Adaptive Streets: Increasing social and ecological resilience along a cross-city bicycle boulevard

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ABSTRACT: Streets represent roughly 70-90% of cities' public open spaces. Streets connect a variety of citizens with diverse needs. In addition to being conduits, streets act as an important amateur on which an array of public services can be built for social and ecological benefit. This paper examines the case study of the design of a bicycle boulevard in Tucson, Arizona and the tailored community engagement activities used to address the needs of six unique neighborhoods across its length. To complete the design, a public-academic partnership was formed between neighborhood associations, Tucson Department of Transportation planners, County Flood Control District hydrologists, and the University of Arizona (UA). Led through an UA upper-level design studio, the partnership used speed studies, pedestrian and bicycle counts, online surveys, participatory community mapping, and participatory visioning exercises to collect quantitative and qualitative data to tailor the designs to each neighborhood's expressed needs. The final design used a kit-of-parts approach to propose an adaptive street model that addressed chronic ecological and social equity issues along its length. Adaptive elements reduced flooding, shaded pedestrian and bicycle protected paths, increased safety measures and traffic calming, and diversified neighborhood place-specific social areas. The paper argues that context-specific, adaptive designs can be systematically created through community engagement processes tailored to the diverse communities along the extents of a city street. The six-mile bicycle boulevard design is slated to be constructed from the northern to southern city limits.

KEYWORDS: adaptive streets, ecological resilience, social equity, bicycle boulevard
PAPER SESSION TRACK: Inclusive Urban Landscapes

INTRODUCTION

Transportation systems have historically been designed to move the greatest number of vehicles as efficiently as possible across a city from point to point. However, streets also represent roughly 70-90% of cities' public open spaces (NACTO 2020). Streets connect a variety of citizens with diverse needs. In addition to being conduits, streets act as an important amateur on which an array of public services can be built for social and ecological benefit.

Flooded streets are not safe or accessible streets. The Fourth National Climate Assessment warns of increases in the intensity and duration of precipitation events, leading to a greater severity and frequency of flash floods in portions of the United States (Wuebbles 2017). In 2016 alone, the United States suffered estimated property damages of $15 billion dollars and 83 deaths from flash floods – comprising over half of all damages caused by natural disasters in the United States and the highest death rate. This concern is exacerbated by a national trend in deteriorating storm water infrastructure and increased urbanization with densification of impervious land cover (Wuebbles 2017). Solutions are provided by new Complete Streets policies that enable safe use and support mobility for all users (USDOT, 2020) and green stormwater infrastructure (GSI) installations that reduces flooding while offering multiple community benefits. Green stormwater infrastructure filters and absorbs stormwater where it falls and can be implemented at multiple scales (EPA 2020). However, these multi-user and multi-benefit solutions require community engagement to be optimally design and implemented for specific community needs and conditions. These multi-user and multi-benefit designed streets are "adaptive streets" unique to the social and ecological needs of the community.

This paper examines the case study of the design of a bicycle boulevard in Tucson, Arizona and the tailored community engagement activities used to address the needs of six unique neighborhoods across its length to increase neighborhood assets and reduce flooding. This work was supported by a new city Complete Streets policy and Green Stormwater Infrastructure fee and conceptualized as an adaptive street. To complete the adaptive street design, a public-academic partnership was formed between neighborhood associations, Tucson Department of Transportation planners, County Flood Control District hydrologists, and the University of Arizona (UA). Led through an UA upper-level design studio, the partnership used speed studies, pedestrian and bicycle counts, online surveys, participatory community mapping, and participatory visioning exercises to collect quantitative and qualitative data to tailor the designs to each neighborhood's expressed needs with a kit-of-parts approach that allowed crucial adaptability. This paper discusses the community engagement, kit-of-parts approach, and the resulting community designs of the adaptive streets. Overall, adaptive elements reduced flooding, shaded pedestrian and bicycle protected paths, increased safety measures and traffic calming, and diversified neighborhood place-specific social areas. The paper argues that context-specific, adaptive designs can be systematically created through community engagement processes tailored to the diverse communities along the extents of a city street.

