Recycled paint can cost $3 less/gallon
Wood products	Certified Wood door costs is $150 less expensive
Lighting	Sola-tubes and LED lighting
Windows regular glazing	Optimized wall to window ratio, U-factor 0.31 & Shading Coefficient of 0.39
Glazing $12 per sft	Spandrel glass $18 per sft
Roof-absorptance 0.7	Cool/White Roofs - Absorptance of 0.3
HVAC coupled with min required insulation	Highly efficient Active system Integrated with Passive cooling (Solar chimney, Cooling towers & fans)
Flooring - Regular Carpets	Carpets with recycled contents costs $15 per yard less than traditional carpet
Energy codes – IECC	ASHRAE has higher efficiency (10% higher R-Value)

Figure 38 is an example of case study in which the Energy Efficiency measured in a Building prototype showed energy cost reduction by 37% as compared to the conventional design, materials and systems.

	Base-Case Building Annual Energy Cost	Sustainable Building Annual Energy Cost	Percent Reduction
Lighting	$6,100	$3,190	47.7
Cooling	$1,800	$1,310	27.1
Heating	$1,800	$1,280	28.9
Other	$2,130	$1,700	20.1
Total	$11,800	$7,490	36.7

FIGURE 38. ENERGY EFFICIENCY MEAURES IN CONVENTIONAL AND SUSTAINABLE BUILDING PROTOTYPES. FIGURE SOURCE: UNITED STATES DEPARTMENT OF ENERGY

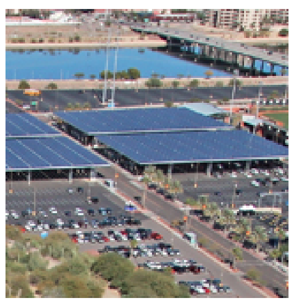
5.3 Solar Shading and Parking Structures

We propose the location (Figure 15), as a convenient location for solar shading on parking structures for Mesa, Arizona. After talking over our given locations with the Mesa coordinator on the Google Map that was shared with the class, we believe that the Mesa Convention Center parking lot(s) are the best chance that we have to achieve the shading structures in order to reduce heat vulnerability. Several factors lead us to this decision. The first one being that the size is comparable to Lot 59, which makes for a tremendous comparison and model. Lot 59 in Tempe serves a power source (solar), shading, security cameras, charging stations for electric cars, and lighting systems at night in 800 parking spaces. All of these ideas should be included for the convention center lot. Also, after several discussions on our proposals for existing

FIGURE 39. PROPOSED LOCATION FOR PARKING STRUCTURE AT MESA CONVENTION CENTER. IMAGE SOURCE: GOOGLE (EDITED BY THE AUTHORS)

parking lots, it was clear that it would be difficult to convince commercial parking lots to go solar and that government owned property would be a more reasonable proposal especially for the foreseeable future. That is why the Mesa Convention Center makes for a great location for this proposal and it happens to be of a similar size to that of lot 59 (lot 59 is roughly 6 acres and Mesa Convention Center is 3.5 acres). It should be noted that after talking to members of the environmental group that focused on tree cover for shading, it was concluded that all parking lot needs to have some sort of shading, whether it be tree or solar shade. However, our group and the environmental group for solar shading agreed upon the location we selected.

When looking at the Mesa Convention Center, the area according to Google Maps Area Calculator Tool is 3.6 acres making it about half the size of Lot 59. Although this may be a scare because it is a smaller parking lot, it actually serves as a reasonable serving size for one of the first parking lots to implement solar panels over the area that was assigned to our class. The total cost to implement Lot 59 was $11,171,132, so if the Mesa Convention Center were to use the same panels and materials, we could estimate that the total cost would roughly be around $5,585,566.



PARKING LOT 59 @ RIO SALADO

(provides 842 shaded surface parking spaces, covering 5.2 acres)

Campus: Tempe
Address: 200 S. Package Drive, Tempe, AZ 85287
Peak DC Output: 2124.00 kWdc
Actual Annual Production FY 2014: 3,540,251 kWh
Average Daily Production FY 2014: 9,699 kWh
Capacity Factor: 23.78%
Commissioned Date: 12/2011
Number of Panels: 7,616
Panel Size: 280 Watts
Panel Model: YGE280
Panel Type: Multicrystalline
Panel Manufacturer: Yingli Green Energy
Number of Inverters: 4
Inverter AC Watt rating: 500
Inverter Model: PowerGate Plus
Inverter Manufacturer: SatCon Technology Corporation
Racking System: Custom steel canopy
System Type: 8-degree Fixed
System Designer/Installer: Strategic Solar Energy, LLC
System Owner: NRG Energy, Inc.
Contract Type: Power Purchase Agreement
REC Incentive: $0.0835/kWh (APS)
Total Project Cost: $11,171,132

FIGURE 40. DETAILS OF LOT 59, TEMPE

Figure 42 lists more information about the project that was constructed on Lot 59. Arizona State University's website states that one megawatt of solar energy can power 250 homes. Although the measuring tool that we used to determine this area said the lot was 6 acres, it covers 5.2 acres of shade. Another projection to estimate the financial side of solar shading is the National Renewable Energy Laboratory website. Once an area is selected from Google Maps, it calculates the amount of solar radiation, AC Energy, and Energy Value per month. Figure 43 shows the calculations that the website made. It estimates that within a year, the energy value in for the convention center parking lot will be $338,942. The rectangular shape representing the parking lot roof coverage also covers the green space in the southwest corner (very few trees in the green space which essentially provide no shade as shown in Figure 32).

RESOURCE DATA SYSTEM INFO **RESULTS**

RESULTS Print Results

3,070,126 kWh per Year *

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Energy Value ($)
January	4.50	190,087	20,986
February	5.54	211,019	23,297
March	6.38	262,004	28,925
April	7.67	299,213	33,033
May	8.04	319,651	35,289
June	7.95	299,550	33,070
July	7.66	299,303	33,043
August	7.42	290,798	32,104
September	7.01	266,685	29,442
October	6.25	252,391	27,864
November	4.98	199,467	22,021
December	4.24	179,959	19,868
Annual	6.47	3,070,127	$ 338,942

FIGURE 41. MESA CONVENTION CENTER PARKING STRUCTURE PREDICTIONS

Another strategy for solar usage particularly for parking lots is to push commercially owned property to communicate with the City of Mesa on how to work together so they can reach an agreement on implementing solar panels on their property. The project manager from Mesa spoke about how these businesses can retain the energy gained from the solar panels and promote themselves as solar users. There would be very little cons to working together because it makes sense for businesses economically (savings from energy), socially (marketing themselves as going green) and environmentally. If the city were to push for this, it could be a tremendous upgrade for everyone involved but it is the city's responsibility to properly outline all of the positive benefits to the local businesses.

6 Institutional and Social Analysis

6.1 Importance of Developing a Plan

The City of Mesa, along with the rest of the Phoenix Metropolitan Area, has continued to progressively develop in a sprawling fashion throughout the twentieth and twenty-first centuries. This type of development has led to the creation of an urban infrastructure network that only serves a minimal amount of services and lacks functionality. The current infrastructure in place provides little to no counter-measurements for an anticipated increase of extreme heat events that put the residents of Mesa and Maricopa County at risk. As the City of Mesa and its surrounding metropolitan region continue to develop to meet the needs of future populations, it is important for decision makers to plan for increases in the frequency and duration of Extreme Heat Events (EHEs) and incorporate infrastructure that has the ability to counter the effects attributed to EHEs.

