ASSESSING BIKEWAY DESIGN ALTERNATIVES: DALMAC ROUTE CENTERAL MICHIGAN CASE STUDY

By

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ABSTRACT

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The objective of this thesis is to explore the differences and possibilities of bikeway design implemented with different treatments by examining the DALMAC bicycle camping tour. In the following steps, the thesis conducted series of analysis to select the final route by assessing three segments (Site A, Site B, and Site C) as study sites from DALMAC ($b = 3$). The investigation studied treatment including: 1) Existing Treatment, 2) Balance Treatment, 3) Extremely Safe Treatment, 4) Extremely Enjoyable Treatment, and 5) Extremely Environmental Treatment ($k = 5$). In order to test the differences among treatments statistically through Freidman Test of variances, there is a scoring criteria consisting of 30 questions. As a result, this data indicated that at least one treatment yield different values among all treatments ($p \leq 0.005$ or $p \leq 0.001$). Furthermore, among all treatments across 3 sites, the Extremely Enjoyable Treatment statistically performed best ($p \leq 0.05$). In conclusion, this thesis investigated the potential values of bicycle enjoyment for a specific segment of DALMAC route.

Key words: Bikeway Design, Cycling Infrastructure, Environmental Design, Landscape Architecture

This thesis is dedicated to my 7 years long study abroad experience.
Also to my beloved hometown, Shanghai.

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a. Introduction and Original Inspirations

This thesis describes my interests in bikeway design and my curiosity in the Dick Allen Lansing to Mackinaw Bicycle Camping Tour, Michigan (the official name is abbreviated as DALMAC in the following paragraphs). This interest began with my apperception for greenways.

In the beginning of the research processes, I was interested in the topic of urban greenways. This interest was inspired by a greenway along Zhao Jia Bang Road (one of the major road connect local neighborhoods to the central shopping area in Xu Hui District) two blocks away from my house in my hometown, Shanghai, China. This roadway (see Figure 1.1) consists of eight motorized lanes in the middle and two non-motorized lanes on the side. In addition, there is a massive in the form of vegetated islands inserted in the middle. This

Figure 1.1 A digital sketch of Zhao Jia Bang Rd stretching two directions and the related greenway is installed in the middle.

greenway has always been fascinating for me concerning how different types of traffic are interactive with landscape architecture elements. Interestingly, there are several related planning and design knowledge bases that I found which can connect the topics of urban greenway and linear space design of a bikeway (this term is usually summarized as bikeway design in the following paragraphs).

b. What is an Urban Greenway and its Purpose?

Urban greenway is a planning term associated with green spaces that has become popular in urbanized settings. The concept of the greenway evolved from the ancient boulevards to a form of multi-objective greenways in dense urban areas; this evolution simply goes beyond recreation and beautification (Searns, 1995). Furthermore, urban greenways are often used as a possible solution to the growing rates of urbanization and mitigating effects of urbanization.

Hellmund and Smith (2006) stated, greenway is usually addressed as a landscape phenomenon occurring in both the city and the countryside. The major purpose of a greenway can be divided into two aspects. The first purpose is that a greenway has a contribution concerning the environment. For example, a greenway can improve flooding water quality and preserve the wildlife habit under certain condition. The second purpose is to pursue natural landscape integration, especially in dense urban areas. Sharma (2015) also claims that greenway differences can be addressed through the texture, pattern/shape, material, and form.

Firstly, a vital role of the greenway is to satisfy human needs of green spaces through

achieving aesthetic perception. On the other hand, a study about greenways in China raised an interesting statement that society in urban area expansions are going to demand recreational possibilities for greenways (Yu et al., 2006). Specific to recreational aspects of greenways, many studies have addressed the strategy of utilizing greenways as trails for walking, hiking, and cycling. For example, as what O'Dwyer and Deenihan (2013) mentioned, first phase of Great Western Greenway in the northwest of Ireland proposed under Ireland's first National Cycling Policy Framework has achieved a huge successes in cycling tourism. Another example was found in Hudson River Greenways and its proposed extension toward Riverdale water front, the popularity of walking and high participation rate of cycling activities in this greenway has resulted in $75 million multistage plan (Murtha, 2014).

c. Transformation from Urban Greenway into Linear Space Design of Bikeway

By studying the attributes of urban greenways and thinking about potential usage of greenways, I gained interest in how to transport people through appropriate transportation methods and link natural parcels in the urban context. As what Lindsey et al. (2008) claims, urban greenways are often designed as multi-use trails that provide service for various types of recreations, physical activities, and transportations, due to their shapes of linearity and proximity to natural areas such as rivers, streams, ridgelines, or historic infrastructure corridors.

The overall idea of linking originated from greenway reminds me the motions and activities caused by variety of transportations through Zhao Jia Bang Rd Greenway. This greenway is not only a buffer separated from motorized lanes, it is also a transitory shading

area for pedestrians. In addition, this greenway is also a traffic island function as waiting zone. It is also a connectable green parcels to the adjacent Xu Jia Hui Public Park. As a result, I believe the concept of greenway can be a linking connection between different design elements through motions and activities in one context.

Therefore, I finalized my thesis topics to examine a linear space design of bikeway. For sure this maybe an unusual topic, however, bikeway design is actually a combination of motived linking actions and landscape features. There are considerable similarities between greenway and bikeway design (see thesis development diagram in Figure 1.2).

Figure 1.2 The thinking processes of thesis topic from urban greenway to bikeway design. Copyright © 2017 Yinliang Li, all rights reserved, used by permission.

CHAPTER 2 LITERATURE REVIEW

2.1 The Cycling Concept "Linking and Sharing" and Explanation

With the development of the society, people's perception of cycling has significantly changed. As many journal articles suggest, cycling or bike usage's benefits include but are not limited to reducing air pollution, contributing to energy consumption, improving person fitness (2018 Physical Activity Guidelines Advisory Committee; Sun et al., 2017; Maizlish et al; 2013; Ojc et al., 2011), and many other potential benefits. From the aspect of cycling, the concept of linking and sharing can be addressed from two aspects: multimodal transportation and a term "Sharing the Road". Furthermore, these two inspirational terminologies can influence the planning and design aspects of bikeway development.

a. Linking and Sharing of Cycling through Multimodal Transportation

As what Buehler and Hamre (2015, p.1082-1083) claim, the meaning of multimodality refers to "the use of more than one mode of transportation during a specified time period." Moreover, this multimodality is also considered as an importance mechanism for decreasing automobile dependence; in most of the cases, the available transportation modes usually overlap among automobiles, walking, cycling, and other public transportation (Nobis 2007). By studying the travel trends among young adults in Germany, Kuhnimhof et al. (2012) commented upon the action of multimodal transportation to contribute and increase the sustainability of transportation systems by declining car use. Meanwhile, the multimodal networks mitigate traffic congestion by offering transportation alternatives and routes, such as the usage of bike and bikeways (Rouhieh and Alecsandru, 2014). Through multivariable

analysis of modality groups and methods from the aspects of demographic, socioeconomic, and land-use characteristics, some researchers believe bicycling is one of the essential transportation methods in multimodality (Buehler and Hamre, 2015; Buehler and Hamre, 2012).

Another statement can be strongly associated to this support argument--Martens (2006) states that in many scenarios, bike usage is promoted because of its sustainability, accessibility, flexibility, and efficiency. Thinking from a daily perspective, bicycling is relatively accessible, and it is often favored by young age group because it is economically affordable. Also, there are many real life examples that can be found when connecting attributes of multimodal transportation and bike's presentation. For instance, there are bike racks installed in front of bus to support multimodality overlap between public transportations and cycling. On the other hand, the application of multimodality can be also observed in tourism. In Michigan, there is one famous attraction: Mackinac Island. The island is prohibited to use motorization which means people are transported from the nearby harbors. Besides riding horses and walking, tourists use cycling as an alternative to commute on the island. It is another example of multimodality.

When one excludes the dominance of automobiles in multimodal transportation, there is a large potential for the participation of bicycles and implementation of bikeways. There are many investigations that have demonstrated the benefits cycling; however, it is more important to discuss the bike's compatibility with other mode of transportation. Other than prompting usage of bicycles blindly, professionals should also consider the overall cycling environment and cyclist's behavior while linking bicycle usage throughout sites. Similar to

what Wen et al. (2014) notes bikeway path planning is essential for biking and any other transportation activity. Thus, cycling deserve attention for providing qualities of service through bikeway or bike path. In other words, professionals should promote cycling more carefully with evidence-based designs and properly planned bikeway design guidelines.

b. Bicycle's role in the term "Sharing the Road"

Other explanations of the relationship between automobile and bicycles can be associated the term "Sharing the Road". As what has stated earlier, cycling is a relatively ideal transport alternative to the car that serves for many purposes. Particularly, cycling as a sustainable and recreational transportation goals are being adopted and enjoyed worldwide (Lin and Liao, 2014; Broach et al., 2012). By comparing annual bike trips, bike share of trips, daily bike commuters, and bike share of workers in both United States and Canada, Pucher et al. (2011) indicate that there is a considerable growth in cycling over the past few decades. By reference the data from Statista website, the result indicate there are around 66.21 million people who have been cycling for around 12 months in the year of 2017. In 2012, there was around 51 million riders that had been cycling for around 12 months ("Number of Cyclists/bike riders in the U.S. 2017", 2017). The differences in data value indicate the amount of cyclists are growing dramatically yearly. While the increase of cyclists continues, there is more capacity capability for sharing portion roads or implementing additional cycling infrastructure. However, there is still a controversial argument toward the dominance of road.

When people mentioned the term "Sharing the Road", it usually indicates the safety

responsibilities transportation parties should take while they are riding on the same segment of the road. As Hartmand and Prytherch (2015) suggest, streets as a category under transportation infrastructure should be considered as public space, where individuals is seeking are fair usage of roadway's benefits and harm. Consequently, there are the potential concerns toward social environmental justice and injustice.

Cyclists and motorists appears to be two major conflicting groups while achieving the concept of "Sharing the Road". An interesting point raised by Kaplan and Prato (2016) that both cyclists and motorists experience emotional stress while sharing the road. However, human behaviors or their actions are not the only cause for the inequality that happens while sharing the road. In general, promoting cycling through a more pleasurable and comfortable environment would be an important criteria toward bikeway design.

Haileyesus et al. (2007) indicate there are 62,267 persons experiencing unintentional cyclist injuries from motorized vehicles that need emergency treatment annually. Throughout time, the higher accident rate causes numerous cyclists abandoned cycling behaviors in heavy traffic (Wood et al., 2009). Daley et al. (2007) commented that cyclists concerns toward safety issues are usually caused by the lack of cycling infrastructure and the low respect of cyclist's needs by other road and path users. Under situations, streets are not designed for cyclists. Kaplan and Prato (2016) pointed that cyclist forced to share the road with motorists due to cycling infrastructure scarcity. Hartman and Prytherch (2015) suggest that asphalt roadway's general intention is to provide service for automobiles, thus, it is a relatively inaccessible, non-sustainable, and dangerous environment for cyclists and other non-motorized. Under current situation, the development of cycling infrastructure is lagging

behind due to absence of road width, continuity, and design (Pucher et al., 2011). In contrast, the number of cyclists groups are constantly growing in awareness of bike safety. Therefore, it is essential to consider linking and sharing the roads safely through cycling.

2.2 Central Michigan Bike Corridor Documentations and Considerations

Prior to presenting bicycle safety research, a cycling infrastructure information for Central Michigan is presented. This documentation is organized through categories of different bike typologies. In addition, the presentation of photos visually indicate the physical conditions and potential concerns of existing bikeways.

What people called “bikeway” is designated in a system of terminology, common names of cycling infrastructure include but not limited to: Bike Boulevard, Bike Lane, Bike Route, Neighborhood Greenway, Shared Roadway, Shared Use Path, and Sidewalk Bikeways (City of East Lansing, and the Greenway Collaborative, INC., 2011, p.2-5). Description of each type of cycling infrastructure are quoted as following:

> Bicycle Boulevard: a low-volume and low-speed street that has been optimized for bicycle travel through treatments such as traffic calming and traffic reduction; signage and pavement markings; and intersection crossing treatments.
>
> Bike Lane: a portion of roadway designated for bicycle use. Pavement striping and markings sometimes accompanied with signage are used to delineate the lane. Example can be found on portions of Grand River Ave and Abbot Rd.
>
> Bike Route: a designation that can be applied to any type of bicycle facility. It is intended as an aid to help bicyclists find their way to a destination where the route is not

obvious.

Neighborhood Greenway: a route that utilizes residential street and short connecting pathways that link destinations such as park, schools and Shared Use Path. Neighborhood Greenways share the characteristics of a Bicycle Boulevard but, in addition, provide accommodations for pedestrians and sustainable design elements such as rain gardens.

Shared Roadway: bicycles and vehicles share the roadway without any portion of the road specifically designated for bicycle use. Shared Roadways may have certain undesignated accommodations for bicyclists such as wide lanes, paved shoulders, and/or low speeds.

Shared Use Path: a wide pathway that is separate from a roadway by an open unpaved space or barrier or located completely away from a roadway. A Shared Use Path is shared by bicyclists and pedestrians. There are numerous sub-types of Shared Use Path including Sidewalk Bikeways that have unique characteristics and issues. An example of a Shared Use Path would be Northern Tier Trail.

Sidewalk Bikeways: a specific type of Shared Use Path that parallels a roadway generally within the road right-of-way. This is also known as a Sidepath.

The cycling infrastructure documentations is inspired and referenced through different public trail information websites (“NORTH Trails, WEST Trails, and EAST Trails.”, 2018; “Urban Bikeway Design Guide.”, 2018). Delicate to this thesis, there are 11 slides selected from the entire documentation in Central Michigan are (targeted in the City of East Lansing and City of Lansing).

In the process of conducting documentations, there are many interesting features and potential considerations are founded that can be contributed to the bicycle safety research later and the future design processes. East Lansing is the home of Michigan State University, and it is located in Central Michigan area. Due to its proximity to the university, the residential areas are often concentrated in one zone. Therefore, there are a decent amount of bikeways in the area that are considered as Neighborhood Greenway (see Figure 2.1). Also, there is no complete bicycle network planned in East Lansing area. The lack of a comprehensive designated bikeway system results in inconsistent bikeway qualities and discontinues bike routes (see Figure 2.2, Figure 2.3 and Figure 2.4). Therefore, the riding experience is less enjoyable for some cyclists. However, there is one exception, known as the Northern Tier Trl. It is one of the most popular multi-use trails in the area that connects several community parks and reaction fields (see Figure 2.5 and Figure 2.6). Additionally, on the university campus, the riding experience is often challenged due to the severe conflicts among cyclist, automobiles, and pedestrians (see Figure 2.7). City of Lansing is the capital of Michigan State. The cycling environment is more urban compared with other areas (see Figure 2.8 and Figure 2.9). The existence of railroad interactions and crossing bridge in the bikeway network are special for the riding experience (see Figure 2.10 and Figure 2.11).

Figure 2.1 The bicycle racks in Castle Pointe provide conveniences to the cyclists around the residential complex. There are many apartment complexes built in the East Lansing area, which result in most of the bicycle corridor around residence area fall into the category of Neighborhood Greenway. Unlike other types of the bikeway, Neighborhood Greenway usually does not intersect with major roadways. It often connects with green space and residence parking lots. It is a relatively safe and enclosed bike route for neighborhoods to access and entertain.

Figure 2.2 The sidewalk in the picture functions as bikeway in the form of Shared Roadway/Sidewalk Bikeways along Grand River Ave. in East Lansing. Cyclists are likely utilizing the sidewalk when there is no designated bikeway. Especially in a higher speed traffic corridor, cyclists often consider traveling on the sidewalk safer. In this case, cyclists are sharing the sidewalk space and traffic rules with pedestrians. However, similar to pedestrians, cyclists riding on the sidewalk still face the potentials danger causing by turning automobiles.

Figure 2.3 The picture is the bike lane (with symbols and marking) on Abbot. Rd in East Lansing. This bike lane is designated for cyclists, and it is installed between a roadway and a strip of parallel parking spaces. From the observations, the narrow width of the bike lane limits the usage of this bikeway. There are also potentials that cyclists encounter with automobiles as well as people exiting from parked cars. On the other hand, this bike lane intersects with MSU Union drop-off area, which is a busy location that might interrupt the continuity of riding.

Figure 2.4 The picture of the bike signage shows that the bike lane is going to end in the next segment. As a result of this signage, cyclists are forced to travel on the sidewalk or the road shoulder. Therefore, the overall riding experience will be less safe and interrupted. In the East Lansing area, due to the lacking of comprehensive bicycle networks, there is no sufficient continuous bikeway for cyclists to enjoy. One of the crucial considerations here there is no further orientation for the cyclists.