1.0 LITERATURE REVIEW

1.1 Adaptive streets: complete streets policy and design approach for multimodal users

Complete Streets are streets designed to ensure safe and assessable use across multiple modes and user types. By 2018 nearly 1,500 Complete Streets policies had been adopted across the U.S. (Riveron 2018). Complete Streets have been found to improve community health, increase safety, and advance economic development (Dodds 2017). However, comprehensive reviews of these policies find a consistent deferral to idealistic goals without recognizing the need to negotiate the trade-offs between the many users and modes prioritized in Complete Streets (Gregg and Hess 2019). Further, there is an existing literature gap in the integration of flood mitigation in Complete Street design toward the accomplishment of the fundamental goals of safety and access. Transportation systems require a new tool for GSI implementation that supports Complete Street goals under climate change and social equity considerations. GSI is a modular, scalable infrastructure solution that can be cost-effectively integrated into problem locations in the transportation network for environmental, social, and economic co-benefit. This research addresses this gap through the conceptualization of Complete Streets designed with an adaptable GSI kit-of-parts.

1.2. Community engagement: reaching diverse user groups during COVID

Street design has traditionally favored cars in design considerations. The COVID pandemic has underlined the important role streets can play in providing safe and healthy outdoor social spaces across users and modes (Sharifi, 2020). Streets are critical social infrastructure (Kuiper et al., 2020). Adaptive streets that are complete streets and provide this important social infrastructure, design for a diverse set of public interests. As Lisa Abendroth and Bryan Bell outline, there are five principles when engaging in public interest design: (1) advocate with those who have a limited voice in public life, (2) build structures for inclusion that engage stakeholders and allow communities to make decisions, (3) promote social equity through discourse that reflects a range of values and social identities, (4) generate ideas that grow from place and build local capacity, and (5) design to help conserve resources and minimize waste (Abendroth and Bell, 2015, 13). The engagement work undertaken in this bicycle boulevard design followed these five principles across engagement with six neighborhoods and the resulting proposed bicycle boulevard design. Design teams sought out community members beyond the obvious stakeholder neighborhood leaders, created a variety of activities to solicit input and inclusion, focused on design moments that strengthened existing assets in the community, and created budgets for their kit-of-parts that efficiently used city and neighborhood resources.

The initial COVID lockdown occurred midway in the community engagement process of this project. The work endeavored to use a tactical urbanism and experimentation methods to ground-truth design approaches for each unique situation. This process includes five steps: (1) empathize, (2) define, (3) ideate, (4) prototype, and (5) test (Lydon, 2015). Although this process was followed, the testing of various kit-of-parts prototypes shifted from live street interactions with the community to online surveys and social media. Community needs also changed and amplified as a result of COVID as an awareness of the importance of streets as outdoor social spaces for safe and meaningful community interaction increased. Thus, in addition to changes in community engagement modes, designs also refocused as a result of the COVID pandemic. COVID changed approaches to design and community engagement across the design disciplines – creating greater limitations and also greater incentives and urgency to the work (Cabral et al., 2020).

2.0 METHOD

2.1. Study area: street history and recent policies

This research designed a 6-mile bicycle boulevard across Tucson, Arizona (FIGURE 1). Tucson experiences annual events of severe flooding and has recently adopted a Complete Streets policy and a Green Stormwater Infrastructure fee. Located in the Sonoran Desert, Tucson is subject to fluctuations in daily volumes and seasonal patterns of rainfall. Tucson has a light (roughly December through February) and heavy (roughly July through September) rainy season joined by intense stretches of heat and dryness.

Tucson has a unique stormwater management history. The majority of the urban center of Tucson does not currently have storm water piping. Streets were designed to carry the heavy rain flows that occur during the winter and monsoon seasons to washes throughout the city. Over time, the city grew and greatly shifted its majority pervious land cover to impervious. Tucson has the highest yearly extreme storm count across Western US Metropolitan Statistical Areas (Bakkensen and Johnson, 2017). These urban water extremes affect citizens directly and disproportionately. Tucson averages $9.5 million in property losses each year from flooding in the city center where stormwater infrastructure was historically not installed, predominately in lower income areas (Bakkensen and Johnson, 2017).