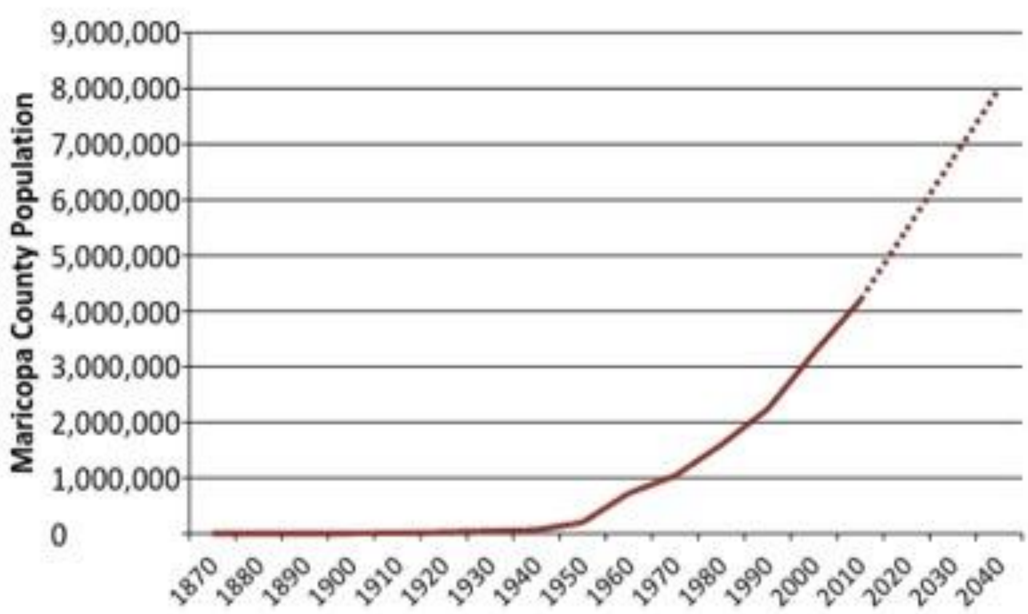


FIGURE 42. POPULATION GROWTH FOR MARICOPA COUNTY, ARIZON (1870-2040). IMAGE CREDIT: CHESTER (2015)

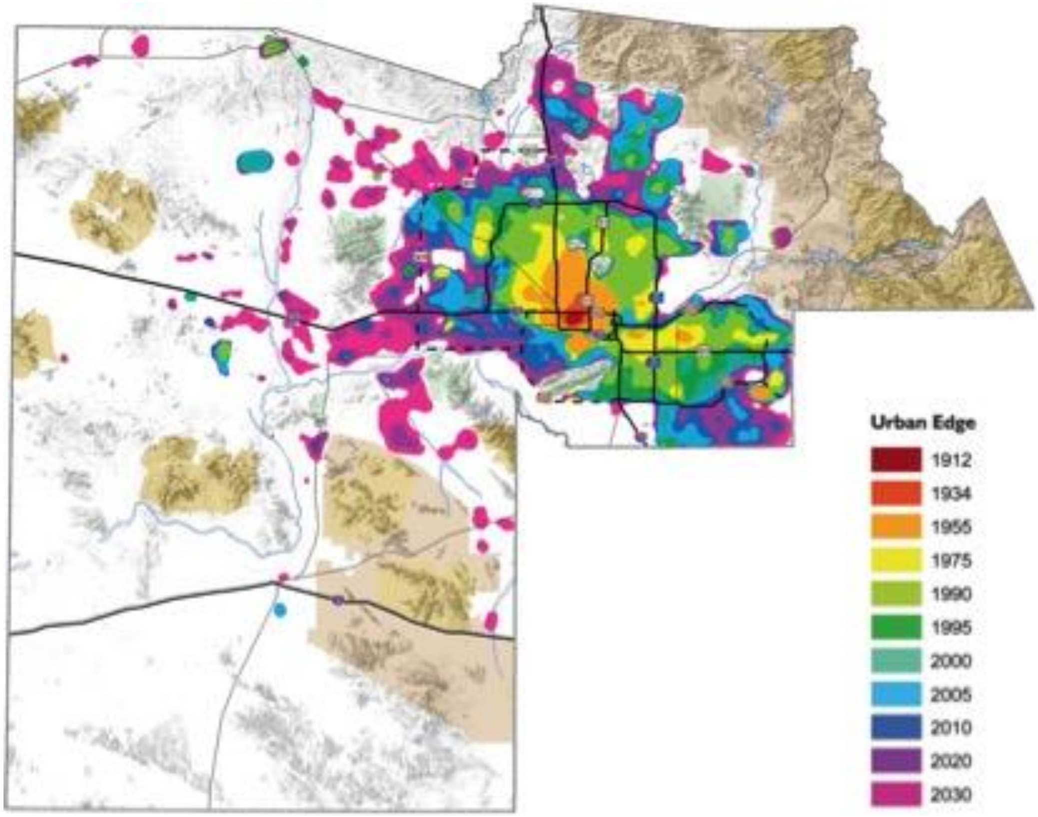
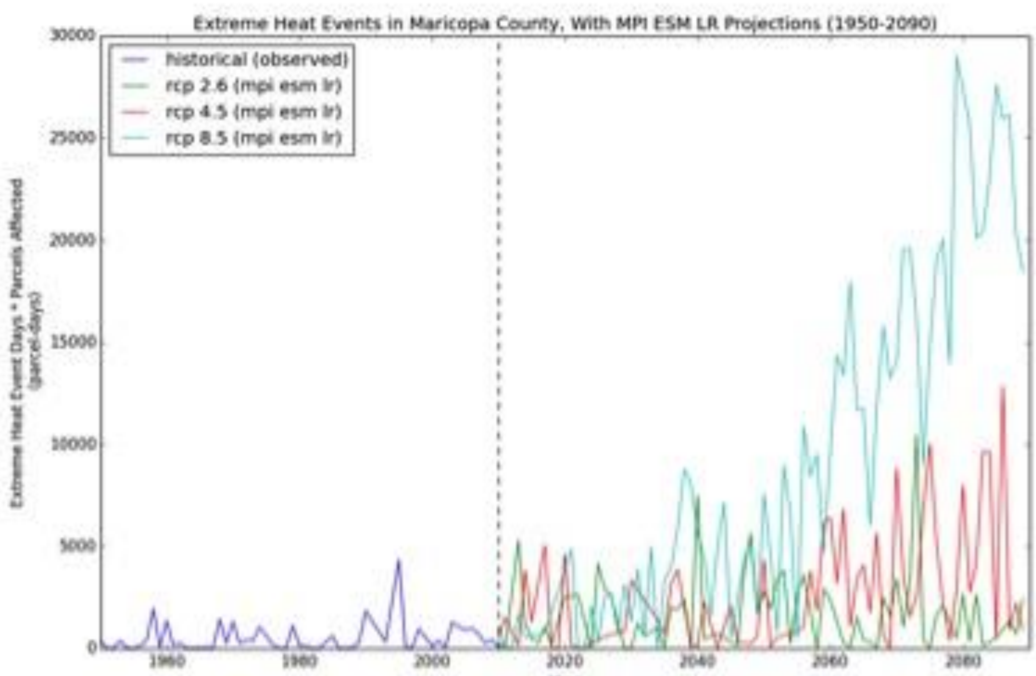


FIGURE 43. GROWTH OF BUILT INFRASTRUCTURE IN MARICOPA COUNTY, ARIZONA (1912-2030). IMAGE CREDIT: CHESTER (2015)



MARICOPA - RCP 2.6: 340—415% increase; RCP 4.5: 380-510% increase; RCP 8.5: 1200-1800% increase.
LOS ANGELES - RCP 2.6: 150—210% increase; RCP 4.5: 230-440% increase; RCP 8.5: 590-840% increase.