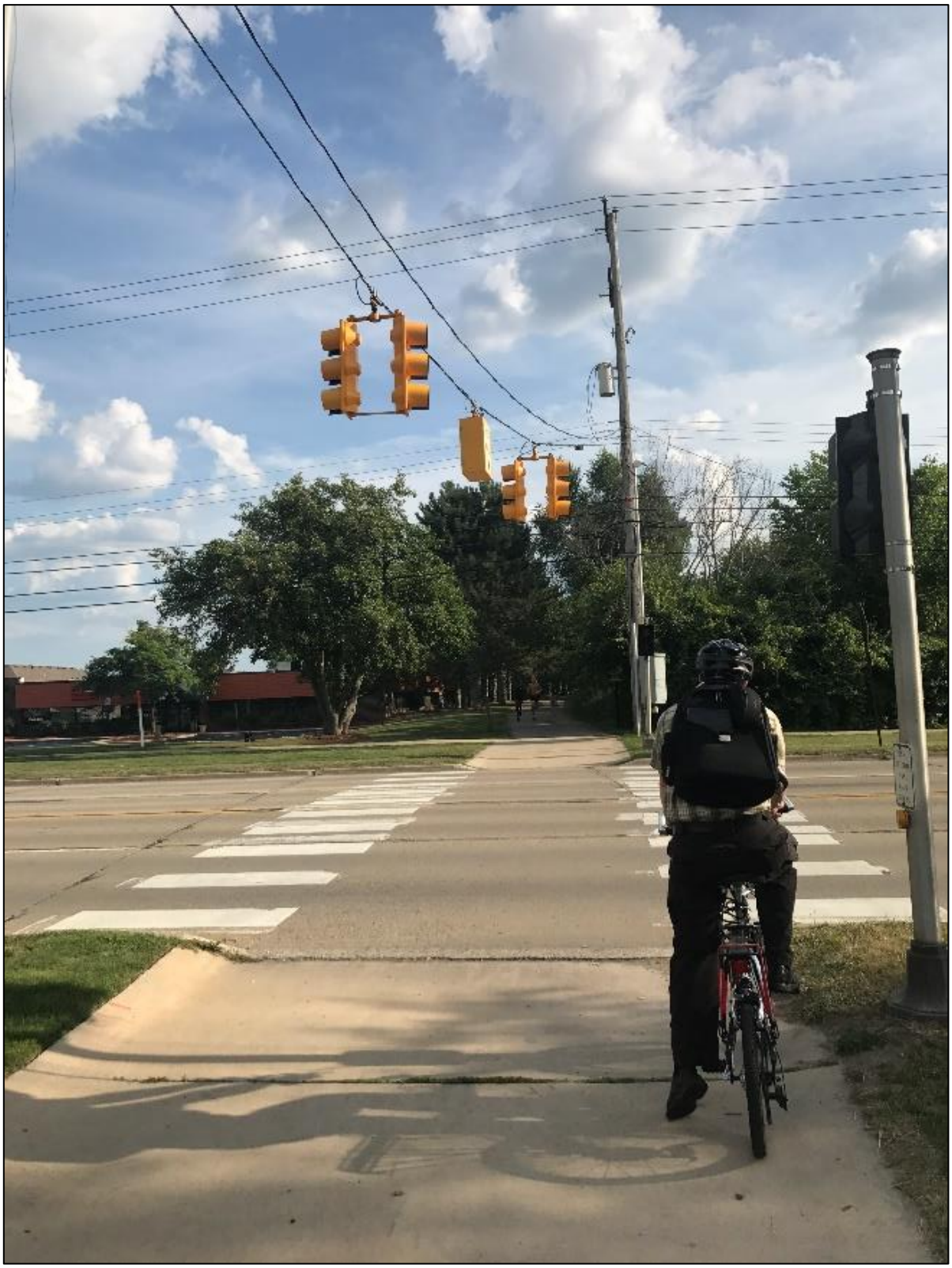

Figure 2.5 The picture shows a male waiting to cross the Lake Lansing Rd. in the segment of Northern Tier Trl. Northern Tier Trl. is a paved pathway consists of several community parks and recreation facilities in East Lansing. A controllable Pedestrian Push-Button Stations is going to enhance the safety level for both cyclists and pedestrian while crossing. However, sudden stopping is still going to interrupt the riding which might result in a less continue and enjoyable riding experience.

Figure 2.6 The picture shows the view in the segment of Northern Tier Trl. As a Shared Roadway, the primary pathway is paved with concrete which makes the bike corridor more durable. However, in the picture, the pathway showed cracking in the center of the road that might cause bumpiness while bicycling. The maintenance of trails is always challengeable due to the weather in Michigan. Therefore, the physical conditions of the bike corridors might not meet with cyclist's expectation.

Figure 2.7 This picture shows a portion of the bike lane (with symbol and marking) along Shaw Ln. The bikeway portion of Shaw Ln. is under the category of Bike Lane as well as Shared Roadway. Usually, it appears to be a designated bike route with marking on the ground. However, Shaw Ln. is also one of the busiest roadways in Michigan State University Campus. Therefore, there is always an intense conflict between cyclists and pedestrians during the peak hour. Another essential consideration here is the orientation for cyclists to ride within the appropriate boundary.

Figure 2.8 This picture shows a segment of sidewalk along Grand Ave. In this case, the sidewalk is functioned as bikeway under the category of Shared Roadway/Shared Use Path. In the Lansing downtown area, the sidewalk elements are different from other areas. The sidewalk space includes public facilities, vegetation, and different textures of paving patterns. Therefore, the type of Shared Use Path will increase the conflicts between pedestrians and cyclist. Therefore, the riding experience is going to be improved if the bike lane is routed differently or buffered with screens.

Figure 2.9 This picture shows the road shoulder on Marshall St, and the majority of the road is under construction. This portion of the road is functioned as bikeway in the form of Shared Roadway because cyclists are sharing the road shoulder with automobiles. However, it can also be Neighborhood Greenway because of the route's local relationship with Marshall Park and Lansing Catholic High School. Due to the existence of multiple attractions, it is vital to connect cyclists from points to points. Additionally, cyclists are likely to meet traffic peak after school is ended.

Figure 2.10 This picture is showing the bike corridor interacted with railroad along Mt. Hope Rd. in the Lansing area. As a bikeway, the portion of the road is functioned as Shared Roadway, where cyclists can share the right side of the road with automobiles. However, when the traffic is stopped by the incoming trains, there is no suitable location for cyclists to wait. Also, there is also no appropriate signage for bicycle orientation. The road surface is going to be rough for cyclists when the roadway meets train tracks. Therefore, it is crucial to warn cyclists to slow down beforehand.

Figure 2.11 This picture shows a crossing bridge over Grand River in the downtown Lansing Area. This portion of the bikeway can be considered as a Bike Lane. Crossing bridge is an attractive feature for cyclists to ride through. However, when crossing the bridge, slope and height are often the primary concerns. The bridge is also built with railings to increase the safety level. Interestingly, the routes intersect with the bridge Bike Lane are Shared Use Path. In this case, one of the essential considerations is to smooth the transition between two types of the bikeways.

2.3 Bicycle Safety Considerations and its Potential Bikeway Design Solutions

a. General Bicycle Safety Considerations

Bicycle safety is an important component and concerns with the development of bicycle network (Lowry et al., 2016; Wall et al., 2016). Improving bicycle safety level is a mutual understanding for various agencies and organizations. However, when it is involved with implementations of cycling infrastructure and treatments, the final decisions could be controversial. People would argue the effectiveness of certain implementations and whether ideas are economically appropriate to be practiced. The main reason behind that is cyclists or other relevant transportation users might share different perceptions of bicycle safety, which means, cyclists and other users have preferences toward cycling infrastructure which will result different levels of usage and impact (Deenihan and Caulfield, 2015).

In general, bicycle safety is not a simple topic. Caulfield et al. (2012, p.414-416) mentioned, the attributes influence on the level of cycling confidence and usage include "adjacent traffic speed, type of infrastructure, travel time, number of junctions on route, and cycle traffic on rout route." Recreational cycling development has attributes that can impact cyclists' participation including "vehicle parking, directness, comfort, weather, type of facility, ancillary facilities, time, cost, route slope and route length (Deenihan and Caulfield, 2015, p.95-96)." On the other hand, Stinson and Bhat (2003, p.10-11) have concluded that the most important factors in the aspect of effecting commuter bicyclist' route choices include: "lower travels times, road classification, types of cycle infrastructure, barriers between motorists and cyclists, pavement quality, surface slope, and fewer intersections." Therefore, one of the most complicated portions of promoting bicycle safety is to come up

with universal solutions and treatments that are workable in every scenario. The aspect of being safe can be applied to cyclists, drivers, and pedestrians. In this case, the concerns of bicycle safety can addressed from the aspect of being subjective and objective.

b. Subjective Bicycle Safety Considerations and Solutions

The subjective aspects of bicycle safety associated with unchangeable environmental conditions, include weather, the physical attributes of cycling infrastructure (surface, slope and intersection), speed limit, and proximities (potentially conflicts) to automobile. In order to solve subjective bicycle safety concerns, the fundamental principles are to treat subjective bicycle safety concerns are creating a low-stress cycling atmosphere for both cyclists and motorists, and making the overall cycling environment volume controllable (Lowry et al., 2016; Li et al., 2012). There are many treatments that can be utilized and implemented, solutions include: 1) Effectiveness of planning cycling infrastructure, 2) Awareness of the existence of a designate cycling infrastructure, and 3) Implementation of a protective cycling infrastructure components.

Firstly, the deficiency of the bike network improvement is generally due to the scarcity of qualified cycling infrastructure. Larsen et al. (2013, p.304-308) noted an idea that use of Geographic Information System (GIS) as an effective method of identifying locations for new cycling infrastructure. Though their research, they have analyzed data from “observed bicycle trips, potential bicycle (short car) trips, segments of bicycle paths suggested by survey respondents as being high priority, bicycle-vehicle collision data, or bicycle facilities that end abruptly (dangling nodes).” As a result, they have successfully found solutions to

improve traffic (cycling) congestion situation on the Island of Motreal, thus, the methodology has suggested to “install several parallel cycling facilities running north-south to provide alternatives other than the sole path in the area (Larsen et al., 2013, p.314).” Another convincible example presented by Aultman-Hall et al. (1997) is that the result of GIS analysis suggest professions should focus on improving cycling conditions bases on the factors from the road network. In detail, the overall conditions can be improved by providing wider curb lanes and implementing traffic signal detectors for bicycles in order to accommodate commuter cyclists that use local roads, paths or trails.

Larsen et al. (2013) also stated the usage of GIS to analyze cycling infrastructure in the region raises the awareness to the important data, measurement, and methodological issues. This awareness are likely to impact future research in cycling infrastructure. Yet, the aspect of solve cycling demand effectively through GIS can contribute to increase safety levels of cycling. GIS as a digital analysis software might not be appropriate under certain context. However, through analysis process of GIS, relevant professions will be notified by demands and expectations of cycling infrastructure. Thus, the quantities and qualities of cycling infrastructure will be enhanced. Ideally, cyclist will not force to share the road through Shared Roadway (description found in earlier section) as frequently with motorists. Meanwhile, like what Moudon et al. (2005) also stated, “Policy and intervention programs (GIS) could increase cycling by improving both actual and perceived environmental conditions.” In additional, the connectivity of local roads and pathways network can redirect cyclists in particular manner which is going to promote cycling, as well as increase the safety level of cycling (Lowry et al., 2016; Aultman-Hall et al., 1997).

Secondly, many researchers found that the existence of a designated cycling infrastructure dramatically impact the behavior of cycling, and potential contribute to the increase of bicycle safety. As one of the essential results presented by Deenihan and Caulfield (2015, p.92), their research indicate that in the aspect of cycling tourism, "It was found that a tourist is willing to increase their cycling time by approximately 100% while using a fully segregated route from traffic; and tourists are willing to increase their time by 40–50% to be able to cycle along a road with a cycle lane rather than a road without cycling facilities." On the other hand, by analyzing different categories of crashes for urban commuters in New York City, Chen et al. (2012) stated installation of bicycle lanes has increased number of cyclist and resulted in a more stable or even reduced accident rate. For this result Chen et al. (2012, p.1120) believed that “the most likely explanations for the lack of increase in crashes are reduced vehicular speeds and fewer conflicts between vehicles and bicyclists after installation of these lanes.” Larsen et al. (2011) stated that a majority of researches indicate a unanimous statement that there is a positive relationship between cycling infrastructure and cycling. In conclusion, the presence of cycling infrastructure or a designated route promote the behavior of cycling and attract decent amount of cyclists due to the rise of safety level (Larsen et al., 2011; Aultman-Hall et al., 1997). Meanwhile, this statement about reducing vehicles and cyclists conflicts is instructive, which leads the research toward different types of protected cycling infrastructure.

Thirdly, among all protected cycling infrastructures, a separated bikeway is one of the accepted and broadly practiced solutions to enhance the level of bicycle safety. The concept "Sharing the Road" are hard to develop due to the misunderstanding and realistic conflicts

between bicycles and motorists, which have caused increased rates of bicycle accident yearly. As a result, Kingsley (2016) stated, that the bikeway is pursued to be high quality and low stressed in a form of protected bike lane. Protected bike lanes are also known as separated bicycle lanes and cycle tracks. Protected bike lanes are typically treat as an investment in public health and safety. In many context, implementations of protected bicycle lanes are likely to impact ridership, rider preferences, and safety performance in a positive way.

However, DuBose (2011) mentioned an opposite idea that many professionals are hesitant to install physically separated bikeway facilities even though they are aware of the potential benefits. When this concept of separated bikeway first was introduced to the U.S, official organizations seemed to lack a design standard to be adapted to the local environment. Moreover, there were argument concerning the safety consideration when separated bikeway intersected with roadway. Meanwhile, as DuBose (2011) also stated, the behaviors of sharing separated bikeway with different types of pedestrian users dramatically impact the accessibility of cyclists.

Therefore, bikeway has valued to be developed under the guidelines of American Association of Highway Transportation Officials (AASHTO), as well as under the manual of HWA Separated Bicycle Lane Planning and Design Guide (Kingsley, 2016). When the right of cyclist is clarified, the existence of a separated bikeway with qualified elements (suitable dimension, functional attractions, smooth surface, acceptable slope, and signage) will promote the usage of cycling in a safer environment. According to the ITE Pedestrian and Bicycle Council survey, DuBose (2011) analyzed that the “less experience bicyclists would be

more inclined to bike on facilities where they feel more protected from traffic." Wall et al. (2016) determined that the usage of sharrows (road lanes shared with bicycles and cars), painted bicycles lanes, and physically protected paths decrease the accident rate and injury level than untreated bikeways.

Besides bike lanes and bikeways there are other infrastructure features. For example, bike boxes and crossing intersections can facilitate bike safely. The bike boxes can be defined as advanced stop lines as well as advanced stop boxes which are usually implemented at signalized intersections. Dill et al. (2012, p.126) noted the primary objective is to "increase visibility of cyclists and reduce conflicts between motor vehicles and cyclists." In particular, the existence of the bike boxes prevents potential "right-hook" situations (refers to blind spots when motorists turning right and accidently crash with cyclists). By utilizing before and after videos in the study area, Dill et al. (2012, p.126) found "a high rate of compliance and understanding of the markings by general observations and survey of motorists." Therefore, there is less encroachment by vehicles towards cycling infrastructure and pedestrians. Interesting, bike boxes are not clearly understood by users for certain transportation settings. As what Hunter (2000) sated, in Eugene, Oregon, it was found there is 59% of survey respondents was indicated they were unsure of the objective of bike boxes. Consequently, the installation and usage of bike boxes is only effective while road users are educated about this concept.

Bike boxes are strongly associated with the safety level of intersections while pedestrians and cyclists are crossing streets. Dill et al. (2012, p.127) also commented that "in theory, reported bicycle crash data would offer concrete evidence of changes in intersection

safety." Besides the installation of bike boxes, there are many constructive intersection treatments are installed to provide additional safety for both pedestrians and cyclists.

c. Objective Bicycle Safety Considerations and Solutions

On the other hand, the objective aspects of bicycle safety associated with autonomous behaviors presented by cyclist, include the choices of wearing safety equipment, usage of illegal substances, riding styles (furious or calm), and route decision making (choosing routes, turning, and following the guidelines). Throughout research, key findings to solve objective aspects of bicycle safety include 1) Improve the quality and connectivity of cycling infrastructure, and 2) Educate in order to increase the safety awareness for cyclists.

Firstly, cyclists' objective actions are strongly related with the subjective bicycle safety factors. In the subjective aspect of bicycle safety section, there are many statements indicating the importance and possible values of a qualified cycling environment. Larsen et al. (2013) also indicated that the trend of cycling infrastructure research targets on how different facilities and environments can potentially affect cyclists' travel behavior. This idea is somewhat notes by Yang et al. (2015, p.36-37) through the analysis of a hazard-based duration model. The result indicated that safety relevant behaviors of cyclists (crossing behavior) at an intersection are impacted by "the attributes of rider type, gender, waiting position, conformity tendency, and crossing traffic volume." In other words, when cyclists are waiting for a long period in a stressful cycling atmosphere, they are likely to make a hazard violation. Therefore, it is essential to have protected cycling infrastructure to lower the emotional stress for cyclists. Stinson and Bhat (2003) stated the majority of the cyclists

prefer fewer major crossing streets, continuous bicycle facilities on major or minor arterials, few stop signs, and fewer red lights. In conclusion, the important factor here is have a coherent, as well as connective cycling infrastructure for cyclists transport from area to area while they can still enjoy the cycling experience (Larsen et al., 2013).

Afterward, cyclists' personal behaviors are one of the most powerful factors to effect the bicycle safety level. In the past when bicycling was not widely accepted, cyclists' and other transportation users' perception of bicycle safety are relatively low. Lack of understanding of bicycle safety and cyclist protection resulted in high bicycle accidents rate in form of fatalities, incapacitation, non-incapacitation, and possible injuries or non-injury (Kim et al., 2007). In order to promote the necessity of bicycle safety, there are several actions that should be taken under considerations, which include: increasing cyclist's education about bicycle safety, driver and training toward sharing the road with cyclists. One of the most important concept is to advertise cycling as another normal mode of transportation (Purcher et al., 2011). Promoting safety gear (helmets) and equipment (lighting on the bikes), are essential to increase cyclist's awareness of bicycle safety. Harlos et al. (1999, p.183) presented an analysis involved with "factors of age, gender, helmet use, riding companions, location type, correct helmet use, and use of headphones while cycling." The results indicate a low usage of helmets by different groups of cyclists, especially teenagers.

The willingness concerning wearing helmets is only one aspect for the study of cyclists' behavior toward bicycle safety. There are many other considerations such as the violations of traffic laws and illegal substance prior the action of cycling. The most issue is to increase

cyclists' awareness of bicycle's current conditions and safety considerations. Meanwhile, it is also important to promote cycling from a healthy and green perspective.

2.4 Bicycle Environment Considerations and its Potential Bikeway Design Solutions

By introducing bicycles usage and cycling activity earlier, it was found by many research studies that cycling has multiple environmental benefits. For example, Manton et al. (2013) stated cycling can help with energy consumption and reduce the carbon footprint. In the urban context, the usage of cycling is an ideal alternative for automobiles; however, there are still a majority of cycling activities take places in natural environment. On the other hand, there are also many articles are concerned that cycling has negative impact toward natural environment.

Some studies found negative impacts toward natural environment caused by cycling activities, especially the mountain bike activity. Steven et al. (2011) stated that the outdoor recreation such as cycling activities are likely to impact wildlife's physiology, immediate behavior, as well as changes in abundance reproductive success in the case of birds. Pickering et al. (2012) analysis suggested the activities of hiking, mountain biking, and horse riding all have certain levels of negative impacts to vegetation. Those activities could damage the vegetation in different levels of severity. In detail, Pickering et al. (2012, p.555-556) also stated the negative impact to the vegetation area include "damage to existing trails, soil erosion, compaction and nitrification, change in hydrology, trail widening, and exposure of roots, rocks and bedrock."

Even through most of the findings are delicated to the activity of mountain biking, the

concern level should increase while implementing cycling infrastructure to a more rural context. The behavior of trampling has dramatically impact on vegetation height and biomass; thus, the creation of informal trails is not only changing the species composition, but also resulted in spreading of weeds and pathogens (Barros et al., 2015; Pickering et al., 2012; Ross, 2006). In the example of DALMAC, there is a percentage of the route traveling through natural areas or attractions. Therefore, cycling and its related activities could impact the natural environment.