To address these issues, the County and City have worked over the last decade to collaboratively develop policies to address current flooding issues and retrofit Tucson with a network of GSI. The City of Tucson established a Green Streets policy in 2013 which requires that the department of transportation design new upgraded streets that convey stormwater into GSI features. Additionally, a goal of covering streets with a 25% tree canopy is stated. In 2019, the City passed a Complete Streets policy with the goal of ensuring safety and accessibility to the transportation network to a diversity of citizens. In spring 2020, the Tucson City Commissioners adopted a new GSI fee, previously absent from community water bills. In contrast to the two existing fees for potable water and sewer, this third fee funds the planning and construction of a decentralized GSI system throughout the city. The goal of using GSI in Tucson is to reduce areas of localized flooding and improve co-benefits such as increased shade, reduced heat island effect, and decreased nonpoint source pollution throughout the city. These three recent policies support the implementation of efficient and connected transportation and stormwater networks, like the funded bicycle boulevard which is the focus of this research.

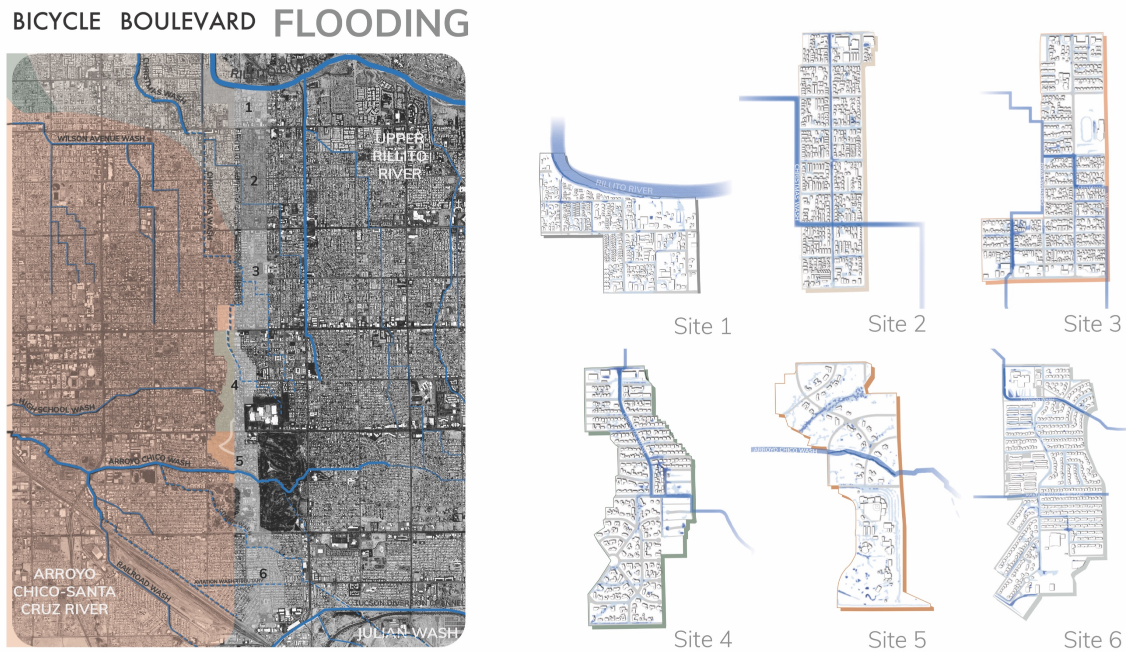

Figure 1: Map of bicycle boulevard and research-design area (Credit: ARCH 451a studio, 2020)