FIGURE 44. PROJECTIONS FOR MORE FREQUENT EXTREME HEAT EVENTS IN MARICOPA COUNTY, ARIZONA (1960-2080). IMAGE CREDIT: CHESTER (2015)

The current population estimate of Maricopa County is roughly 4.5 million. However, trends in the region's population project that the population of Maricopa County will continue to increase in an upward trend, reaching nearly 8 million residents by the year 2040 (Figure 61). Along with the increase in urban population growth comes an increase in future infrastructure development (Figure 62). As development in this area increases, so will the EHEs associated with the Urban Heat Island (UHI) effect (Figure 63). Mesa and other cities within Maricopa County have the opportunity to incorporate alternative methods of infrastructure design as the periphery of urban development continues to grow

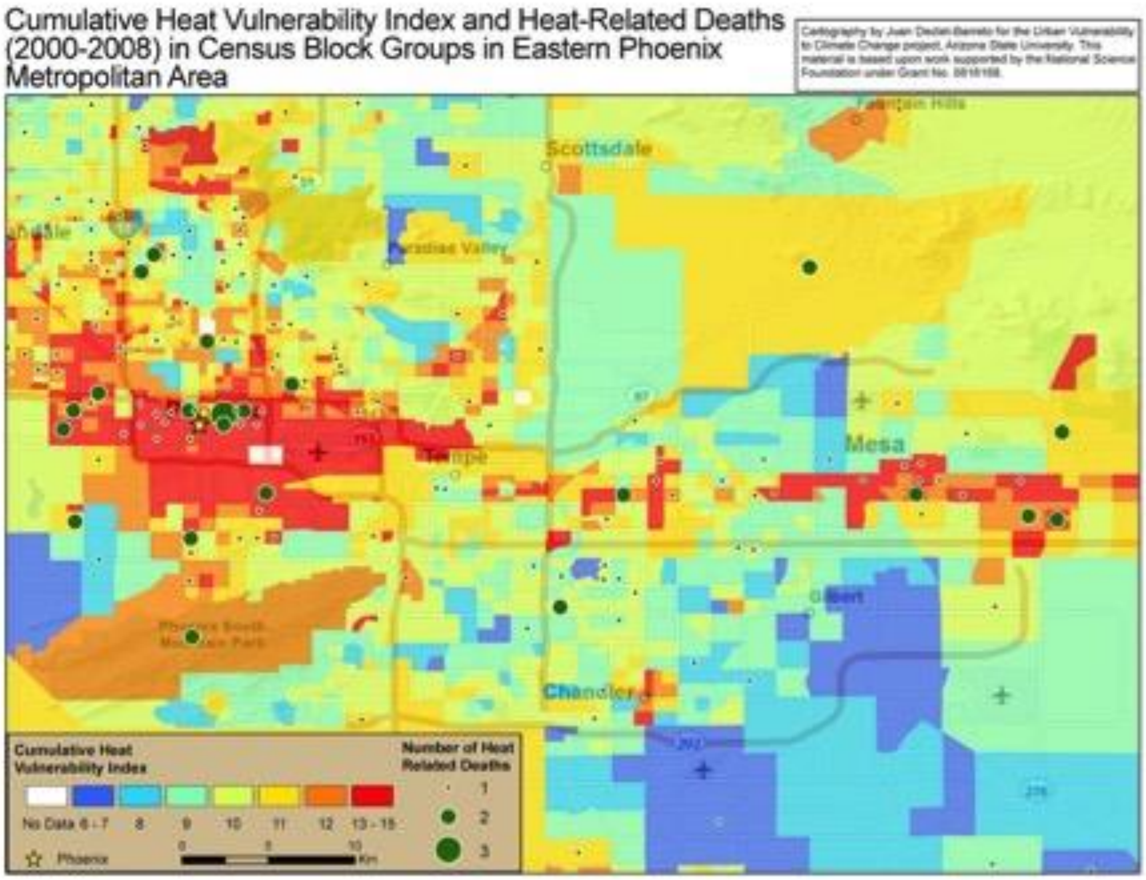


FIGURE 45. HEAT VULNERABILITY INDEX AND NUMBER OF HEAT-RELATED DEATHS BY CENSUS BLOCK GROUPS IN THE EASTERN PHOENIX METROPOLITAN AREA (2000-2008). IMAGE CREDIT: HARLAN ET AL (2006)

in order to accommodate increases in population. This is the ideal time to build new urban infrastructure with alternative materials and methods that not only counter disasters associated with EHEs but could also potentially reduce the factors associated with contributing to the occurrence of EHEs, such as UHI mitigation strategies, reducing GHG emissions, and alternative energy production.

Another important element of EHEs is that these events must be recognized as chronic issues with life threatening consequences and therefore must be planned for accordingly. EHEs are natural disasters that are often responsible for many health related impacts on large portions of the population, especially portions of the population that are considered more vulnerable to heat events than others, as discussed throughout this paper (**Error! Reference source not found.**). When compared to other natural disasters, such as Hurricane Sandy, which occurred in 2012 and resulted in a reported 273 casualties, EHEs are not portrayed in the media as severely life threatening events. But in Maricopa County, EHEs are responsible for nearly 100 deaths per year (Figure 65). This only accounts for the number of deaths (mortality) associated with EHEs in Maricopa County and does not factor in the number of illnesses or hospitalizations (morbidity) that are also a result of exposure to extreme heat. This means that the exposure to heat during these events are more than likely voluntary as