In order to prevent excessive damage to the natural areas through cycling, potential solutions can be addressed such as 1) Adopt the concept of Ecotourism to remind cyclist's behavior within the acceptable level, and 2) Guide the cycling route on selected or treated surface to avoid direct contact with protected nature area.

Cyclists tend to have their unique riding styles and motions, and Pickering et al. (2012, p.555-556) stated that the extent and severity of cycling impact to the environment are possibly connected with different riding style. Yet, "Impacts are likely to be greater when riding is faster, less controlled, occurs on steeper slopes and in wetter conditions." Therefore, the ideal situation is to avoid protected natural areas (natural trail). Cyclists are encouraged stay in a more consistent speed and motion level to create less impact to the ground. Thus, the idea of Ecotourism is suitable to be introduced here. McGahey (2012) stated Ecotourism as an antidote to prohibit tourists from damaging the natural and cultural interests. This concept includes following objectives: 1) Protecting the nature, 2) Preserving the culture, 3) Enhancing that local economy, and 4) Educating the tourists. In addition, a well-developed signage system should also be implemented to notified cyclists' behaviors while riding along

the protected nature area.

Secondly, cycling activity should not be promoted with the risk of damaging the protected nature area. However, as what Barros et al. (2015) stated, in order to generate economic revenue, relevant agencies and local communities are likely to promote tourism activities in the natural area. If the cycling activity is insisted upon, cyclists should be encouraged to ride on a more treated or paved pathway. Cyclists should ride on a specifically built cycling infrastructure that protects the natural environment. By measuring sediment yield, Pickering et al. (2012) noted that treated trail systems had only 1% of erosion compared with untreated trails. Furthermore, Newsome and Davies (2009) noted, an assessment tool can effectively quantify the actual area impact. Their study was in John Forrest National Park, Western Australia. As a result, the development of monitoring program for natural area will contribute to visitor management efforts, as well as protect natural areas damaged from extreme cycling activities.

2.5 Recreational Cycling and its Potential with Michigan Bicycle Tourism

Cycling is one of the most common exercises people have been practiced in their daily lives. People are encouraged to use bikes as an alternative commuting method due to cycling's benefits. There are many recreational opportunities associated with cycling.

Often, cycling and associated biking activities are considered as a valuable recreational activity for various sizes of user groups. Other than the conventional cycling benefits, there are also environmental benefits (Pucher et al., 2011; Terzano and Morckel, 2011). Cycling also contributes effectively to human health though recreations and tourism activities. For

example, the Taiwan government has specifically proposed bike and relevant activities as a health, tourism, and parent-child interaction activity for the development of tourism (Chen and Lee, 2017). As what Lin and Liao (2014) stated, the percentage of recreational bicycling and relevant bikeway development are increasing significantly throughout the year.

This increasing trend of recreational cycling indicate the acceptance and usage of bicycles from different aspects. Meanwhile, bike entertainments and relevant attractions are usually providing service for the public. With level of public input and attention, studying and designing for a widely known and utilized attraction will apply value and usage to this specific study of bikeway design. From this point, the concept of recreational cycling inspires this thesis to locate a study site relevant to bike recreational attractions (in example of DALMAC).

2.6 Study Intent and Hypothesis

In conclusion, the purpose of this thesis is to assess bikeway design in a selected context (DALMAC). Bicycling includes safety considerations, recreation and tourism, environment impacts, as well as special features of cycling infrastructure.

For this thesis, there are three major objectives: promoting safety, enjoyment and environmental concerns. Therefore, the general plan would be to study the possibilities and potentials for treating bikeways with disparate treatments targeted with different concepts.

Therefore, this thesis will explore in DALMAC as a study site (project) to implement different treatments from various perspectives. DALMAC's slogan, urban greenway's linking, and overall transportation statement of "sharing the road" are interesting aspects to study.

Furthermore, the overall concept of linking and sharing are also well addressed toward the cycling environment and public acceptance of bicycling.

In brief, the study would utilize DALMAC as a study site to improve the overall biking environment from the aspect of being safe (people's awareness of safe biking), enjoyable (the entertainment impact of biking), and environmental (an advanced improvement toward the sustainability value bike already has).

In this stage of the study, the hypothesis is that one treatment will be significantly better than other treatments.

CHAPTER 3 METHODLOGY

3.1 Introduction

In this section, an experiment is designed to compare the differences between various design treatments concerning a bike oriented project. In this case, the improvement plan of DALMAC (Dick Allen Lansing to Mackinaw) Bike Camping Tour is chose for the study. The investigation include four steps: 1) Create Scenarios, 2) Define Criteria, 3) Measure Variables, and 4) Statistic Calculation.

3.2 Scenarios Development

To create scenarios, the processes involved three parts: inventory, analysis, and design. The result of this section will be present mainly figures, and supported by descriptive texts and tables.

a. Inventory

The first phase is an inventory that contributes to gathering background information of the study area, which is going to address the following topics:

1) Project Background: this section include an introduction of DALMAC, a brief on the study area, and the presentation of reasons behind the selection of DALMAC.

The Dick Allen Lansing to Mackinaw (DALMAC) Bicycle Camping Tour is Michigan's annual bicycle camping tour, hosted by the Tri-County Bicycle Association (TCBA) of Lansing, MI. DALMAC typically happens at the end of the summer; the event offers several (see Figure

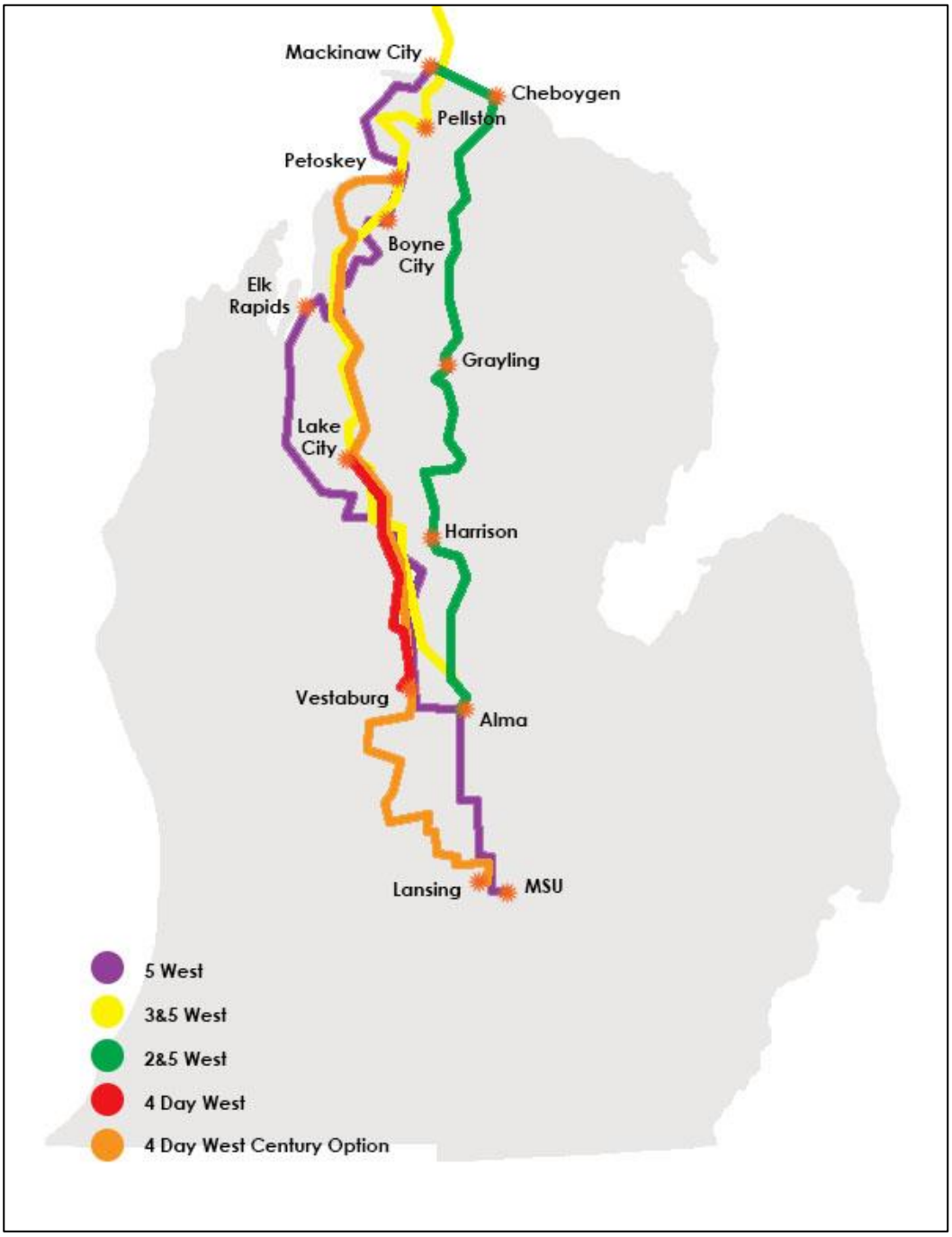

Figure 3.1 2017 DALMAC route choices display and the major township along the event.

3.1) northward routes that vary in number of days, distances and attractions for different levels of cyclists to participate (“About DALMAC”, 2018).

This bicycle camp tour originated in 1971 by Dick Allen, who was the former State Representative (Zepp, 1991). Specifically, the bike tour intended to challenge Dick Allen's

colleagues and constituents with the spirit of "ride all the way to the bridge (Mackinac)." The core idea was to prove the possibility of bikes sharing the roads safely with automobiles in the Michigan area. This concept of promoting physical exercise, ensuring biking safety and enhancing community cohesion stay consistent throughout entire event (Li, 2017). Moreover, in the DALMAC Fund section proposed by from Tri-county Bicycle Association, the objective and attitude of the event organizers are described as following: “1) Improve the bicycling environment in Michigan, 2) Expand bicycling in Michigan, 3) Promote good will towards bicycling in the community, and 4) Increase bicycle safety (DALMAC Fund).”

There are several reasons behind the selection of DALMAC. Recreation or tourism as an initial impression is often not compelling enough at the beginning stages. Fortunately, the DALMAC’s value is found to be a nearly synchronous match with the initial concept inspired from greenways, which is linking and sharing. As an event stretching throughout Lower Michigan, the idea of linking is expressed through the event guiding and traveling all the beautiful cities and townships northward. Furthermore, with the “sharing the road”, DALMAC’s original founder wanted to promote the possibilities of automobiles and bicycles sharing the road safely in Michigan. Finally, one of the objectives of DALMAC is to encourage challenging themselves physically.

In conclusion, the DALMAC is not only a valuable event for the local bike communities, it is also a meaningful event consist of cultural, social, and recreational considerations. Therefore, the complexion of DALMAC allow the thesis to approach and study the relevant bikeway design from various aspects, such as enhance the overall cycling environment being safe, enjoyable, and environmental.

2) Project Problem Statement: this section include a statement addressed potential concerns and issues of DALMAC inspired by the researching of DALMAC oriented news.

The DALMAC event draws an average of 1,000 people every year, and the number of participants is increasing yearly. Since this event is extremely popular and crowded, there are potentials that many concerns can develop. Following as the major four categories of potential considerations summarized from several electronic news (Bradley, 2017; Haxel, 2016; Stafford, 2015; Palmer,2014):

The first category is safety. This portion is going to discussed and raised questions whether the guided route is suitable for large numbers of people riding together. To be asked more specifically, whether the bikers will disturb automobile traffic condition and whether the road has physical limitations (steep elevation change). In many cases, one of the argument is whether the road was designed as a bikeway initially. Ideally, a comprehensive bikeway should contain elements such as buffer, protection zone, passing distance, and proper signage. Finally, the sponsor should have an accessible plan that can ensure healthy conditions for participants from different aspects, such as injury, accident or weather.

The second category is rest interval. There are series of concerns raised in this category such as whether participants can rest and eat conveniently in certain times and locations; and if there are appropriate overnight accommodations other than high school playground (existing choices). Ideally, proper resting interval for cyclists are potentially achieved from the installation of shelters, surrounding retails, as well as other recreational attractions.

The third category is about wayfinding system. One of the questions raised in this

category is if the route is guided clearly for people to follow; and if the participants can join/exit the group easily under any circumstances. Ideally, the installation of orientation board, signage, and map is necessary to enhance the existing wayfinding system.

The final category is environmental issues. One of the questions raised in this category is if

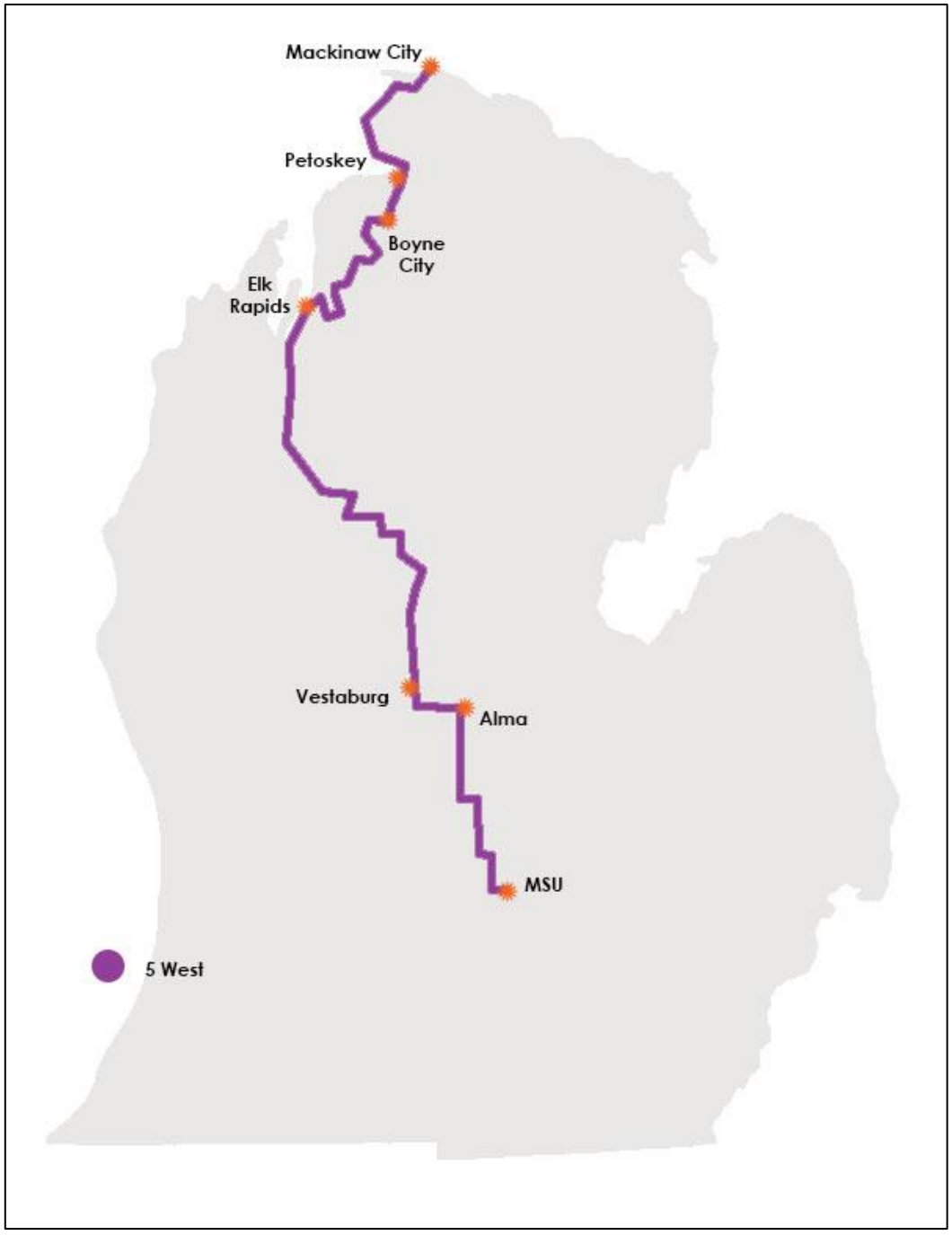

Figure 3.2 2017 DALMAC 5 West route that started in Michigan State Univeristy and ended in Mackinaw City. Other major townships along the event are disaplayed as well.

there is a risk for participants and sponsor to damage the natural environment they have interacted with, as well as what they could do to prevent damage. Ideally, in order to increase the envrioenmtal protectoin to the sorrounding natural resources, the distrution of waste/recycling bins should be considered. Meanwhile, physical buffers or screens should also be installed to prevent natural resources from possible constriction.

3) Route Selection Criteria: in order to narrowing down the scale of DALMAC, this section include the selections of 5 West Day 1 route and specific segments from DALMAC referencing rest interval factors and other supportive materials.

Due to the scale of the DALMAC Bicycle Camping Tour, it will be more reasonable to narrow the site boundary down first. Additionally, it is more accessible and practical for implementing route treatment detail and potential bike facilities. As a result, the 5 West Day 1 has been selected.

5 West (illustrated as purple route in Figure 3.2) often has the most amount of participants because of its water-front riding opportunity and accessibility of crossing the Mackinaw Bridge. Thus, the selection of 5 West will be more valuable in the aspects of contributing to the thesis development and the overall impact upon on cycling promotion.

Afterward, the Day 1 portion for the 5 West route is selected. In many facts, Day 1's route is deserved for more attention due to its current conditions. Unlike other portion of the route, in Day 1, cyclists are crossing farmland, forest and more rustic terrains where there is no designated bike path and most of road are poorly maintained. What’s more important, due to the poor population density, there is no sufficient accommodation and

rest spots to take care all levels of cyclists. The overall condition is rural and lack of bike associated service and protection. Therefore, it is the most problematic area has the potential to implement some cycling infrastructures.

In the next step, the intent is to narrow down the project boundary even more for precise design ideas. For this stage, the rest interval factors as a strong reference when briefly define the site boundary.