2.2. Public-academic partnership

This paper examines this Tucson case study where a public-academic partnership was formed between neighborhood associations, Tucson Department of Transportation planners, County Flood Control District hydrologists, and the University of Arizona (UA). Led through an UA upper-level design studio, the partnership used spatial mapping, quantitative analysis, hydrological modelling, and design inquiry to create a six-mile bicycle boulevard that is slated to be constructed from the northern to southern city limits, passing through the largest municipal park. The City of Tucson sponsored the research studio course. The project designed the bicycle boulevard with a kit-of-parts of context-specific GSI to provide localized and network benefits including flood reduction, shaded pedestrian and bicycle protected paths, increased safety measures and traffic calming, and neighborhood place-specific social areas. The six design teams completed research across the six areas to design the bicycle boulevard as an adaptive street. Research included community engagement activities, pedestrian and bicycle counts, speed studies, and hydrologic and hydraulic modelling unique to each of six areas along the bicycle boulevard informed which if these kit-of-parts was used where along the length.

2.3. Hydrologic and hydraulic modelling of the street network

As a part of this public-academic partnership, Pima County Flood Control completed hydrological modeling across the 6-mile bicycle boulevard design. This modeling was completed with Flo-2D, a fluid dynamics software that combines hydrology and hydraulics to model flooding conditions. Student were provided with three iterative flood analyses to inform their designs: a baseline case for their site, flow reduction and storage capacities for their mid-term design, and flow reduction and storage capacities for their final design.

2.4. Community engagement method and COVID

The six design teams completed multiple community engagement activities to understand and prioritize local needs and desires for the bicycle boulevard. Design teams were each required to follow the same sequence of community engagement meetings and activities. This sequence ensured communication across all levels of existing community organizations. First, design teams meet with city departments and local ward offices and corresponding city commissioners for their area. Second, design teams completed a speed study and bicycle and pedestrian counts for their area at a key intersection at three times of day. This gathered data also contributed to the expansion of the local bicycle and pedestrian count database for key streets and intersections in Tucson, which is run through the Pima Association of Governments. Thirdly, design teams met with neighborhood association(s) for their area and completed an asset and challenges assessment. At this meeting, design teams also shared the gather quantitative assessment data of speed, bicycle and pedestrian counts at the key neighborhood intersection. Fourthly, design teams presented an initial design proposal at midterm review to city officials, neighborhood leaders, and design critics. Fifthly, based on initial research and midterm feedback, design teams devise and completed an experiment to gather more specific feedback on implications of their design. As a methodology for these live urban experiments, design teams were originally planning to use concepts such as “tactical urbanism” where low-cost, scalable interventions are used to catalyze change. However, as COVID hit weeks before these experiments were going to be rolled-out, design teams had to devise new methodologies that were virtual and could answer the same or similar questions. Sixthly, using the received feedback from the experiment, design teams finalized and presented the complete design to the community partners that were engaged throughout the process. City and County administrators, neighborhood representatives, and engaged citizens attended the virtual and recorded presentation. Lastly, one design team was selected to continue the implementation work for all six areas through a summer internship with the city department of transportation and mobility.

3.0 RESULTS

3.1. Kit-of-parts. Approach for adaptive streets across diverse neighborhoods

Along the 6-mile bicycle boulevard, the street moved through six different neighborhoods with varying safety, pedestrian comfort, social wellbeing, and ecological adaptation challenges. Kit-of-part sets were designed to addressed each of these four main topical concerns for the variety of conditions that occurred across the six diverse areas. A kit-of-parts adaptive street design approach implemented city-wide was a cost-effective and practical long-term maintenance solution for the city. By comparison, one-off street designs that are completely different for each neighborhood create thousands of unique maintenance issues and expensive construction for thousands of unique details. Kit-of-parts addressed at least one of the four main topical concerns and often overlapped with multiple concerns. For example, the safety kit-of-parts included traffic circles, bump out basins, and signage. The traffic circles and basins also were found in the topical areas of ecological adaptation for flood mitigation and the pedestrian comfort to provide shade. The total kit-of-parts forms a comprehensive menu of multi-benefit design solutions to the variety of conditions and concerns along the cross-city bicycle boulevard throughout varied neighborhoods with differing equity issues. The six design teams used engagement activities to identify which of these kit-of-parts were most appropriate for the neighborhood conditions and to refine them for their area.