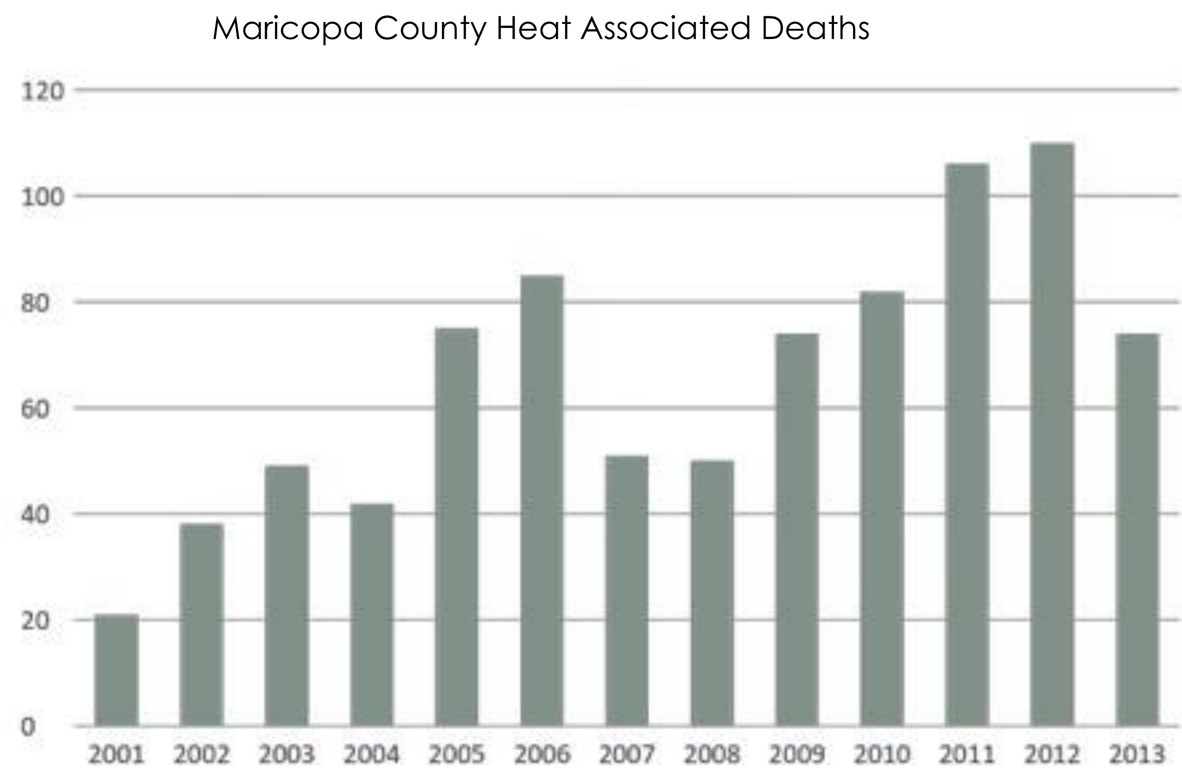


FIGURE 46. ANNUAL NUMBER OF HEAT-RELATED DEATHS IN MARICOPA COUNTY, AZ (2001-2013). IMAGE CREDIT: MARICOPA COUNTY DEPARTMENT OF PUBLIC HEALTH (2013)

people carry on and go about their personal business as usual; walking to transit stations or work, going for a run outside, walking to school or work, etc. A majority of these incidences could be prevented with the proper placement and implementation of both hard and soft infrastructure.

6.2 Defining Social Vulnerability to Heat

High temperatures are associated with higher mortality rates, and increased illnesses such as heat stroke, heat exhaustion, and cardiovascular and respiratory problems, as well as infectious diseases (morbidity). Future projections suggest that the heat differential between urban centers and adjacent areas such as suburban communities will grow wider, known as the Urban Heat Island (UHI) effect. For each 10 degree Fahrenheit increase in mean daily apparent temperature there is an associated 2.6 percent increase in cardiovascular mortality (Basu & Ostro, 2009). The UHI effect will ultimately increase the extreme heat related risks associated with living in urban areas, especially for marginalized populations, those that have been determined to be more vulnerable to extreme heat than others(Harlan, Brazel, Prashad, Stefanov, & Larsen, 2006). The impacts of extreme heat are exacerbated under drought conditions, making populations living in drought prone areas, such as the Phoenix Metropolitan Statistical Area (PMSA), inherently more susceptible to heat vulnerability (Revi et al., 2014). However, studies indicate that residents in regions more prone to extreme heat events, such as Phoenix, AZ, are more likely to ignore heat warnings, feeling that they are not susceptible to heat and heat-related stress (Sheridan, 2007).

Our project area is located along a light rail corridor zoned for transit-oriented development (TOD), and as a result the surrounding area is projected to experience significant growth and development in the near future. As the community of Mesa continues to grow and develop into a larger urban area, UHI effects will continue to grow with it. In the face of continued climate change, urban areas are experiencing increasing hazards and are becoming increasingly vulnerable (Revi et al., 2014). As Mesa plans for further development and growth, it is critical to take into consideration future UHI effects, and other climate change vulnerabilities. Heat vulnerability in the PMSA is increasing, and despite its serious consequences has received very little attention in government policy and planning.

The greatest amount of extreme heat related morbidity and mortality occurs in cities, and specifically in the economically marginalized, minority, immigrant, foreign-born/noncitizens, elderly, and adolescent/infant populations (Basu & Ostro, 2009; Chow, Chuang, & Gober, 2012; Harlan et al., 2006; Ruddell, Harlan, Grossman-Clarke, & Buyantuyev, 2010). The U.S. Environmental Protection Agency (EPA) outlines five demographic factors that affect heat vulnerability: physical constraints, mobility constraints, cognitive impairments, economic constraints, and social isolation (United States Environmental Protection Agency, 2006)

6.2.1 Vulnerable Populations

When comparing demographics to results from heat vulnerability research our team chose to consider the demographic makeup of the entire City of Mesa. Our square mile study area does not conform to a given geographic boundary that is used by the U.S. Census Bureau, making it difficult to estimate the demographics of the study area without including information from outside the boundaries. The study area is also perfect for testing the implementation of extreme heat event physical infrastructure, of which many suggestions are outlined extensively in the Environment, Transportation, and Buildings sections of this report. The following methodology for mitigating social vulnerability will deal with structural changes in how Mesa prepares and responds to extreme heat events. Our recommendations will have an effect upon the entire city, rather than just the study area. For this reason, when comparing relevant literature on what makes people vulnerable to extreme heat events, we chose to look at the demographics of the city as a whole.

Age is a major contributor to heat vulnerability. The very young and the bedridden (elderly and disabled) experience mobility constraints that prevent them from moving to cooler locations (United States Environmental Protection Agency, 2006). In addition, people 75 years and older, or 5 years and younger are less capable of thermoregulation, adjusting to heat extreme because they may not be physiologically capable of perspiring adequately to cool their bodies. 14.4% of the population of Mesa is either under the age of 5 or over the age of 75, which is higher than the national average of 12.5% (United States Census Bureau, 2009-2013c). Other physical constraints that contribute to heat vulnerability include the ability to perspire to circulate blood flow which can be induced by such medical conditions as obesity, heart disease or diabetes, and the use of certain medications for high blood pressure, depression or insomnia. Additionally, mental illness, or the use of drugs and alcohol, decreases an individual's cognitive abilities to recognize the symptoms of excessive heat exposure and therefore increase an individual's vulnerability to heat (United States Environmental Protection Agency, 2006).

Living alone or being socially isolated (not maintaining regular contact with others) also contributes to vulnerability to extreme-heat events, and can confound the vulnerability of those who are already vulnerable due to physical or mobility constraints, or age. 27.2% of the households in Mesa are currently one person households (United States Census Bureau, 2009-2013b). The Sheridan (2007) surveys revealed that only 1% of Phoenix respondents recalled hearing recommendations to check on neighbors and the elderly (Sheridan, 2007). Future heat mitigation plans in the PMSA should place more emphasis on reducing the vulnerabilities of the elderly and the socially isolated. However, social isolation is also likely to be associated with lower income populations who are more likely to live in high crime areas, and less likely to seek out assistance from neighbors or relocate to cooling centers. Individuals in social isolation, such as the homeless or those living alone, are less likely to recognize the symptoms of heat exposure, and are less willing or capable of reaching out to others for help (United States Environmental Protection Agency, 2006). A heat mitigation plan that seeks to reduce heat vulnerability through reduced social isolation should target not only those living alone, but also the homeless and those isolated by crime or fear.