The rest interval factors are the elements determining how often a cyclist should rest in a certain amount of time. The mean factors used in this case is the total distance of Day 1,

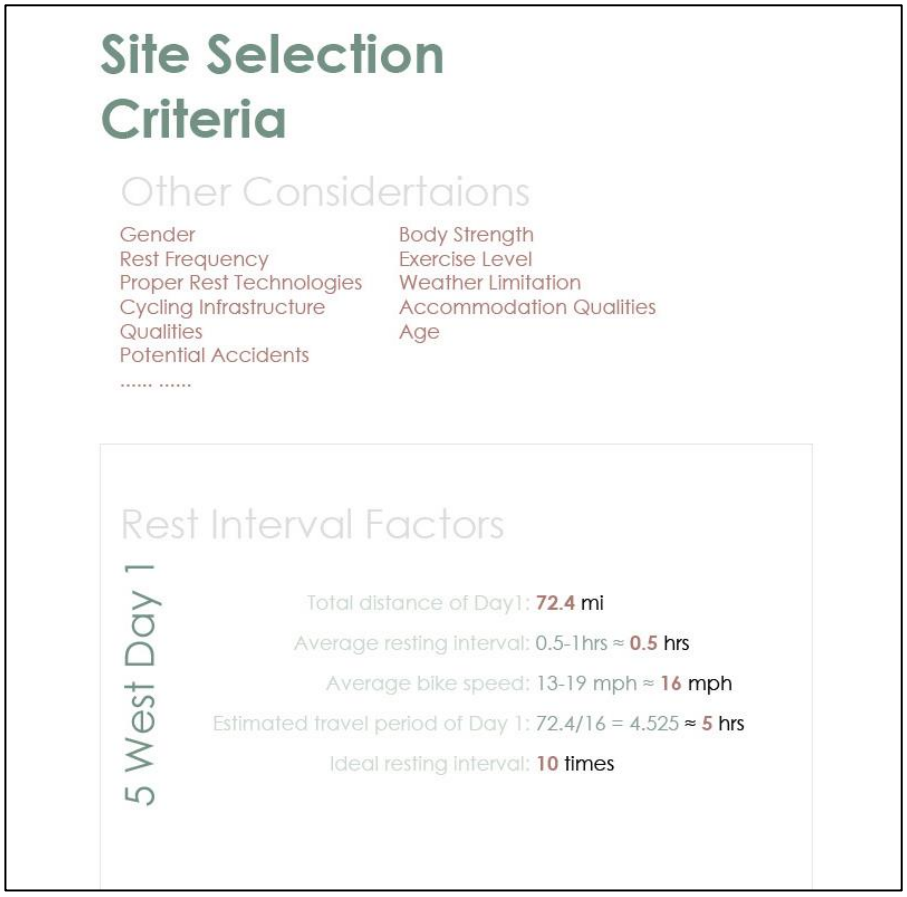

Figure 3.3 The top part of the diagram indicates the comprehensive considerations related with rest interval factors. The bottom part of the diagram indicates the calculation processes of rest interval factors, the result indicate there should be at least 10 rest spots.

average resting interval, average bike speed, estimated travel period of Day 1, and Ideal

resting interval for 5 West Day 1 route. All factors tested for through different references and software for reliability (process diagram see Figure 3.3).

The first factor: total distance of Day 1 is rounded to 70 miles. At first, according to the 2017 DALMAC 5W Day 1 record from Ride with GPS, the total distance is 72.4 miles (start at the MSU Pavilion and be accommodated in the Vestaburg Community High School). Ride

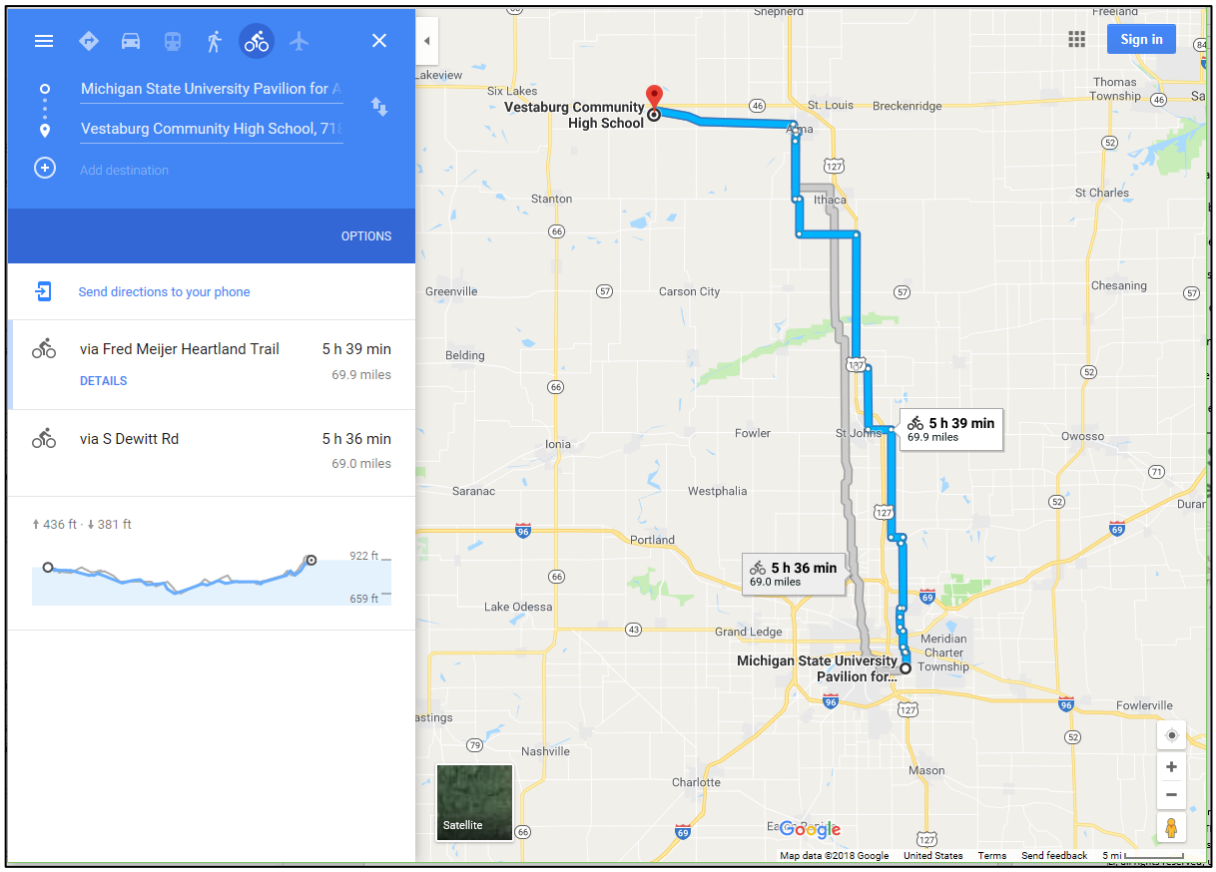

Figure 3.4 Google Map screenshot indicates the method (bicycling), distance (miles) and travel time (hours) from MSU Pavilion to Vestaburg Community High School) from: "MSU Pavilion to Vestaburg Community High School." Map, Google Maps. Accessed on: 2018, May 18. Copyright © 2018 Google, all rights reserved, used by permission.

with GPS is a software, as well as the website for DALMAC participants to follow the major groups while riding to the north (“5W D1”, 2017). Additionally, Google Map (a frequently used mapping service, entered start address: MSU Pavilion and destination: Vestaburg Community High School) indicate the total mileage for the first day is 69.9 miles (Google Maps, 2018 see Figure 3.4).

The second factor is average resting interval, the result is an average cyclist should rest every 0.5 hour excluded potential influences factors. A non-professional adult cyclists should rest every 0.5 to 1 hour. However, by thinking through factors as body strength, exercise

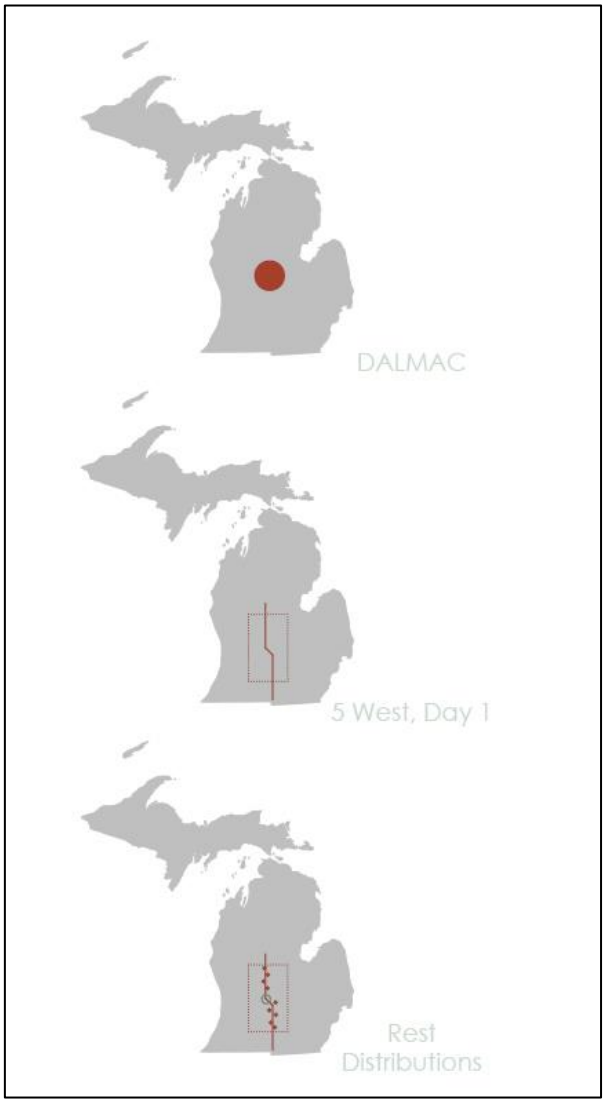

Figure 3.5 The flow diagram visually show the selection of DALMAC 5 West Day 1 route segment by referencing rest interval factor. The first diagram indicates the route of 5 West of DALMAC departs from East Lansing in Central Michigan area. The second diagram indicates the portion of Day 1 from 5 West route of DALMAC. The third diagram indicates how to distribute potential 10 rest sports throughout Day 1, and the study site is selected to be the central one (in the green circle).

level, weather consideration, road conditions, accommodation qualities, and age, and gender, proper test technologies and other, it is safe to say an average participants to the DALMAC with minimal biking experience should rest every 30 minutes.

The third factor is average cycling speed, as a common understanding an average bike speed is around 13-19 mph. In this case, the number is rounded up as 15 mph for future calculations.

The fourth factor is estimated travel period of Day 1, it is safe to say cyclists participated in 5 West Day 1 need 5 hours to traveling through the entire route. Firstly, the total mileage for the first day is 72.4 miles (noted by the Ride with GPS), as well as 70.4 miles (noted by Google Maps). In this case, the total distance of first day 5 West route is rounded up to 70 miles. An average bike speed is around 13-19 mph, in this case, the number rounded up to 15 mph. Total distance = velocity x time, the formula allow15 divided by 50, get the result of 4.6 hours. Secondly, compare with the Google Map result 5 hours 39 minutes, there average of two traveling time will be 5.1 hours which can be rounded up to 5 hours.

Consequently, as a non-professional should rest every 30 minutes, it is calculated that there should be around 10 rest spot/period distributed along the Day 1 route (see Figure 3.5 for rest spot graphically). However, in reality, the general condition is sufficient enough to provide that. Response to this, the design should improve the existing condition by designing the central area of the Day 1 route (see Figure 3.5 for the location). This location is not only a decent area with complex of different landscape, it is a minimal area to ensure the rest interval.

The initial selection from DALMAC for the study site is the Day 1 from the 5 West route.

In this specific case, the used variables in rest interval calculations are the total distance of Day 1, averaged resting intervals, average bike speed and estimated travel period of Day 1. As the result, there supposed to be at least 10 rest spots under the considerations of gender, rest frequency, proper test technologies, cycling infrastructure qualities, potential accidents, body strength exercise level, weather limitation, accommodation qualities, and age and so on. Additionally, this statement resulted into the selection of the central zone between 10 rest spot.

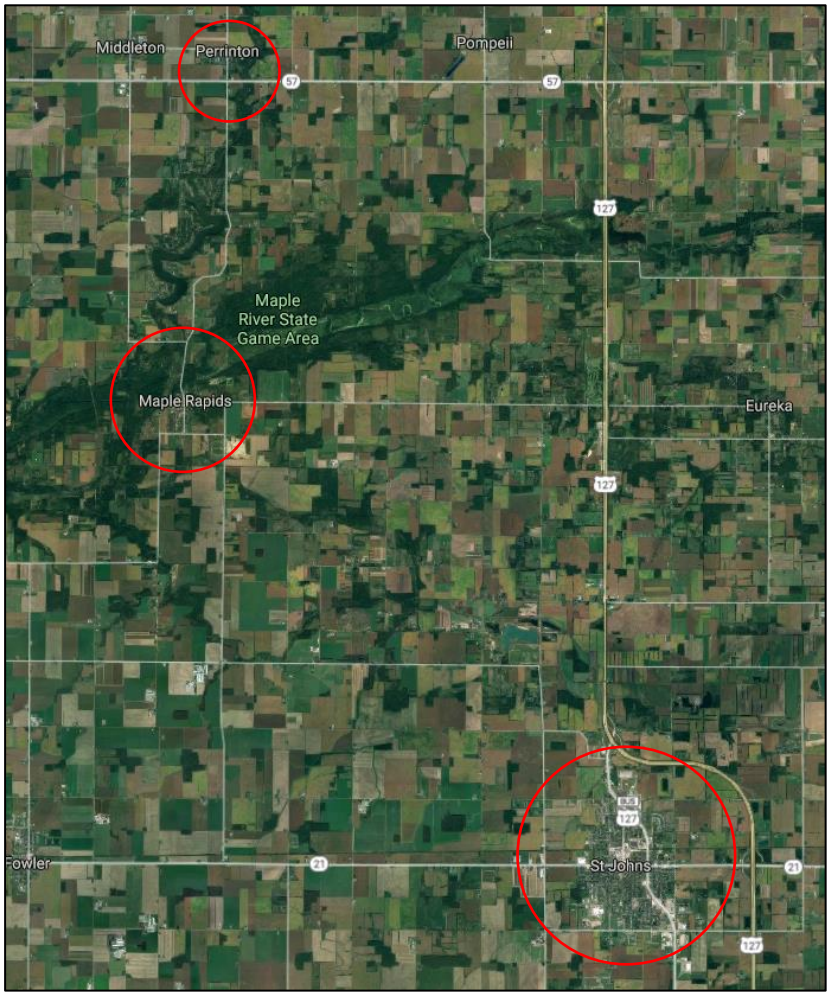

Figure 3.6 Selected design boundary of DALMAC (highlighted by the read circles) regionally associated with three major townships between St. Johns, Maple Rapids, and Perrinton between Highway US-21 and Highway US-57 from: "Maple Rapids, Michigan." Map, Google Maps. Accessed on: 2018, April 04. Copyright © 2018 Google, all rights reserved, used by permission.

5) Site Inventory: this section include a design-oriented investigation to the selected DALMAC segments, which are going to addressed mainly through onsite photographs and envision section study.

The site can categorize as the rural context and the urban context. Generally, there are some universal concerns such as rough road surface, unorganized signage's, absences of signal lights, unintended wildlife interaction and so on. In order to improve the conditions, the following analysis process is going to focus on summarizing the topic of being safe, enjoyable and environmental.

Figure 3.7 This is a set of photos I took during site visit showing the existing cycling environment, landscape, and culture attractions on site. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

Yet, this selected central spot can described as the road portion between Highway US-21 and Highway US-57. There are three major townships located in the region which are St. John, Maple Rapids, and Perrinton (Google Maps, 2018 Figure 3.6).

During the processes, there are multiple pictures took onsite. In Figure 3.7, photos showed content of existing road shoulder functioned as a bikeway for DALMAC cyclists and the existing signage system related to bikeway. On the other hand, the photos also include content of onsite vegetation, farmland, crossing in Maple Rapids, attractive buildings in St. John, welcome signage, and farmland view. Additionally, there is also black gourd profile indicated on the left side to show a general impression of elevation change onsite.

The overall site can be categories of rural context and township context, both context include advantages and disadvantages that should be noted for future design processes. In Figure 3.8, a descriptive diagram is provided to indicate the features on site. The advantage in rural context is the natural attractions; and the disadvantage include narrow bikeway (road shoulder) and rough road surface for cycling. In the township context, the advantage is

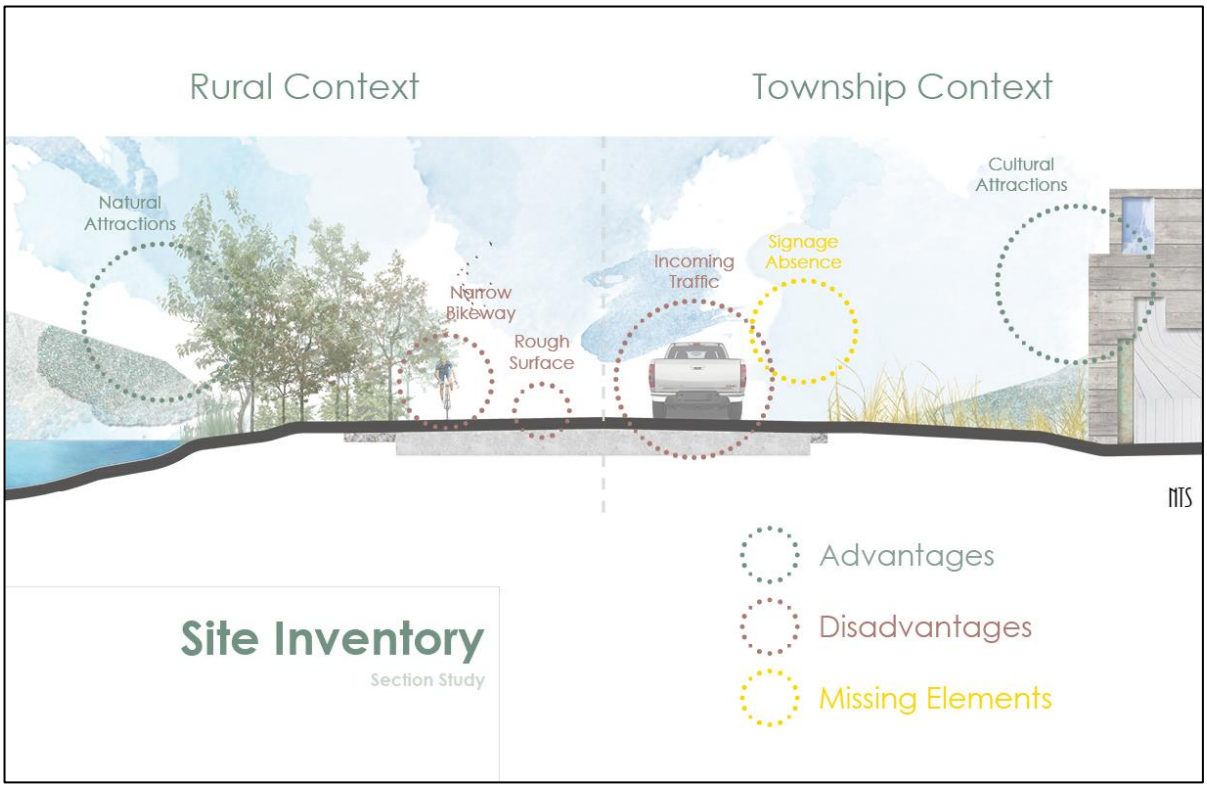

Figure 3.8 This diagram is an explanation diagram to indicate features along 5 West Day 1 route of DALMAC in category of advantages, disadvantage and missing elements. All elements will be useful to inspire for future design processes.

found to be the attractive culture attractions. The disadvantage is the busy incoming traffic that bring pressure for group of cyclist. Moreover, in the township context, there is lacking of bike-oriented signage to provide bicycle safety.

b. Analysis

The second phase is analysis, which is going to address the following topics:

1) Concept Statement: the written statement indicated the interest of enhancing the DALMAC bikeway from the aspect of being safe, enjoyable, and environmental.