3.2. Neighborhood results: six engagement and design approaches

Area 1 was an industrial area that mainly had curbless and inverted crowned streets. As this area bordered the Rillito River, it was the deposit point for the urban flooding starting in area 4 and flowing into the Rillito River. In addition to the pedestrian and bicycle counts and speed study (there was a high incidence of speeding in this area), the design team completed an online survey with the two involved neighborhood associations and many dozens of area businesses. The curbless street were desirable for the industrial businesses for versatility of large trucks and equipment parking. On the other hand, there was a heat island and lack of shade concern for bicyclists and pedestrians using the cross-city bicycle boulevard. Given the proximity to the river, there was an ecological concern that storm water was naturally treated through basins before reaching the river habitat. Students took these community concerns and designed a series of basins to address critical points in the stormwater flow and chronically flooded areas (FIGURE 2). One road was closed for pedestrian and bicycle safety and shade was added.

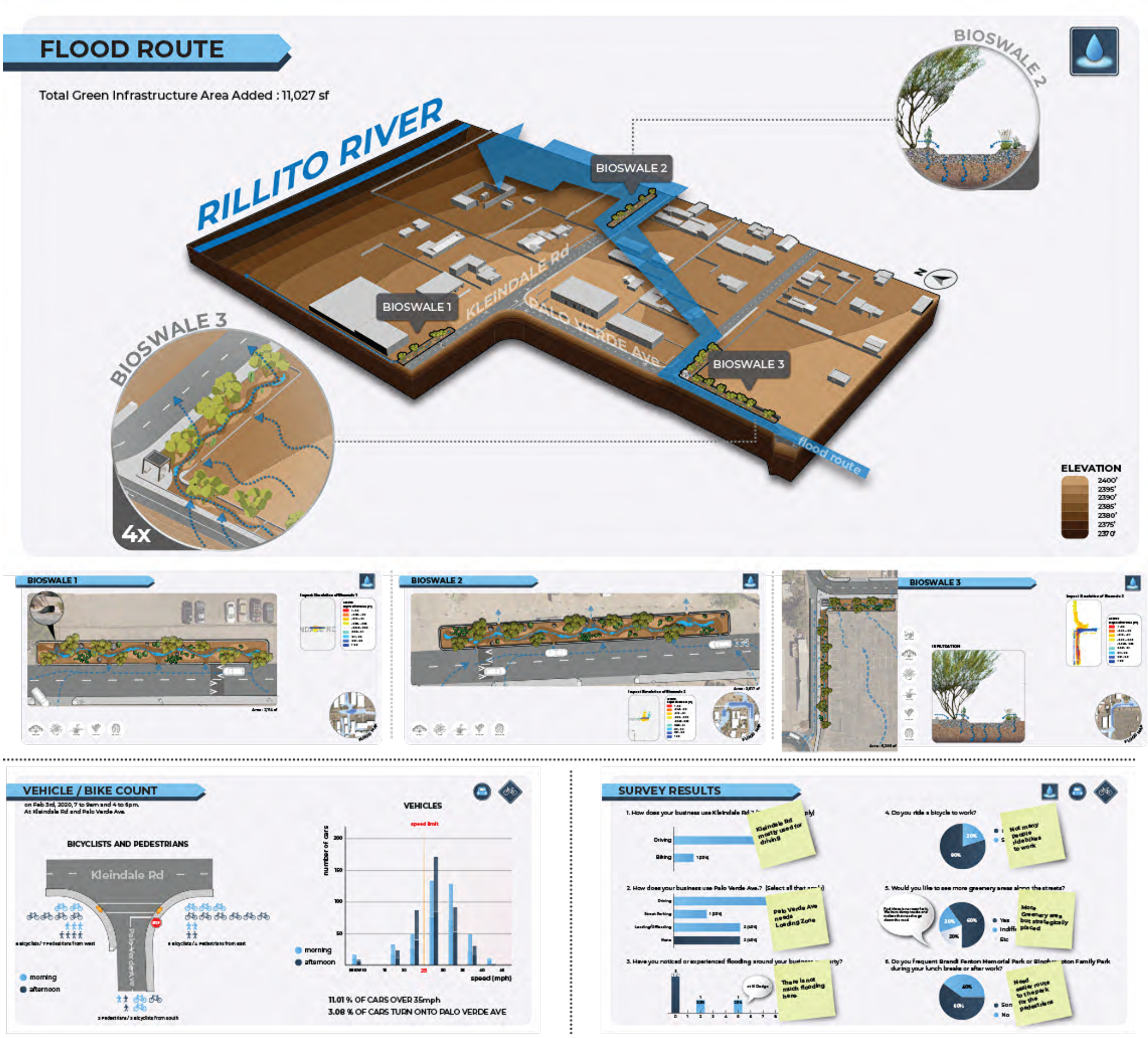

Figure 2: Area 1 Bicycle Boulevard Engagement and Kit-of-Parts (Credit: ARCH 451a studio, 2020)

Area 2 was a residential area with mainly inverted crown streets. There were four smaller neighborhood associations that comprised this lower income area. In addition to the pedestrian and bicycle counts and speed study, the design team attended neighborhood association meetings and administered an online survey to all community groups. The survey results revealed a great frustration with the amount of flooding along the bicycle boulevard street and some safety and speed concerns. In response to the expressed flooding and safety concerns, traffic circle basins were added at every other intersection along the street and corner basins were added throughout.

Area 3 was a residential neighborhood that was middle income and included a large neighborhood high school. The street was largely inverted and had curbs. In addition to the pedestrian and bicycle counts and speed study, the design team attended neighborhood association meetings and sent out an online survey to the neighborhood association (FIGURE 3). Due to the neighborhood high school, there was a lot of pedestrian and bicycle activity noted both in the early count studies and also expressed at the neighborhood association meetings and online survey. To address the expressed safety, ecological, multimodal, and social needs, the design team implemented a set of median and traffic circle basins on the inverted crowned segment of the street and bump out basins when the bicycle boulevard turned into a crowned street.