Social isolation can also occur through language or communication barriers. In a survey on the effectiveness of heat warnings and residents perceptions, 92% of residents in Phoenix responded that they were aware of a heat warning through the television media, 22% through radio, 38% through the newspaper, 17% through a friend or relative, and only 8% through other means (Sheridan, 2007). Lack of access to primary forms of heat warning/advisory communication and language barriers may make a population more vulnerable due to lack of awareness of heat warnings and advisories. Educating vulnerable populations through additional forms and outlets of communication, across multiple languages, will reduce the vulnerability of populations with language or other communication barriers.

Ethnicity has been identified as another contributing factor to heat vulnerability. Hispanic and black populations have been identified as being more vulnerable to extreme heat (Basu & Ostro, 2009; Jenerette et al., 2007) found higher vulnerability of black populations to heat in California, but no significant difference in the heat vulnerability of Hispanic populations compared to white populations. The Basu and Ostro (2009) hypothesis is related to the social connectedness of Hispanic families, or comorbidities associated with black populations that exacerbate heat-related morbidities. However, Harlan et al. (2006)identified significant heat vulnerabilities associated with Hispanic populations in Phoenix as a result of lower incomes and increased likelihood of living in dense, homogenous settlements with low vegetation density. African American and Hispanic descent makes up 29.4% of the population of Mesa, slightly above the national percentage of 29.2% (United States Census Bureau, 2009-2013c). Chow et al. (2012) identified foreign-born, noncitizen populations and the population of people living in different residences in the past five years as surrogate measures for identifying populations less likely to seek help in case of medical emergencies due to a lack of social capital- community integration and support. Gender, educational attainment, and exposure to air pollutants have no significant influence on an individual's vulnerability to heat (Basu & Ostro, 2009).

Income is one of the strongest indicators of heat vulnerability. 15.7% of Mesa’s population currently lives under the poverty level (United States Census Bureau, 2009-2013a). Lower income groups are less likely to have access to (working) air conditioning, and are more likely to live in high crime areas. This discourages response to heat stress such as opening doors and windows for circulation, seeking cooling shelters, or seeking the help of neighbors (United States Environmental Protection Agency, 2006). Surface temperature variation is primarily related to variation in vegetation, and median household income is strongly correlated to vegetation density (Jenerette et al., 2007). Vegetation reduces surface temperature through shading and evaporative cooling, therefore lower vegetation densities are associated with increased heat vulnerability (Georgescu, Moustaoui, Mahalov, & Dudhia, 2011; Jenerette et al., 2007). Access to swimming pools and air conditioning also affects vulnerability to heat (Harlan et al., 2008; Jenerette et al., 2007). Ostro, Rauch, Green, Malig, and Basu (2010) found that access to central air conditioning had a more significant impact on reducing heat vulnerability than access to room air conditioning. Higher population densities that are often associated with lower income developments are correlated with increased surface temperature because denser settlements are often associated to more homogenous land use, which reduces surface temperature variability and the development of microclimates (Harlan et al., 2006; Jenerette et al., 2007). Planning for neighborhoods that include a diverse mixture of incomes, ethnicities, and building uses (i.e. different building sizes) may help facilitate the development of more microclimates compared to more homogenous developments. While vegetation density, air conditioning, and swimming pools have all been found to be correlated with income, heat mitigation planning can reduce the impacts of these vulnerabilities by providing community pools, community cooling centers, and increasing shading in public parks. Further, mixed income housing will reduce the "shade of affluence" affect; coined by Harlan et al. (2008) associated with higher incomes and vegetation density.

6.3 City Recommendations

6.3.1 Community Survey

All members of the population are vulnerable to extreme heat exposure and mitigation efforts must be made with this consideration. However, some portions of the population have been determined to be at higher risk levels than others. In order to produce a well-defined heat map that links the demographic makeup of the more vulnerable populations and their geographic locations within the City of Mesa, the development of a descriptive community survey is highly encouraged. A portion of the Heat Vulnerability Mitigation Plan is designed to determine the population's levels of vulnerability and how their surrounding environment may contribute to an increased vulnerability level. The distribution of a survey that captures the desired information can be a valuable asset to the city.

Unlike existing data that is provided by the US Census Bureau, a well-designed, more defined survey has the potential to compile multiple datasets (demographic, geographic, and behavioral characteristics) into one data source. This will assist the City of Mesa with the implementation of their heat responsive efforts as they target areas in need and allocate their resources more effectively and efficiently. Respondents will be asked a series of demographic and behavioral questions to identify various vulnerability factors that have been identified. Respondents will also be asked a series of questions that will assess the effectiveness of the city's community outreach and education strategies. Within this section, the survey will also identify the community's response to resources that are being offered, such as the use and awareness of Cooling Centers and Hydration Stations. In that regard, the survey will help in refining and completing the Heat Vulnerability Mitigation Plan and provide additional information that can be used to develop further investigations as efforts begin to be implemented and studied.

6.3.2 Heat Vulnerability Mitigation Plan

Currently, the City of Mesa has no plan of action for responding to an Extreme Heat Emergency. We propose that increasing temperatures associated with the Urban Heat Island (UHI) effects necessitate the development of such a plan. The purpose of this plan is to limit the public's exposure to extreme heat and reduce the negative public health effects. The primary goal of the Heat Vulnerability Mitigation Plan should be the implementation of cool technologies to reduce Urban Heat Island (UHI) effects being experienced by cities across the globe. These strategies are outlined in the infrastructure components of the Environment, Buildings, and Transportation teams.

The Heat Vulnerability Mitigation Plan will outline the emergency situations and events that require action, and describe the coordination efforts needed between the Arizona Department of Health Services, Maricopa County, and the City of Mesa to provide assistance to those most at risk of heat related health issues. The plan will also provide information on ways to reduce exposure to heat, what emergency resources are available, and how to recommend action based on various heat related effects. Some of the ailments that will be addressed include dizziness, headache, fainting, dehydration, heat exhaustion, and heat stroke. The plan will also outline the locations of refuges such as Cool Shelters and Hydration Stations.

If someone does find himself or herself within the project area during a heat event, there are several resources that they can take advantage of. There are areas of refuge within the site as well as locations just outside of the boundaries. Within the site, potential areas of refuge include the Mesa Main Library, a Marriott Hotel, and the Mesa Amphitheatre. Just outside of the site is a YMCA, the Mesa Arts Center, and the Museum of Natural History; all which could be good locations to offer air conditioned refuge from the outside temperatures. There are also nearby parks which will be listed as a resource, the vegetation and shading can offer slightly cooler temperatures if travelling to an air conditioned refuge area is not possible.

Other cities have incorporated an action to extend the hours of air-conditioned community buildings during extreme heat events to provide areas of refuge to populations without access to air conditioning. Community buildings within and surrounding the study area that could be considered for extended operating hours during extreme heat events are the Mesa Main Library, the Mesa Convention Center, and the Mesa Amphitheatre. The Mesa Arts Center and the Museum of Natural History both require admission for entry, but during an Extreme Heat Emergency these areas should be considered as potential areas of cool refuge. Nearby parks, such as Escobedo Park, Fitch Park, and Pioneer Park can offer slightly cooler temperatures from vegetation, evaporative cooling, and shading if travelling to an air-conditioned refuge area is not possible. However, the success of these parks in acting as cool areas of refuge relies on the integration of appropriate vegetation and landscaping to ensure maximum shading efficiency. Many cities are incorporating vegetation shading and tree canopy cover programs into their urban heat island mitigation plans.