Enhancing the overall bike experience has been the primary goals for a lot of professions and community bike associations. By researching generally on DALMAC, there are series of concerns raised upon on the overall cycling environment and qualities of cycling infrastructure. As the result, the design solutions are targeted improve the overall cycling environment through proper bikeway design solutions.

In detail, the goals are to propose a bikeway improvement plan from the aspect of being safe (people's awareness of safe biking), enjoyable (the entertainment impact of biking) and environmental (an advanced improvement toward the suitability value bike already has). In another word, DALMAC Bike Tour should be safe, enjoyable, and environmentally friendly for the participants as well as the sponsors. Therefore, all design goals and objectives should be developed within these three core topics.

Concerning safety, the project should design and guide the routes for participants to share the road safely and equitably. Additionally, the design should ensure biking safety in extreme conditions, such as variations in topography and weather constraints.

The project should express the spirit of DALMAC Founder Dick Allen's original slogan “Ride all the way to the bridge,” and encourage each participant to do more physical exercise through the bicycle tour. Additionally, the project should also build relationships with Michigan’s cultural attractions and local communities along the road.

All design components should be utilized, and existing resources should be improved. Ecotourism can protect natural (forests and farmland) and public (drinking fountain and bike racks) resources during the event.

2) Treatments Development: the 5 treatments that are developed delicate to bike improvement plan of DALMAC, they will also contribute to the future measurements and calculations.

The description of treatments can be found as following:

Design Treatment 1: a non-input treatment, address the existing cycling environment/conditions from sites.

Design Treatment 2: a balance treatment that attempts to accomplish all three goals (enhance the overall cycling experience being safe, enjoyable and environmental) without conflict. In detail, there should be essential elements that addressing three objectives included, such as a more improved signage system, suitable bike lane protections, orientation and mapping system, and bicycle parking and repairing infrastructure.

Design Treatment 3: an extremely safe treatment that primarily is focus on increasing the safety levels of the overall cycling experience. Therefore, the treatment should include several protective cycling infrastructures such as bike lane buffer, crossing system, a more

improved signage system, and orientation and mapping system.

Design Treatment 4: an extremely enjoyable treatment that is primarily focus on pleasing the cyclists from all aspects through the overall cycling experience. Therefore, under this treatment, the selected site should build connections with surrounding attractions when possible or try to install cycling infrastructure serve for recreational purpose. Another important point is to think about cyclist's thermal comfort, thus, proper shelter and guide to shading should be programmed.

Design Treatment 5: an extremely environmental treatment that is primarily focused upon solving the potential environmental conflicts between the nature and the cyclists. In order to solve the possible environmental issue, the rerouted bike lane should avoided rural area when possible. If it is necessary to travel through natural resources, paved surface should be considered. On the other hand, it is also important to think about the overall concept of Ecotourism, therefore, it is important to build a healthy economic relationship with the surrounding neighborhoods with the development of DALMAC.

3) Spatial Design Analysis: layers of analysis targeted to the major objectives: safety, enjoyment, and environmental projects.

For safety, the analysis focuses upon dangerous segment, extreme elevation, signage awareness, and speed profile for the cycling environment. For enjoyment, the design assessed focusing upon local attractions, potential resting spots, shading area, and sun exposure level for the cycling environment. For environmental protection, the analysis addresses problematic areas, vegetation composition, and the wildlife corridor surrounded

the cycling environment (see process diagram in Figure 3.9).

The base map (see Figure 3.10) indicates the route direction, township outline, building density, and watercourse in the area. Then I develop series of spatial analysis layer as following:

Safe: Signage Awareness (Figure 3.11), Speed Profile (Figure 3.12), Extreme Elevation

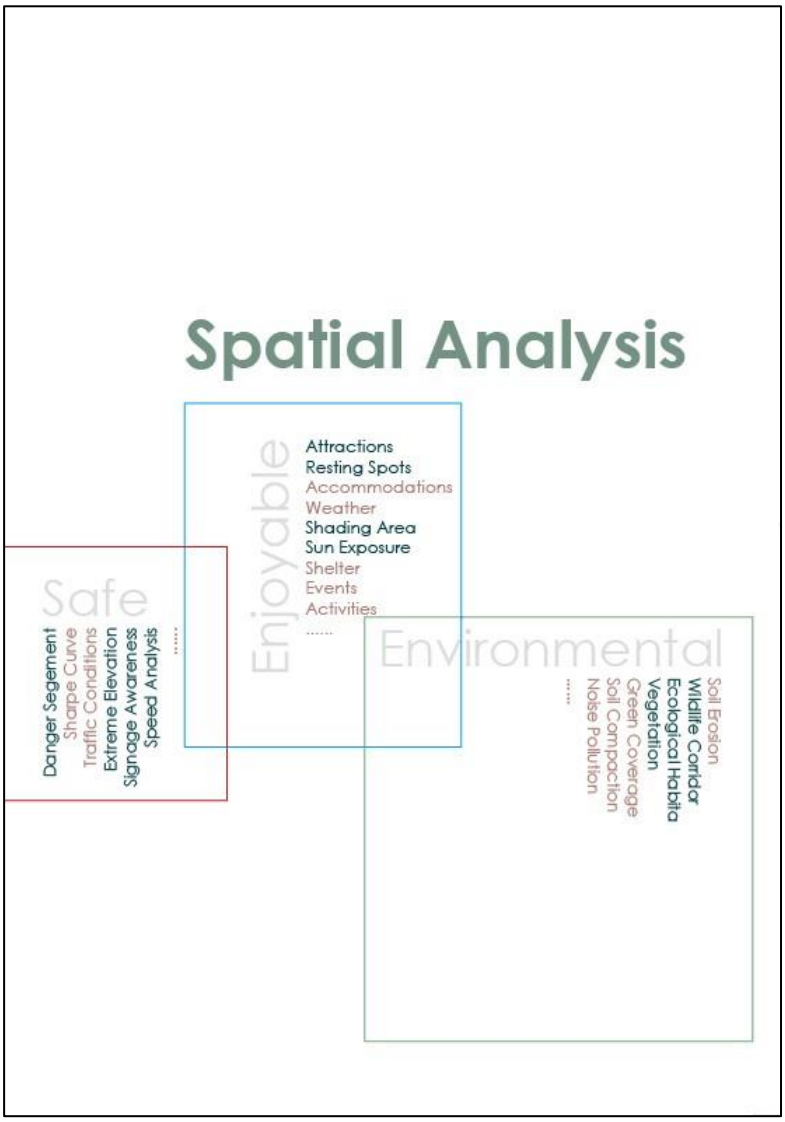

Figure 3.9 The three goals of the spatial analysis process Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

(Figure 3.13), and Dangerous Segment (Figure 3.14).

Enjoyable: Local Attractions (Figure 3.15), Resting Spot (Figure 3.16), Shading Area (Figure 3.17), and Sun Exposure (Figure 3.18).

Environmental: Vegetation Composition (Figure 3.19), Wildlife Corridor (Figure 3.20), and Problematic Area (Figure 3.21).

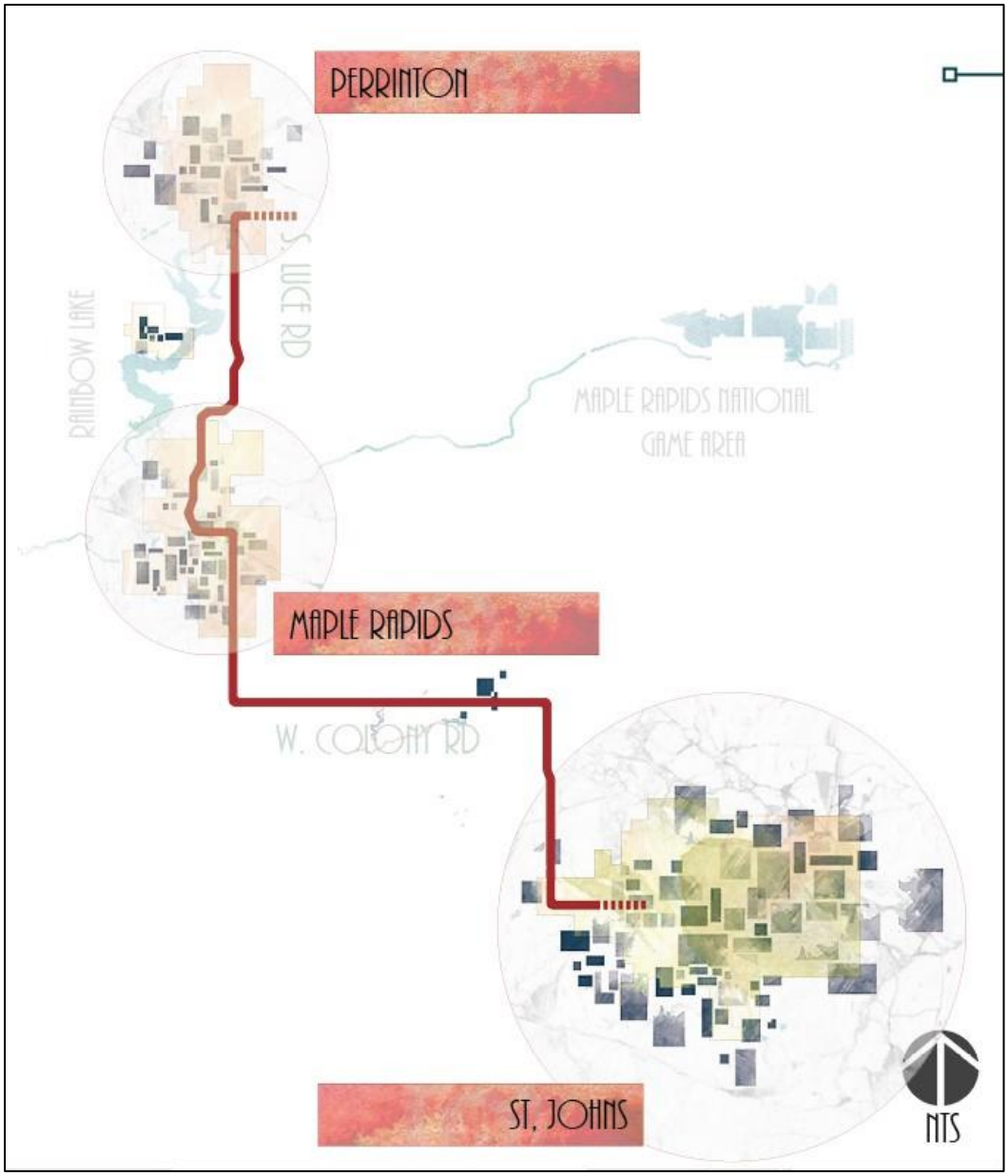

Figure 3.10 The base map of the selected design site, where the township of St. Johns, Maple Rapids, and Perrinton is displayed. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

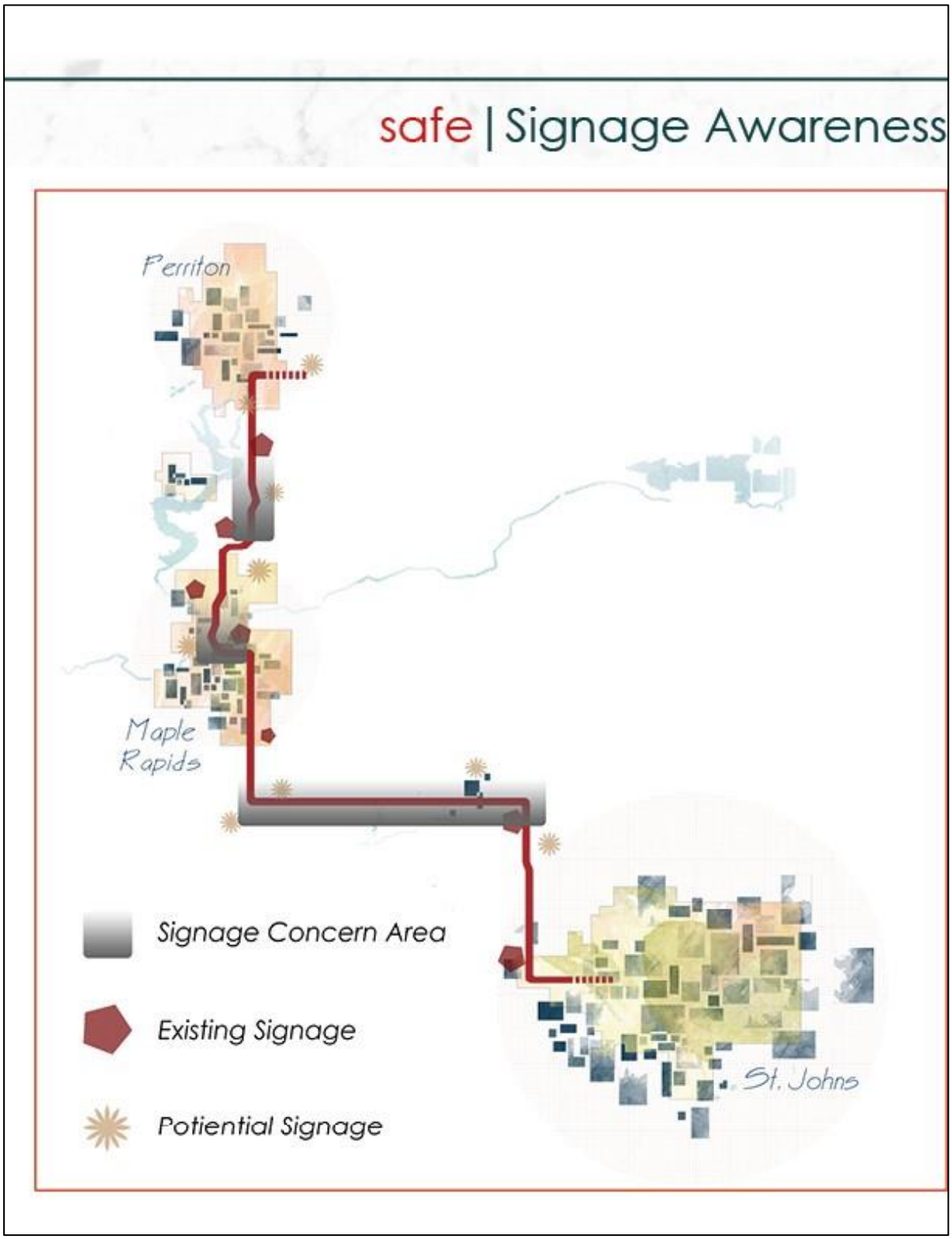

Figure 3.11 This diagram indicate the signage awareness on site, where the gray blocks indicate the areas that are absence from the signage implementation. The red symbol indicates the locations for obvious existing signage. The orange indicates the potential implementations of signage when applicable.

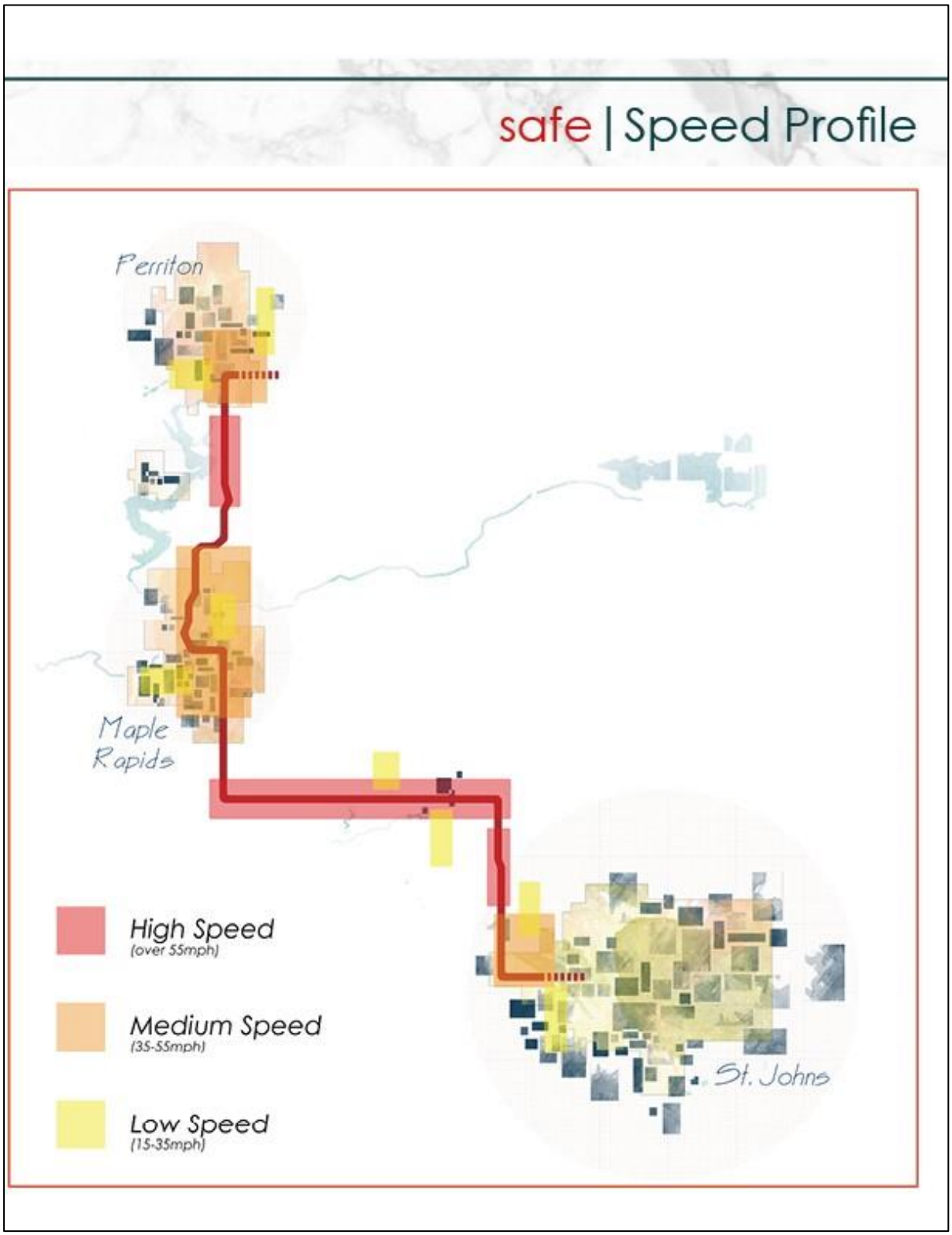

Figure 3.12 This diagram indicates traffic speed profile on site. Specifically, the red area refers to the high-speed zone (over 55mph) where is generally dangerous for cyclist to travel with automobiles. On the other hand, orange area indicates medium speed (35-55mph) which is a tolerable speed for cyclists to travel with automobiles. Finally, the yellow area indicates the low speed (15-35mph) which is the area generally safe for cyclists.