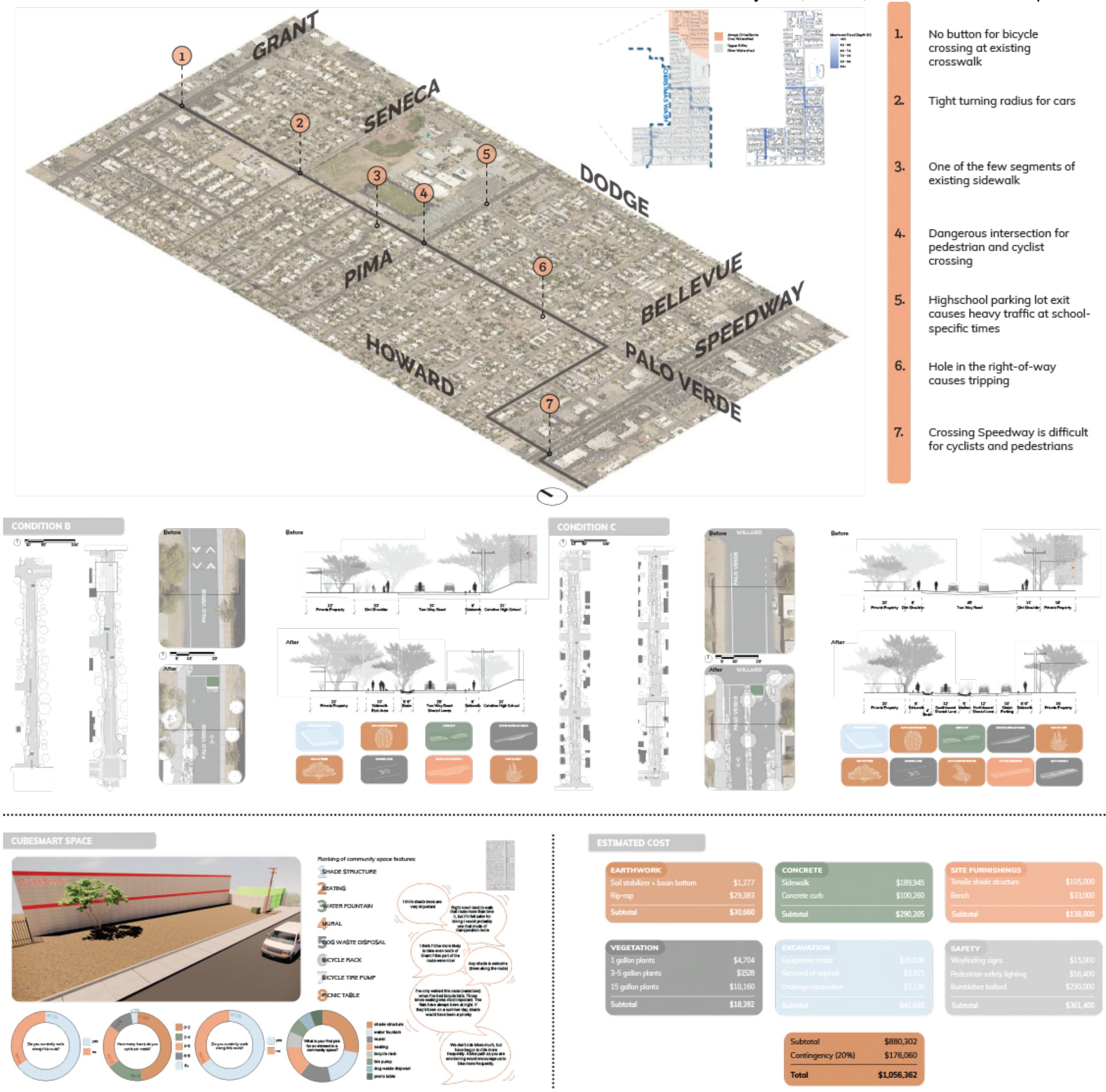

Figure 3: Area 3 Bicycle Boulevard Engagement and Kit-of-Parts (Credit: ARCH 451a studio, 2020)

Area 4 spanned a commercial area buffer and middle income residential neighborhoods. In addition to the pedestrian and bicycle counts and speed study, the design team attended neighborhood association meetings and created a facebook page which asked community members to take photos of good or bad examples of street design. The design team administered this facebook page and solicited community dialogue during COVID from these posted photos and comments (IMAGE 4). This was an effective way to engage a wide section of the community both visually and through writing. It was easier to understand community design desire through seeing the photos and situations they selected. In response to the online engagement, the design team used traffic circle and median basins along the inverted crowned street and incorporated many social spaces along the bicycle boulevard length.