However, even with the implementation of cool technologies, extreme heat events will still occur, and so a supplementary goal of the Heat Vulnerability Mitigation Plan should be the development of an Extreme Heat Emergency Action Plan for when an extreme heat event warning or advisory exceeds expectations. We have identified several potential areas of refuge within the one-square mile study site as well as locations just outside of the study area boundaries that individuals visiting Mesa can take advantage of if they find themselves vulnerable to the health effects of heat.

The City of Mesa has a yearly water bottle drive to provide emergency water to those who have high amounts of heat exposure during the summer. This water, along with the water from a continuous water bottle donation station at the

Mesa Main Public Library, will be distributed among the areas of refuge within the site and also several of the outside boundary locations. Information regarding these locations will be posted on bus stops and light rail stations and will include visuals that can communicate with those who understand more clearly using figures. The information will also be posted in Spanish.

Extreme heat events can also lead to blackouts and brownouts, leaving residents and businesses without access to water and air conditioning. In July 2011, a large transformer fire at an SRP substation located University and Sossaman led to electric outages in the East Valley. The outage prevented people from running water and air conditioning, which led to overcrowding at nearby grocery stores and required police action for crowd-control. Since the occurrence of this event many lessons have been learned, but the issues experienced during the power outage could be compounded by heat during an extreme heat. The Extreme Heat Emergency Action Plan should take the heat related morbidity and mortality associated with extreme heat events seriously and includes extra staffing of emergency service personnel.

During an extreme heat event it will be necessary to evacuate those with physical limitations, such as the elderly, children, and the mentally and physically disabled to cool areas of refuge. When the Extreme Heat Emergency Action Plan warning is issued, a system should be put in place to provide these highly vulnerable populations with a means to access public air-conditioned cooling refuges. Transportation to cooling centers can be facilitated through the use of transit tokens, which would be distributed on a case by case basis to those that are assessed as being in need of a cooling refuge and are unable to get their of their own means. In addition, a voluntary registry of those in need of transport to areas of refuge (highly vulnerable populations) should be established and maintained by city officials so that free public transportation can be provided to assist in relocating registrants to areas of refuge.

Finally, the Heat Vulnerability Mitigation Plan should focus on education and communication.

In its communication role the committee will ensure that heat mitigation infrastructure (hydration stations, air condition refuges, etc.) are labeled and known to the public. The committee would be also overseeing the critical communication information messaging services mentioned in the communication section. Finally the committee will examine efforts to communicate with the homeless and vulnerable public to ensure they are aware of what the city provides. For example, in our meeting with Jeff Mcvay from the City of Mesa we became aware of the City's current program to collect donated water bottles for the homeless and unsheltered, but we noticed the distribution system was not clearly articulated. The committee should identify these gaps and address them through policy and action.

The Heat Vulnerability Mitigation Plan will allow the residents of the City of Mesa to better prepare for extreme heat and take action in emergency health situations. The proposed Measures of Effectiveness will allow the Heat Advisory Committee to evaluate the overall success of the Heat Vulnerability Mitigation Plan implementation. The primary focus of the Heat Vulnerability Mitigation Plan is to shift current perceptions and responses to extreme heat. Currently, the City of Mesa responds to the disasters created by extreme heat; the Heat Vulnerability Mitigation Plan recognizes that Extreme Heat Events should be treated as hazards, and should be given more attention so as to prevent the many disasters they cause.

6.3.3 Education

The development will begin with an advanced warning system that responds to the projected forecasts of extreme heat events, rather than one that responds to events caused by extreme heat. It is important to identify the extreme heat as the event to plan and prepare for since it is often considered a "silent killer" and may not be as threatening (Georgescu et al., 2011). We propose to launch a survey that will assess the population's perception of the risks associated to extreme heat exposure, as well as their awareness of local resources and programs that provide aid and assistance during these events. This survey will be developed in two forms, 1) a public survey for locals residing within the region, and 2) a commercial survey for businesses within the region. A survey would give us the opportunity to obtain more up-to-date information of the vulnerable groups within the region. This will help give us a better understanding of the social aspects that do increase risks and therefore we can plan for specific strategies that target these identified groups.

After our team has identified the vulnerable groups within our site, we can begin to target specific groups for intervention. Specifically designed educational programs will help the diverse groups of people within the region react to the warning and respond adequately, reducing each individual's risk level. Currently, as Sheridan (2007) has stated, the provided resources our severely underutilized in Maricopa County. For example, a recent survey from 2007 found that only small percentages of the population recalled being informed of the recommendations for actions to take in order to avoid being at risk. This vulnerable population remains at risk and needs to have a more aggressive action plan (Sheridan, 2007)

Even though the City of Mesa has developed a strategy to combat heat morbidity by providing hydration stations, cooling centers, alert systems, etc., many of the residents polled declared that they were unaware of the resources being provided through campaign efforts using T.V., radio, newspapers, internet or email but through social connections instead (Hondula, 2015). As stated before, one of the main groups of at risk individuals are those of lower income and of certain age groups. This could result in these groups not having the ability or means to access educational campaigns on resources or media platforms that are distributed on the Internet through websites and online documents, television or radio or smart phones capable of receiving alerts. In an effort to reach out to the more vulnerable groups, a better educational campaign must be implemented that specifically targets the vulnerable groups. Another issue with the effectiveness of educational information is the form in which it is distributed. Material written in documents assumes that the vulnerable targets are literate and can read the information in the languages provided.

Education in an important element in the effort to combat heat related illnesses and casualties. Educational programs for reducing the impacts of extreme heat must consider each of the following:

- Mesa has a wide demographic and a diversity of "at risk" groups
- Information must be distributed in multiple forms
- Diversity of languages including braille
- In audible recording; hotlines
- By using visual imagery
- Information must be displayed within multiple social settings

- At home residences
- Along transit routes (bus stops, light rail stations)
- In public spaces (parks, civic services, schools)
- Key information/tips should be regularly shared
- Avoid outdoor activity
- Stay hydrated and drink plenty of water
- Stay in contact with neighbors/family/friends
- Check on elderly/young
- Share trips with friends/neighbors

With effective distribution of even the most basic information, we may begin to see a decline in the negative effects of extreme heat within an urban area.

6.3.4 Communication

There is a range of demographics present within the project location. The goal is to find a way to communicate any important or emergency information to each individual, regardless of his or her background. The main factors that influence the effectiveness of communication are differences in language, age, income level, and disabilities. The person who is most likely to receive emergency messages through traditional means are those who speak English fluently, have the financial means to afford communication devices, are comfortable with technology, and are able-bodied. The communication plan will focus on the following demographics: non-English speakers, those with low access to communication devices (low income/not familiar with the technology), the elderly, and those with disabilities.

The first method of critical information communication is through broadcast media, which can be delivered as part of the regular news or weather information. With cooperative efforts of local news stations, the messages can be communicated through television, radio, and mobile news applications. This method has the potential to reach the most of the general population in the area.

The next method of communication is through a voluntary emergency message system, similar to those used in other cities and college campuses. This tool would allow anyone living or working in Mesa to sign up for a free notification system that would alert them by text message or email during the event of an emergency. A language preference can be indicated during the initial sign up. This method is also available in the form of telephone calls, which may reach a greater target. Residents are encouraged to help their older relatives sign up for the emergency message system.