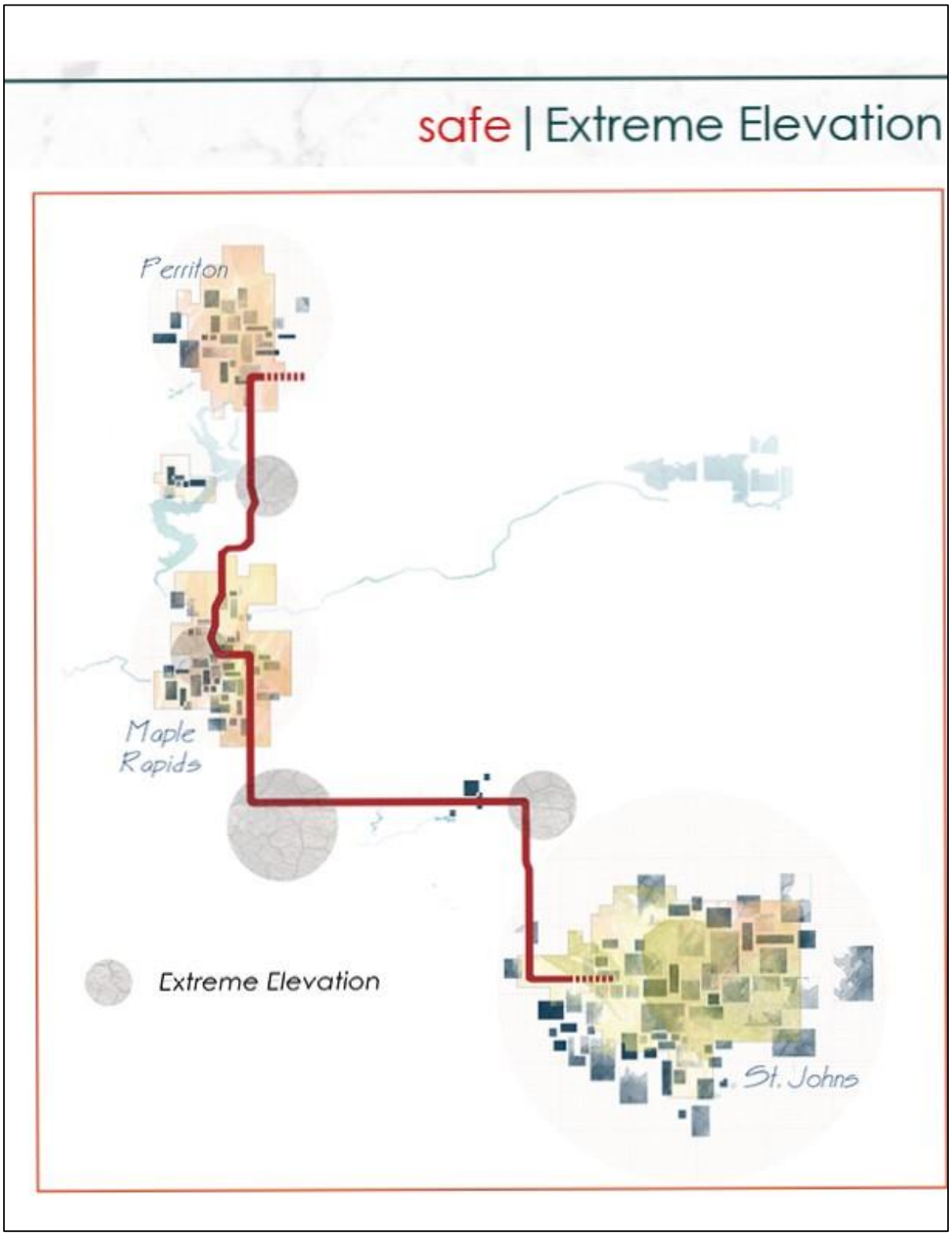

Figure 3.13 The diagram indicates the extreme elevation in the gray circle. In those area, the road slope is generally steeper for cyclists to ride. In this case, protection amenities such as railing, or signage is recommended for bicycling.

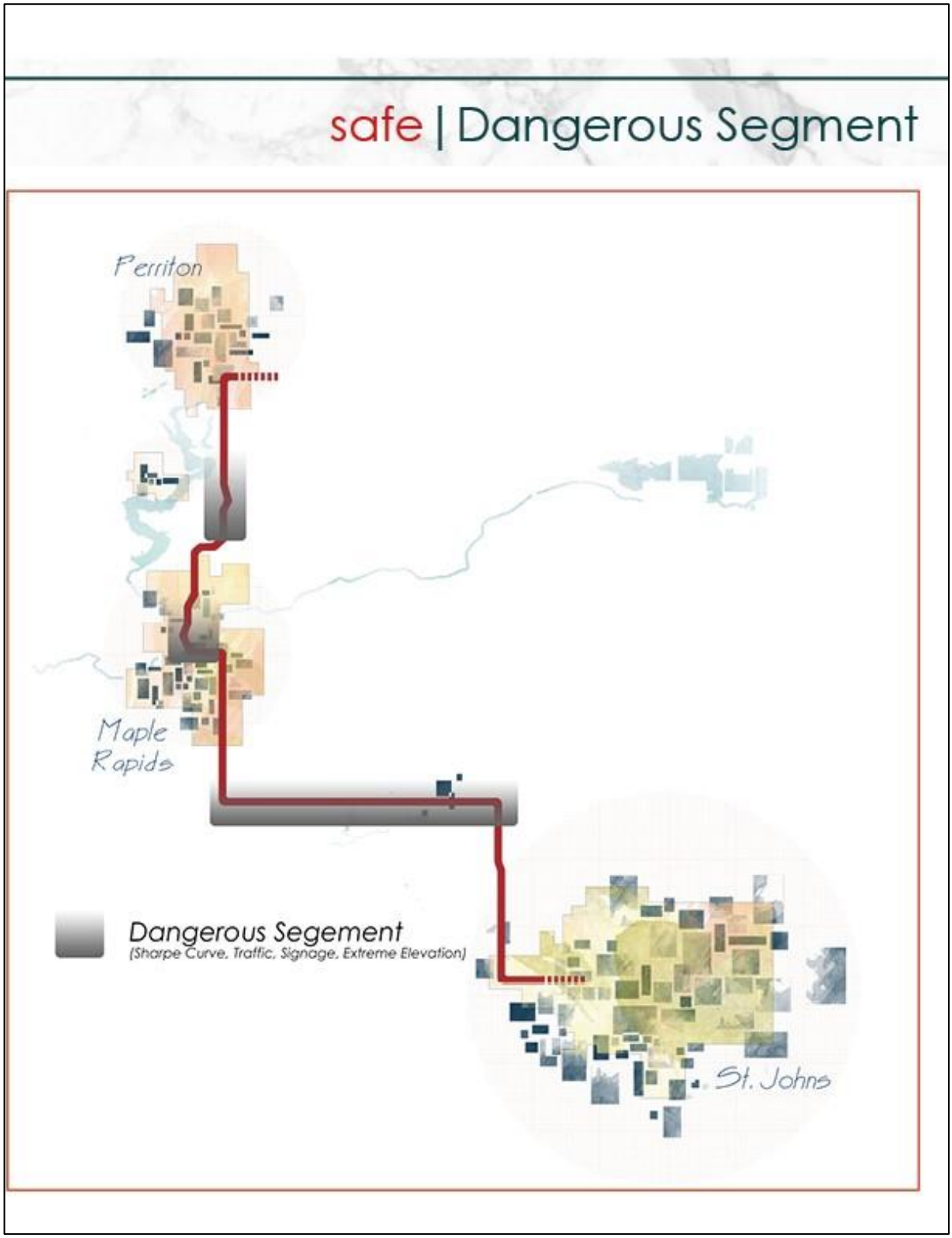

Figure 3.14 The gradient grey area indicates the dangerous segment in this portion of the road. Specific to the topic of dangerous, it refers to the road segment include the elements like shape curve, intense incoming traffic, unclear signage and orientations. These are the areas to be taken under considerations in the design processes.

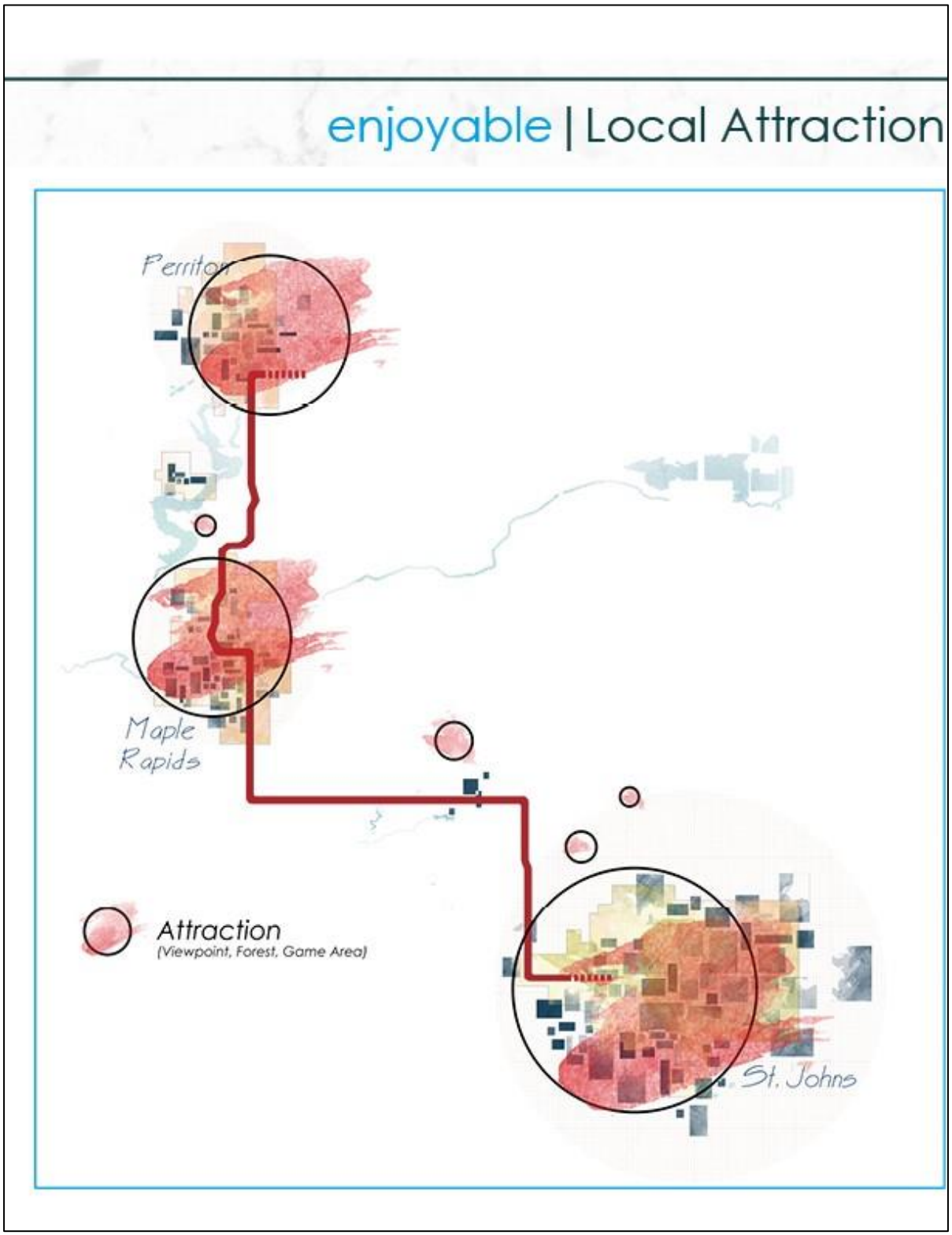

Figure 3.15 In the diagram, the watercolor marked red circle indicate the major attractions in this portion of the road. The biggest attractions are strongly associated within the three townships: St. Johns, Maple Rapids, and Perriton. There are also natural landscape attractions on site such as Maple Rapids National Game Area. Those are the potential locations to build rest sports.

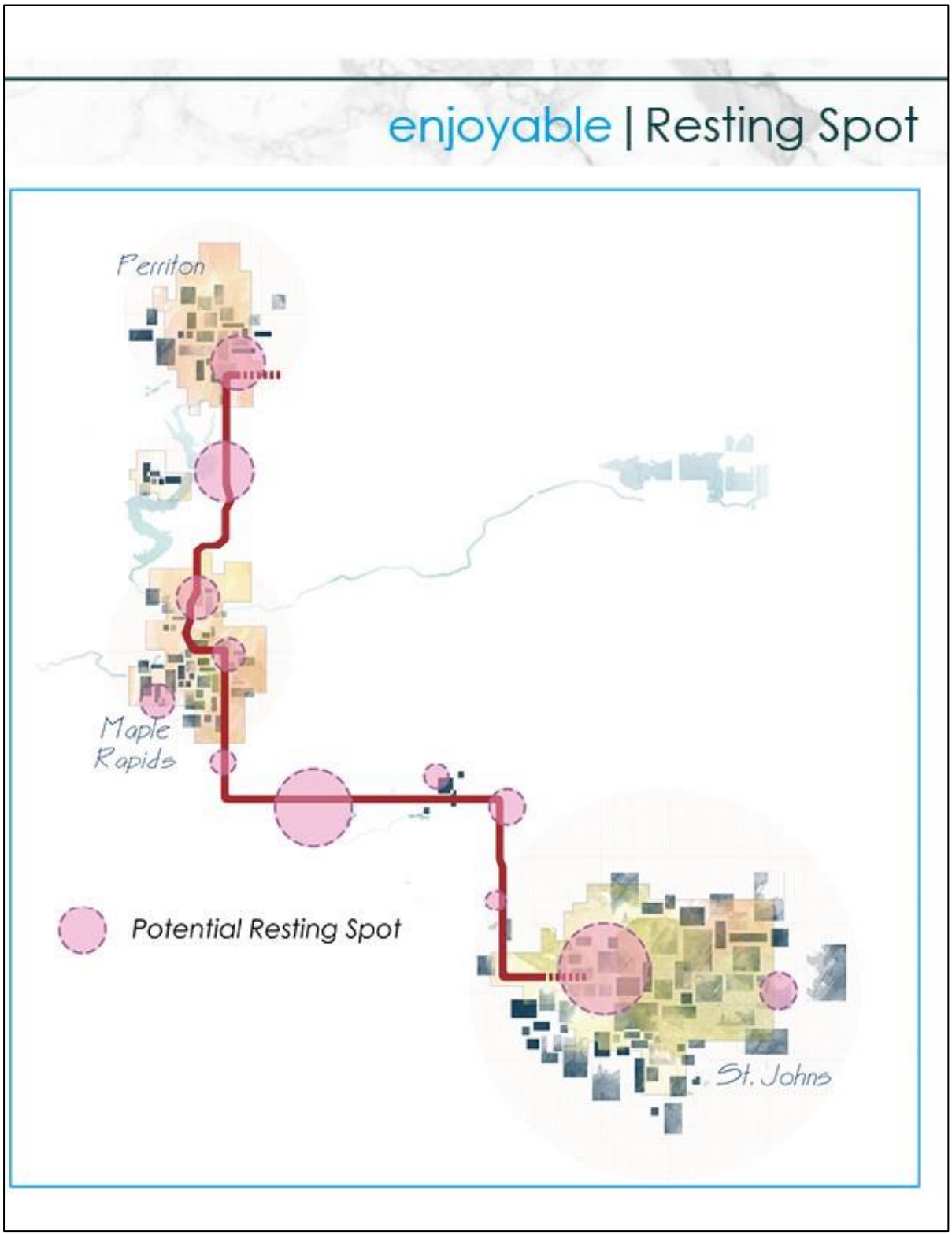

Figure 3.16 The pink circles in this diagram refers to the location for potential rest spots. Ideally, there should be rest spots evenly distributed along the route. In this case, the most practicable locations for rest spots should located closely to the three major townships. Therefore, there are the potentials to associated rest spots with neighborhood communities.