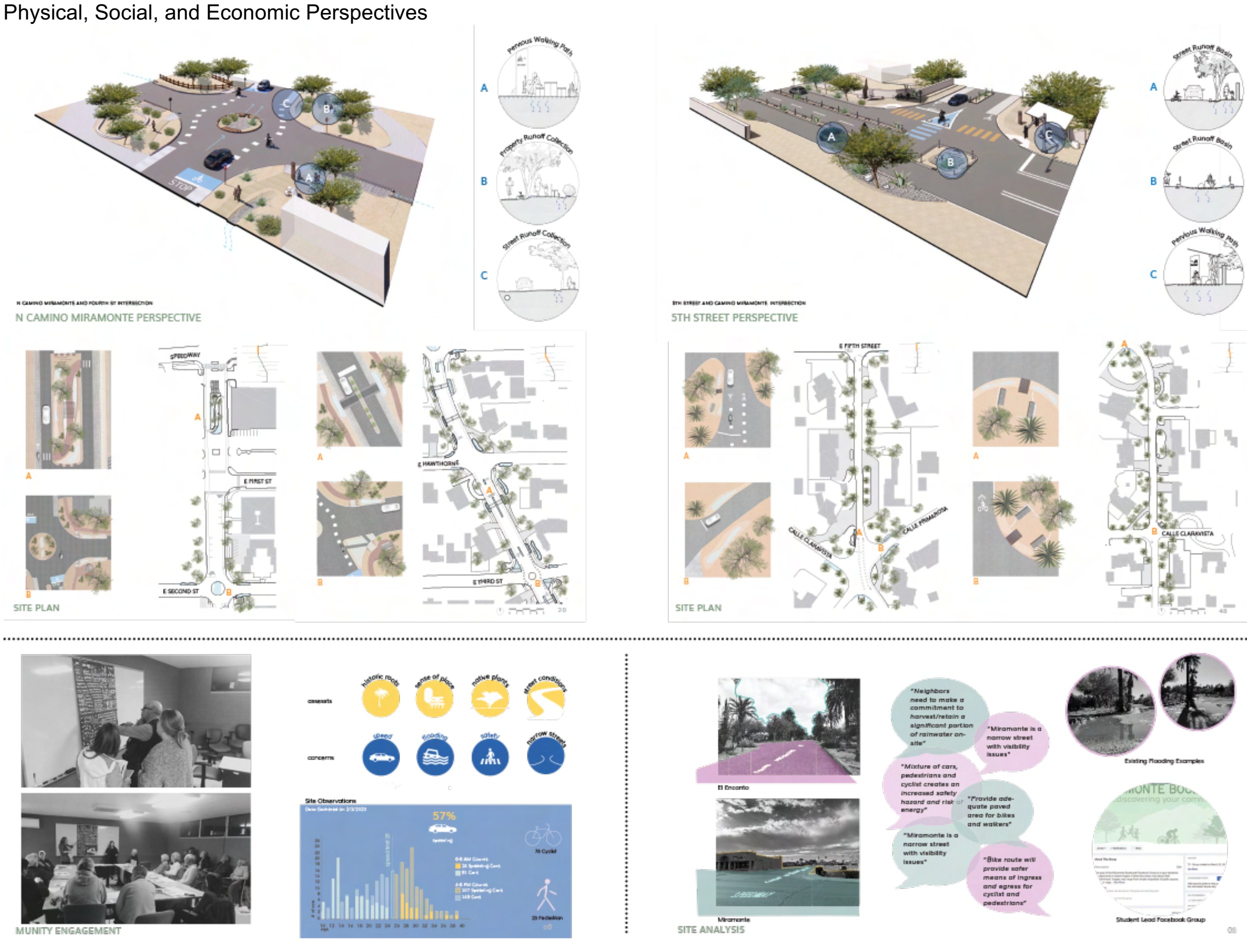

Figure 4: Area 4 Bicycle Boulevard Engagement and Kit-of-Parts (Credit: ARCH 451a studio, 2020)

Area 5 included one of the wealthiest neighborhoods in the city which has narrow, “naked” streets. This area also included the largest municipal park in the city. The design team solicited comments through a comment box station along one of the main pedestrian and bicycle thoroughfares in the park. The box asked for feedback on desired social amenities and other safety, ecological, and multimodal concerns. The design team implemented more specialized crossings, more impervious paving, and expanded social spaces.

Area 6 was a residential area that was lower income and considered to be a food desert. The streets were crowned. Design teams addressed multimodal concerns expressed in an online neighborhood survey and collage activity through adapting existing bus stops for expanded social space and shade. Corner and roadside basins were implemented throughout the neighborhood to address safety, multimodal, and ecological flooding concerns.

CONCLUSION

The final bicycle boulevard designs used a kit-of-parts approach to propose an adaptive street model that addressed chronic ecological and social equity issues along its length. Adaptive elements reduced flooding, shaded pedestrian and bicycle protected paths, increased safety measures and traffic calming, and diversified neighborhood place-specific social areas. The paper argues that context-specific, adaptive designs can be systematically created through community engagement processes tailored to the diverse communities along the extents of a city street. The six-mile bicycle boulevard design is slated to be constructed from the northern to southern city limits. The kit-of-parts of adaptive street design interventions was presented to the city in an interactive PDF book for future implementations.

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