There is great importance to build a higher sense of community to protect each other from extreme heat events. During heat waves in the summer, call your relatives, friends, and neighbors to check-in and lend assistance to those who rely on the outdoors for their daily travel.

6.3.5 Measures of Effectiveness

When planning the implementation of community outreach and system improvement plans, it is important to benchmark current conditions as a reference for the future. Developing quantifiable goals, which can be measured across a period of time, can provide indications of implementation successes or failures. The Heat Vulnerability Mitigation Plan involves many strategies for reducing heat exposure, access to resources, and policy improvements. Creating a measurement tool can give the Heat Advisory Committee and the City insight into which efforts were successful and which efforts were unsuccessful. Utilizing Measures of Effectiveness allows for better prioritization of resources and funding, creating the most significant impact. After one year of the Heat Vulnerability Mitigation Plan, conditions can be evaluated to see how the City's social heat vulnerability improved over the first year. During this analysis, it can be decided if certain efforts should be continued and how to improve other areas of the system. The Measures of Effectiveness is an approach to maintaining a long-term, functional strategy plan that will continue to benefit the City.

The Measurements of Effectiveness will determine metrics for evaluating the heat vulnerability mitigation efforts, and which levels the City will consider to be acceptable and failing. These metrics should be based on per capita proportions and should take into consideration the rate of population growth, community development, and the increased frequency of extreme heat events.

6.3.6 Heat Advisory Committee

In conjunction with a Heat Vulnerability Mitigation Plan, we propose that a Heat Advisory Committee become established to implement, monitor, execute, and update the Heat Vulnerability Mitigation Plan. The committee will function in an advisory, educational, and communicative role. Staffed with a conglomeration of City of Mesa emergency response upper management, city stakeholders, and concerned volunteer citizens, the committee would play an advisory and oversight role.

When extreme heat events happen in the future the committee would ensure that appropriate actions are followed as dictated by the Extreme Heat Emergency Action Plan. After the event the committee would use the Measures of Effectiveness to assess whether the response to the event had been successful and if the response had not been successful and suggest what changes needed to be made to remedy this. The committee will also look at the long-range feasibility of the Extreme Heat Emergency Action Plan given current and projected conditions; are the provisions enough for the projected future growth of population and extreme heat events.

In its communication role the committee will ensure that heat mitigation infrastructure (hydration stations, cooling centers, air conditioned refuges, etc.) are labeled and identifiable to the public. The committee would also oversee the critical communication information messaging services. Finally, the committee will evaluate the executed methods of communication used with the intent to inform and educate various groups of the vulnerable populations to ensure they are aware of the services and amenities that the city provides during extreme heat advisories. For example, during our meetings with representatives of the City of Mesa we became aware of the city's current program to collect donated water bottles for the homeless and unsheltered, but we noticed the distribution system was not clearly articulated. Because of the committee's focus we believe it would be more responsive to weak points in the City's heat mitigation programs.

The overall idea behind the committee is to create a change in how the city perceives and responds to extreme heat events. Currently the City of Mesa responds to the disasters created by extreme heat. The objective is to change the city's perception and respond to the extreme heat event as the disaster.

6.3.7 Inconsistencies or problems in current resources

Many cities, especially cities in the southwest, have been developing programs and strategies in an attempt to mitigate the effects of extreme heat. In Mesa, Arizona, the city has developed a water donation campaign, known as the Mesa Hydration Donation Campaign (part of a county-wide campaign), which provides water to the population in need during the summer months where temperatures regularly reach 100 degrees and above. In 2012, the county-wide campaign collected over 320,000 bottles of water that were donated (it is unknown how many bottles of water were designated for distribution to Mesa residents) at various local businesses and establishments that offered some form of compensation to donors for their generosity. Mesa residents often donate cases of bottled water at a specific list of local establishments in agreement with an incentivized program, e.g., Rhodes Aquatic Complex, Golfland SunSplash, Fiesta Mall and various community centers. The water bottles are then collected by the United Food Bank and then distributed in some fashion to participating agencies across the region on a priority basis based on demand. According to recent studies and public surveys conducted by Hondula (2015) this system has yet to be proven successful in preventing heat-related deaths and illnesses and is questionably efficient in regards to the collection and distribution processes, as stated by City of Mesa representative Jeff McVay during an in-class discussion. Therefore, we would like to propose a solution to this issue.

It is without a doubt that people need quick and easy access to clean, drinkable water year-round and especially during the summer months within the region of the Valley of the Sun and the City of Mesa. One way to make this available to the public is to strategically place electronic water bottle filling stations (commonly known as "hydration stations") throughout the city and specifically within the areas with higher proportions of people at risk. This strategy has the potential to be more effective and efficient in multiple ways such as:

- Reduce the need to organize and campaign for a donation drive
- Reduce the need for collection and distribution strategies and efforts
- Replace old water fountains which have been stigmatized as unclean sources of water
- They will be more accessible, not restricted by hours of operations
- They will help reduce the amount of plastic water bottles that end up being recycled or sent to a landfill

While it may seem that the local businesses and organizations will miss out on the opportunity to participate in the hydration program there is still room for them.

The City of Mesa could develop a sponsorship program for these water bottle filling stations and for the reusable water bottles themselves. Businesses like Golfland SunSplash, Fiesta Mall and others could cover the costs of the water bottles as a tradeoff to have their endorsements labeled on them. This still gets their names and brands out to the public and it still represents them in a positive way, showing that they made contributions to improve the living conditions for residents of Mesa. Citizens, businesses and organizations of Mesa could then purchase and distribute them to customers or those in need and use the water bottles towards the incentive programs at the participating establishments.

6.3.8 Measures of Effectiveness

The primary goal of developing Measures of Effectiveness is to evaluate the success of implementing the Heat Vulnerability Mitigation Plan. Current heat vulnerability conditions can be compared to future heat vulnerability conditions, and areas of strengths and weaknesses can be identified. It can be used as a prioritization tool for limited funding, and give insight into areas of the plan that need to be modified. The measures should be quantitative for clear and consistent benchmarking. Proposed measures of success include: the number of heat-related hospitalizations (morbidity), the number of heat related deaths (mortality), heat-related emergency costs, the number of persons accessing cooling centers and hydration stations, and the ratio of square foot area of air conditioning available per person. It is proposed that the Measures of Effectiveness process be a focus of the Heat Advisory Committee and overseen by the City of Mesa.

6.4 Case Studies

6.4.1 General Heat Mitigation Plans

A number of municipalities have developed general heat mitigation plans that support a wide range of heat vulnerability mitigating strategies, including increased vegetation and green space, green roofs, cool roofs, cool pavements, shade cover, and stormwater management. We offer a review of these plans and strategies as examples that the City of Mesa can use when developing their own Heat Mitigation Plan.

Philadelphia was the first city in the United States to work closely with the National Weather Service (NWS) to implement a Heat Health Watch Warning System (HHWWS) (United States Environmental Protection Agency). When a heat warning is issued in concurrence with the NWS, a number of preemptive actions are initiated to reduce the social impacts of extreme heat events. Under the HHWWS, a NWS issued heat warning triggers media announcements, the activation of a "heatline", the halt of utility service suspensions, extended hours of operation at air-conditioned community centers, increased emergency medical service staffing, home visits from the Department of Public Health to elder and other persons requiring more attention, daytime outreach to the homeless, and activation of the "buddy system" - where neighbors, friends, neighborhood watch, and "block captains" are encouraged and reminded to check on residents in their area. Both Philadelphia and Toronto have designated public buildings, and some specific private buildings with air conditioning to be used as public cooling shelters and provide transportation to those shelters.