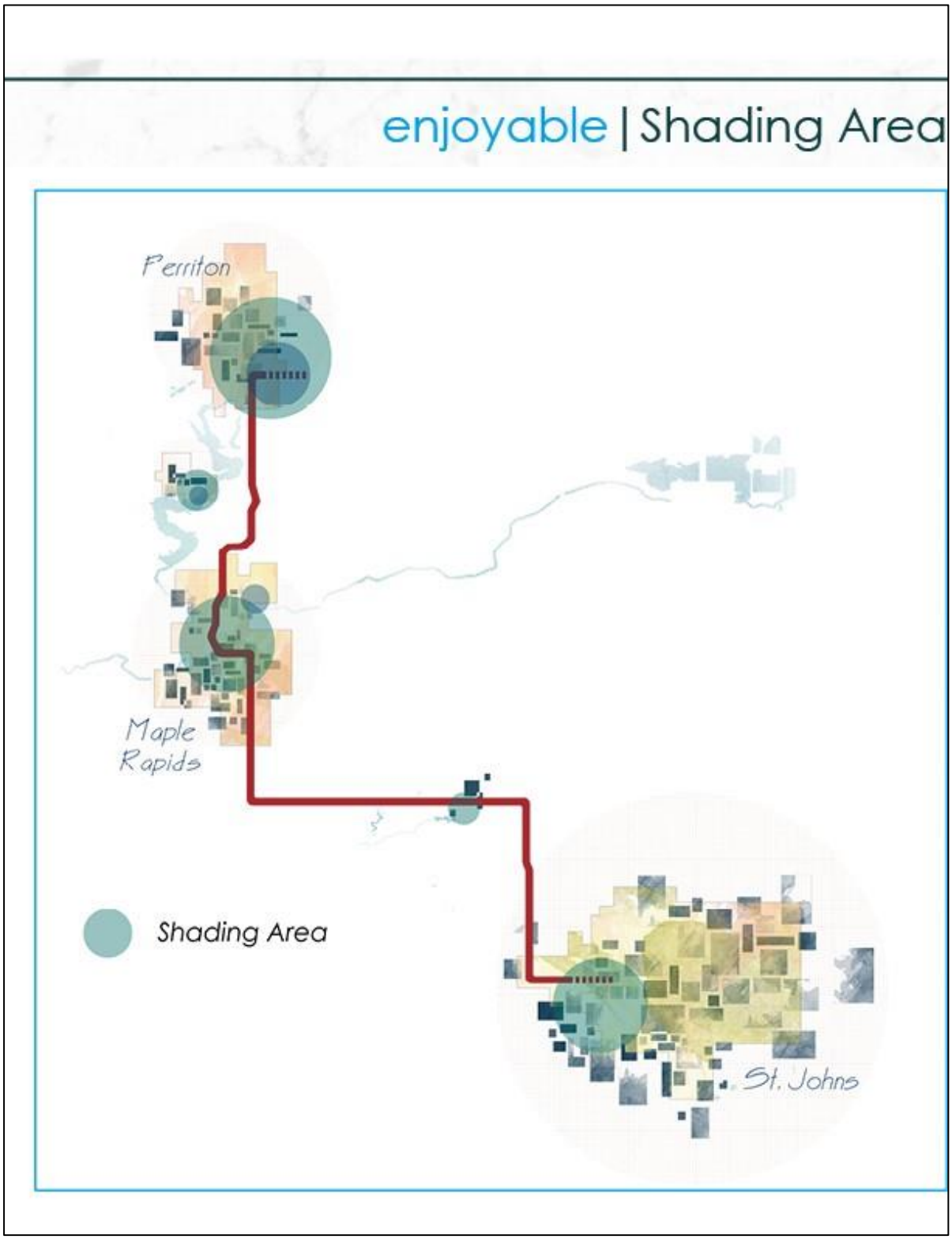

Figure 3.17 In this diagram, the green circle indicates the existing sharing area formed by vegetation and structure. The darker green refers to a more intense level of shading. These are the beneficial area to install rest spots for cyclists.

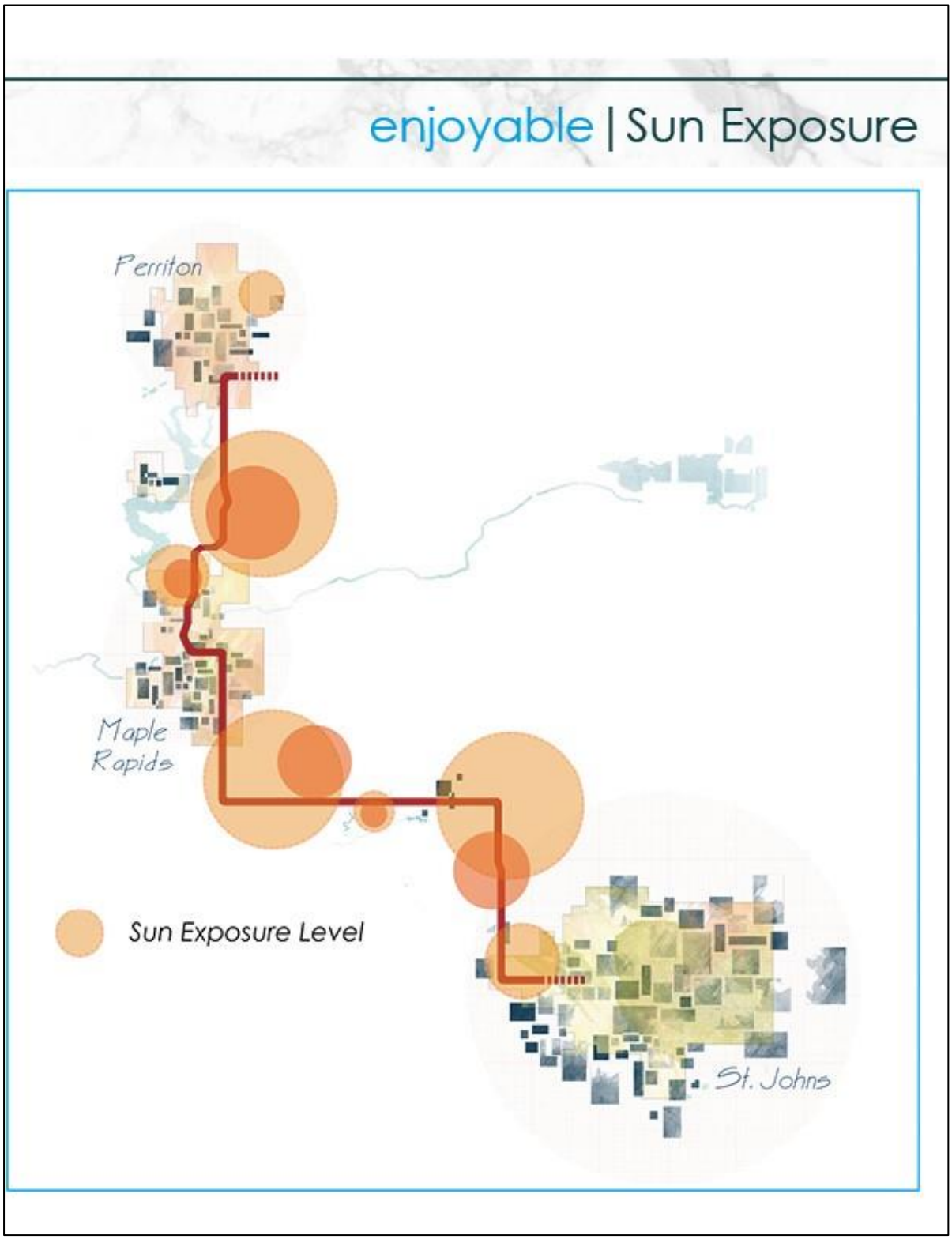

Figure 3.18 In this diagram, the orange circle indicates the sun exposure area. The darker orange refers to a more intense level of exposing. One of the essential considerations here is to protect cyclists from direct sun exposure in extreme weather.

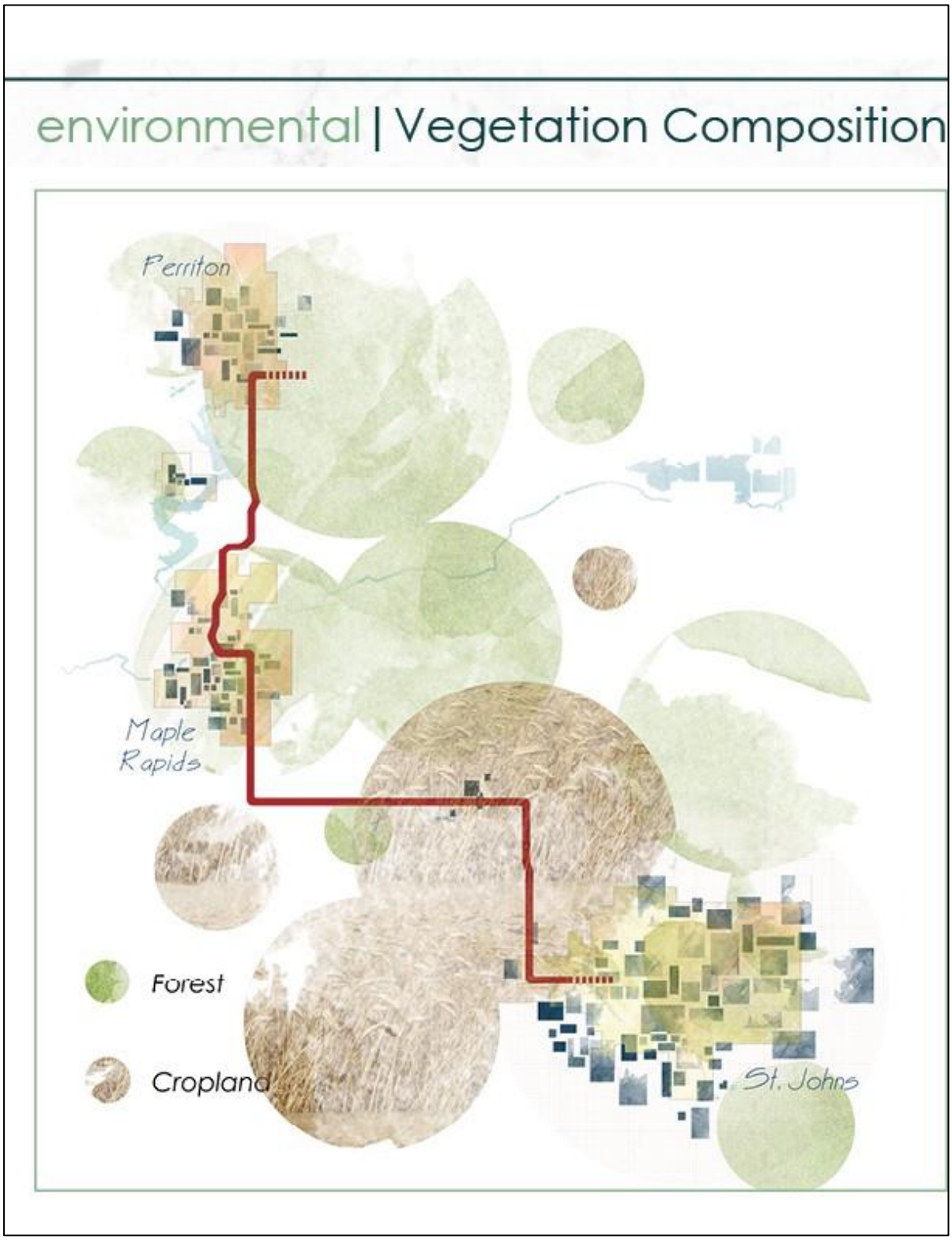

Figure 3.19 Different color circles indicate the vegetation composition on site. The green areas are covered with forest, and the yellow areas area are mainly occurred by cropland. Vegetation composition is an indicator for landscape view presentation. It is important to think about what types of view are available for cyclists.

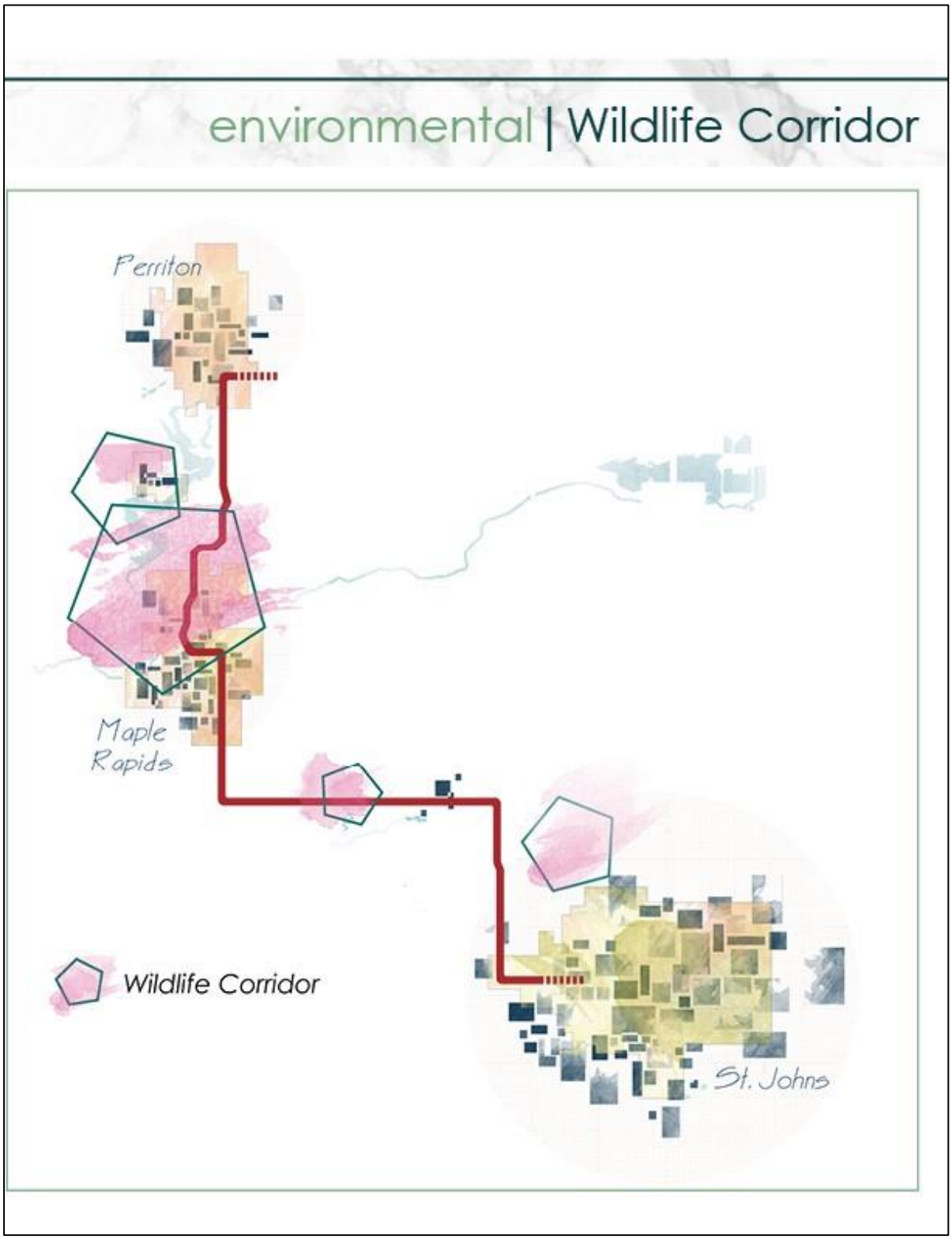

Figure 3.20 In this diagram, the pink polygon indicates the wildlife corridors on site. These are the areas that people could potentially interacted with wildlife. Refer to the previous layer, most of the areas onsite are farmland which means people are possibly to interact with farm animals. For large groups of cyclists consist of different age group, it is important to separated people from nature with a transition zone.

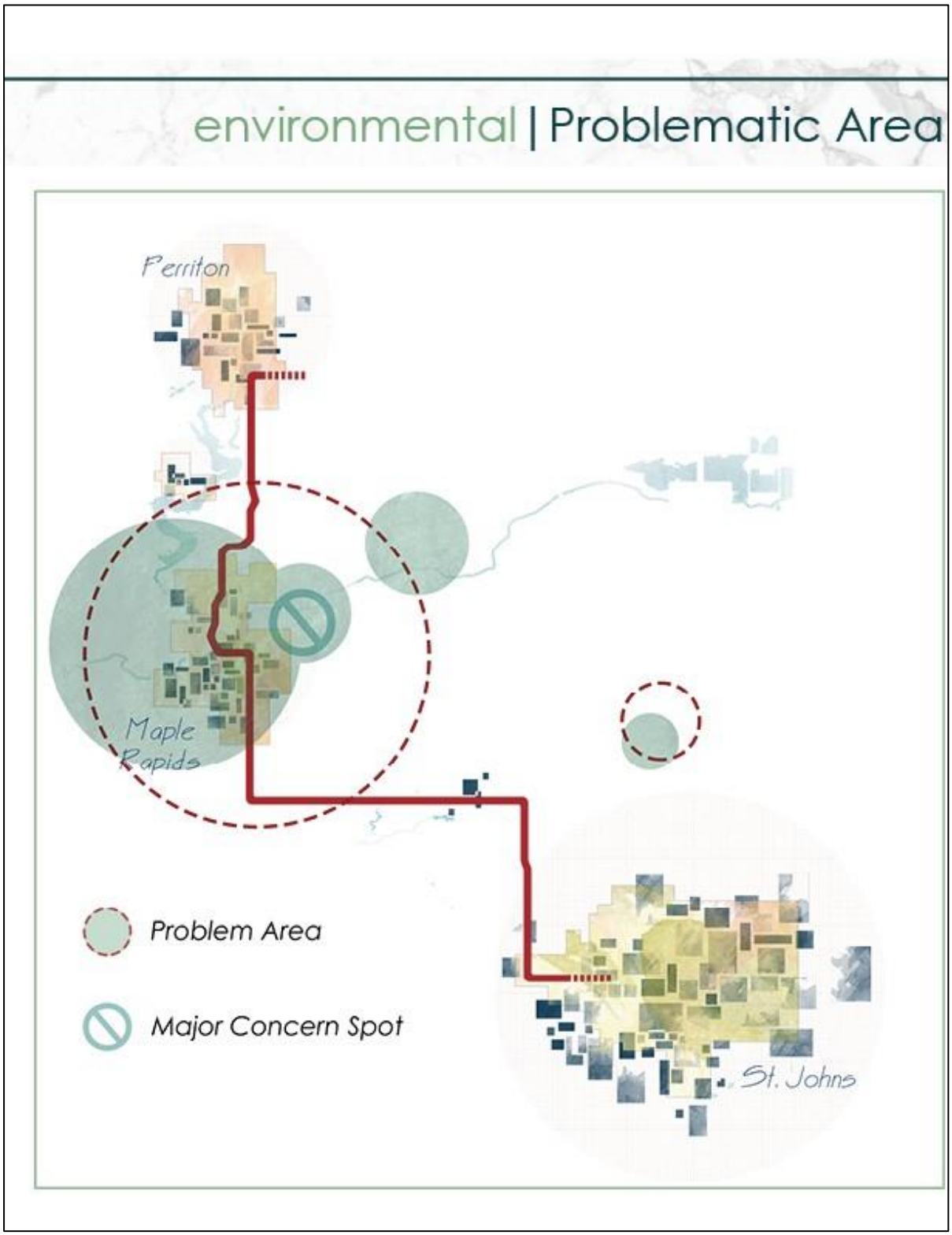

Figure 3.21 The picture indicates the problematic area in green and prohibited symbol on site associated with Maple Rapids National Game Area and Motz Park. These are the area can possibly be impacted negatively by cycling. Therefore, it is essential to define a buffer between human activities in the natural area.

4) Final Concentrated Locations: are the locations achieved through the spatial analysis processes that should be the problematic area overlapped with multiple concerns.