The City of Chicago launched the Chicago Climate Action plan in September 2008. The efforts made by the City were to decrease future impacts of climate change. The action plan developed strategies for preparing for and mitigating extreme heat. The strategies include managing stormwater, incorporating vegetation and green space, green roofs, and shade cover. In the first two years of the program, the City had 1.8 million square feet of additional green roofs installed or under construction (Chicago Climate Task Force, 2008). The plan resulted in the implementation of 265 storm water management projects that increased permeable surface area by 55 acres. A progress update was issued in 2010 to report the current state of the initiative and included measures of effectiveness such as reductions in energy use, cleaner energy, water conservation, improved air quality, and increase in vegetation and shade coverage. The success of the Chicago Climate Action Plan relied on the implementation of a multi-stakeholder task force that outlined the goals of the plan.

The City of Houston's "Cool Houston!" heat mitigation plan outlines strategies for reducing the effects of the Urban Heat Island in the Houston metro area. The initiative, which began in 2004, set several goals including increasing cool pavements, cool roofs, vegetation, air quality, and stormwater management. To achieve a reduction in heating due to pavements, the use of reflective materials is implemented. Reflective materials were proven to reduce solar energy absorption, decrease surface heat, improved nighttime illumination, and improve water management through porous pavements. The cool roofing portion of the plan covers reflective roofing and green roofs, and is associated with benefits such as cooler temperatures around the building, reduced water runoff, improved heating and cooling efficiency, and overall energy savings. Increased natural shade cover and the use of vegetation was another primary focus due to the general cooling potential. The Houston heat mitigation plan was developed as an outline for all heat mitigation goals, and serves as a guide for other cities attempting to implement similar strategies ("Cool Houston! A Plan for Cooling the Region," 2004).

Austin, Texas has begun implementing an Urban Heat Island Mitigation initiative based on recommendations from a Heat Island Working Group that was organized by city council members and initially convened in 2001. City wide development programs taking place in Austin include an ordinance mandating that parking meet 50% canopy coverage shade requirements within 15 years, where 80% of those trees must be native and large shade producing trees (City of Austin). In addition, the adoption of the International Energy Conservation Code (IECC) 2012 requires that all new low-slope roofs have a minimum reflectance of 0.35, with the exception of green roofs, roofs with permanently adhered solar PV, and rooftop pools (City of Austin)

6.4.2 Green Codes and Regulations

A number of municipalities are developing or extending green building and development code requirements that can mitigate the extreme heat associated with the urban heat island effect. Scottsdale, AZ and Chandler, AZ, which neighbor Mesa, AZ, have green building programs that include construction codes worksheets for new buildings and expedited and priority plan review for green buildings. Chandler, AZ has a required green building code for all government buildings. Scottsdale uses the International Green Construction Code (IgCC) Heat Island Mitigation worksheet to establish standards for new commercial buildings in support of both cool surfaces and cool roofs (Scottsdale). For example, at least 50% of hardscape surfaces must meet at least one of the following criteria: 1) use paving material a solar reflectance of at least 0.30, 2) shade paved areas with shade structures or vegetation, and 3) use pervious paving surfaces. In addition, at least 75% of roof surfaces must meet minimum solar reflectance values and thermal emittance values for specific roof slopes or be vegetated and/or terraced.

Seattle has developed a "Green Factor" program which is a score-based zoning code that requires certain new developments in business districts to provide vegetative cover for an equivalent of 30% of the property through the planting of new trees, preservation of existing trees, and the installation of green roofs and green walls. The requirement applies to commercial spaces with greater than 4,000 square feet, more than 4 dwelling units, or more than 20 new parking spaces (City of Seattle-Department of Planning and Development). Through the Green Factor score sheet, commercial businesses must satisfy a minimum score based on the business type.

In support of the "Trees for Tucson" project, the City of Tucson has required that all commercial developers must use rainwater harvesting to supply at least 50% of water irrigation needs for plants. In addition, the City of Tucson also requires that newly developed streets contain as much green infrastructure as possible as a part of their Green Street policy.

By requiring developers to implement green regulations into their development plans the financial burden of implementing certain new green strategies is alleviated from the City, but the region still feels the benefit. The adoption of green development codes in Mesa would be a low cost option for mitigating the contribution of new urban development to extreme heat events and social heat vulnerability.

6.4.3 Funding and Incentives

Chicago has leveraged more than $142 million in funding from federal stimulus funds, utility companies, and national and local foundations in addition to state funds. The plan also receives support and funding from in kind services and pro-bono consultant work from a number of firms and partners (Chicago Climate Task Force, 2008).

The Sustainable Skylines program is an U.S. Environmental Protection Agency (EPA) sponsored public-private partnership that seeks to improve the sustainability of cities. The program includes 7 project categories: central city livability – heat island effects, stationary and area sources of emissions, energy and climate, land use transportation strategies, diesel engines, green buildings and development, and off-road sources of emissions. Successful applicants will implement one project in 5 of the 7 categories.

Other federally funded projects include the installation of a green roof on a courthouse in Florence, SC using Federal General Services Administration funds, and a Department of Energy funded "Trees for Energy Savings" program in Denver, CO. While we were not able to find any case studies where Community Development Block Grant funding had previously or is currently being used for heat vulnerability mitigation, these funds are flexible and their potential in supporting the reduction of social vulnerability to heat should be explored.

As a part of the Cool Houston! Plan, a local utility provider, Austin Energy, provides an incentive rebate of $0.10 for each square foot of installed reflective roofing. Although no cool pavement incentives currently exist in Houston, TX, the Cool Houston! plan includes recommendations for the development of rebates or tax credits to assist residents and commercial business in adopting cool pavements. Austin Energy also provides rebates for reflective roofs to residents in Austin, TX.

In partnership with an organization Trees for Tucson, The city of Tucson, Arizona has begun increasing vegetative shade cover in an effort to reduce the UHI effect. Trees for Tucson provide trees at reduced rates to homeowners, and Tucson Electric Power and Trico Electric Power both subsidize the trees. However, in order to support an increase in tree canopy cover in a desert city, the City of Tucson has implemented water conservation strategies that focus on the capture of rainwater and better management and utilization of stormwater. In the residential sector the City of Tucson offers rebates for homes that install passive or active rainwater capture systems.

Xeriscaping offers the opportunity for significant temperature reductions. Currently, Mesa offers a rebate of up to $500 for the conversion of at least 500 square feet of turf to a low water use landscape for residential landowners. However, Scottsdale currently offers a rebate of up to $1,500 for turf removal at residential properties and $3,000 for commercial properties. Peoria and Glendale offer rebates of up to $1,650 and $750, respectively, to convert 500 square feet of turf to low water use landscape.

6.5 Conclusion

Many large cities are recognizing the need to address the urban heat island effect and associated heat vulnerability. In response to morbidity and mortality associated with extreme heat events these cities have formed committees, developed comprehensive plans, sought funding and partnerships, and implemented strategies to help protect residents and tourists. The first step towards reducing social vulnerability to heat is recognizing that heat vulnerability is an issue, and giving extreme heat events the attention they deserve. The first step Mesa can take towards combating heat vulnerability is through the formation of a Heat Advisory Committee to address issues of funding and the implementation of heat mitigation strategies.

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