As a result from the spatial analysis, there are three final concentrated areas that contains a series of concerns (see the region of the selected locations in Figure 3.22). The first design region is addressed as Site A, it is the beginning segment of W. Colony Rd, which is the portion of road lacking of applicable cycling infrastructure and bicycle safety facilities. The second design region is addressed as Site B, it the potential transaction zone for cyclists transfer from the City of Maple Rapids into the Maple Rapids National Game Area. The third design region is addressed as Site C, it is the area interacted with Rainbow Lake Community which is an area cyclists can possibly assessed with community as well as the water front riding opportunities.

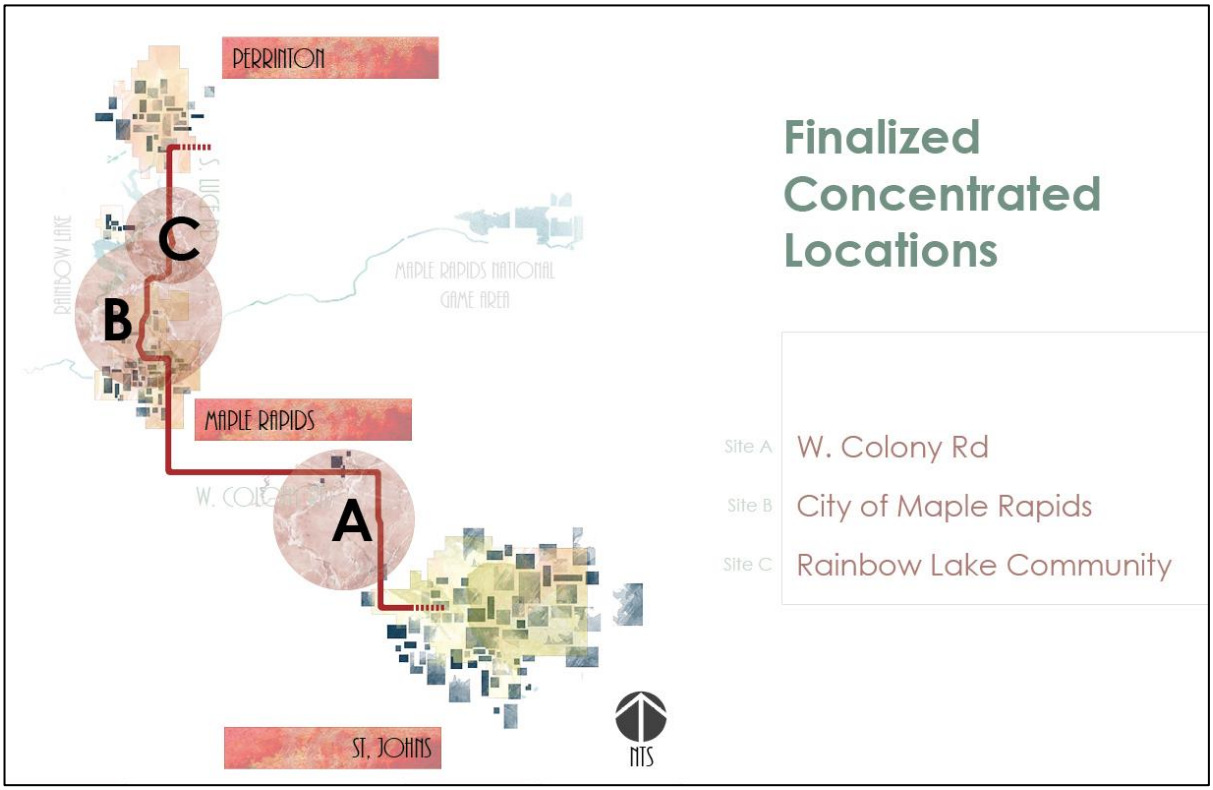

Figure 3.22 Final concentrated locations are highlighted in red circles and marked alphabetically. In this case, Site A is the segment of W. Colony Rd, Site B interacted with the City of Maple Rapids, and Site C is the area associated with Rainbow Lake Community.

c. Design

The third phase is design. This is a creative process that integrates considerations from the analysis as well as combines inspirational bikeway design solutions based upon the literature review section. The design deliverables are going to consist of descriptive paragraphs explaining the concept and amenities, program elements lists, site plans, and

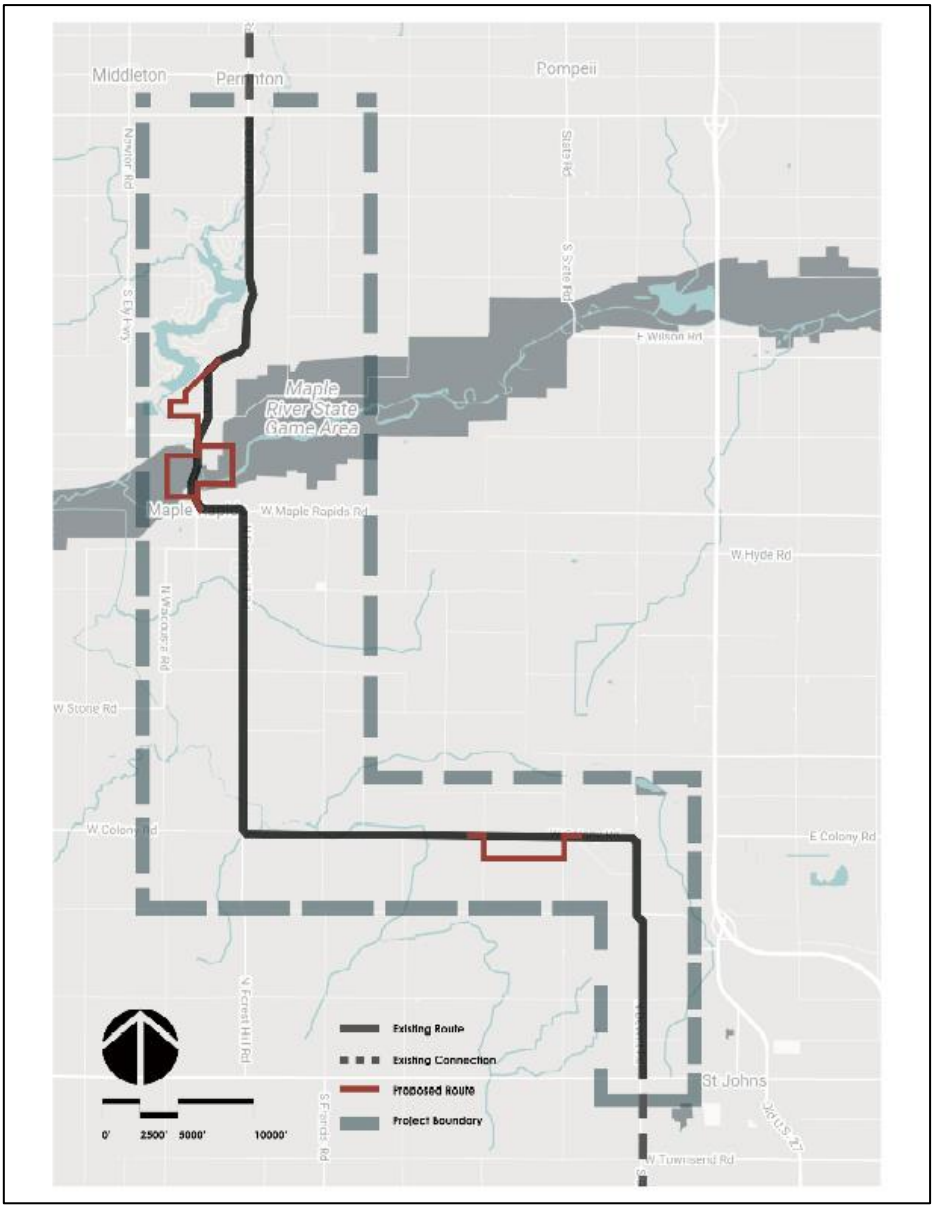

Figure 3.23 This diagram is the master plan of the selected DALMAC segment, as what the legends addresses, the solid black line indicated the layout of the existing route; the dashed black line indicated the existing connections with the DALMAC route outside of the site boundary; and the red line indicated the proposed bike route region on the site.

vicinity maps.

In the design process, the first step is to compose a master plan (see Figure 3.23) so it can be implemented as a key map for future design plans. Since there are 5 treats for one site, there are going to be total of 15 design products.

Design Treatment 1 Site A: the existing conditions in W Colony Rd. (see Google Maps, 2018 Figure 3.24)

The W Colony Rd. is interacting with both N Dewitt Rd. and W Kinley Rd. extending from the city of St. Johns, and the road stretches a long distance toward the west. The whole route is surrounded by farmland and some residential complexes. There is no designate bike path for bike users, the DALMAC participants are likely to ride on the narrow road shoulder. From the traffic section of the inventory analysis process, there is no traffic lights and proper signage system for both automobiles users and cyclists. The only signage system is series of

Figure 3.24 The screenshot indicate the plan view along W Colony Rd. from: "D&K Bike Services, Michigan." Map, Google Maps. Accessed on: 2018, April 07. Copyright © 2018 Google, all rights reserved, used by permission.

stop signs installed at every intersections. Thinking from the aspect of weather protection,

there is no public hard structure, such as shelters. Due the loose distribution of residential complex, there is no groups of shading tree that can be utilized. Generally, cyclists are not protected from extreme weather conditions. Moreover, due to the poor population density, there is no resources of proper accommodation along the route. From the overall consideration, it is not an ideal environment for groups of bike users.

Design Treatment 2 Site A: the balance treatment of W Colony Rd. (See Figure 3.25)

This design is a medium size resting spot along W Colony Rd. The detailed site location is on the portion of the W Colony Rd. between the N Grove Rd. and N Airport Road. The site is chosen because the existence of a bike service store (D&K Bike). Therefore, it become a possible location to expend resting spot. The goal is to achieve the balance to between the goals of safe, enjoyable, and environmental. The site design can achieve the safe goal by having a wider landing zone and an obvious wayfinding system onsite. There are also service stations highlighted in different color zones for people recognize different services from a further distance. Achieving enjoyable by implementing bike parking lots, water feature and picnic locations on site. The design can address the aspect of environmental cycling by implementing more green spaces on site and maintain as much as existing farmland on site. However, the site will be focused more safe and enjoyable aspects. due to the newly input

construction, the site will be less environmental.

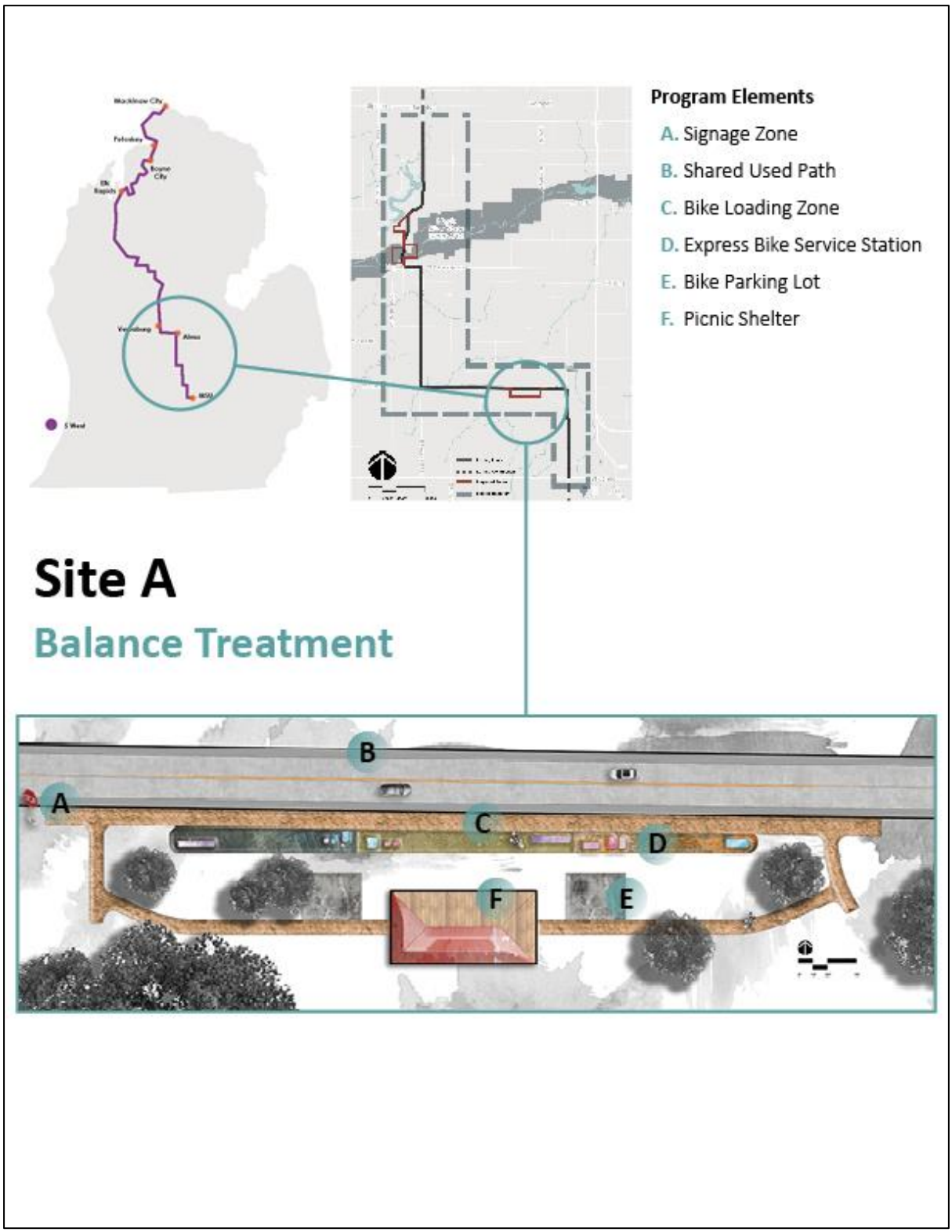

Figure 3.25 The balance treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

Design Treatment 3 Site A: the extremely safe treatment of W Colony Rd. (see Figure 3.26)

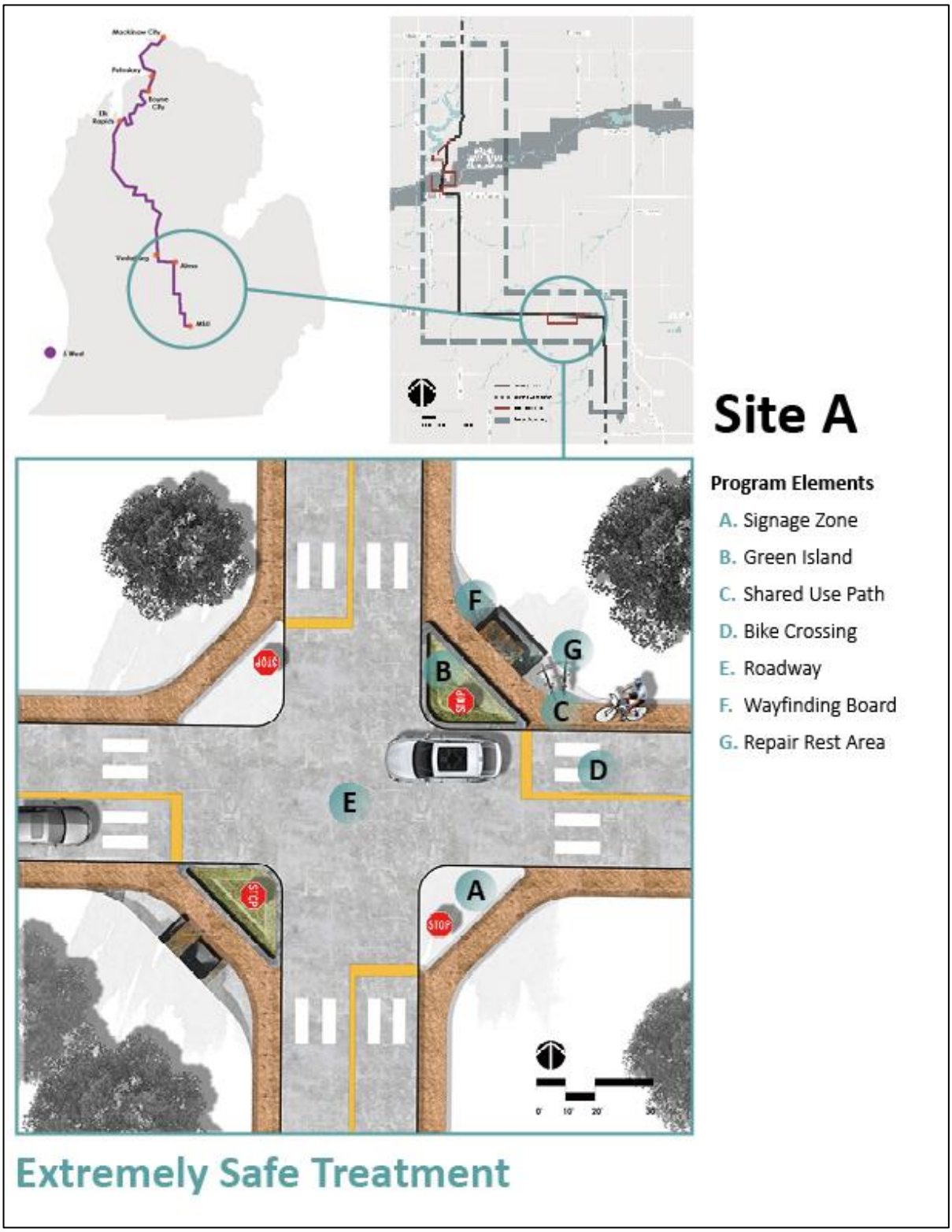

Figure 3.26 The extremely safe treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

This design contains a Dutch bike intersection treatment. The detailed location is at the

intersection of N Airport Rd and W Colony Rd, which is the busiest corridor due to existence of residents and incoming traffic flow from Banner Road. The location is chosen because it is a practical and valuable location to implement a Dutch intersection. The goal is to design this segment of bike route being extremely safe. There are many unorganized intersection along the route. Due to the existing traffic conditions onsite, in this case, there are only stop signs, there is no traffic lights; the idea is to implement a Dutch intersection treatment on this intersection or any similar intersection. The Dutch intersection used raised planters as a buffer, which can potentially increase the safety level. While the bike entering the zone of intersection, the surface of the road is painted into red or possibly any other obvious color to notified both automobile users and cyclists. In the ideal situation, the cyclist will pass the crossing on the paved route followed the rule of stop signs. Additionally, there are wayfinding facilities and a small repair station also be implemented to prevent cyclists lose from the track and also prevent cyclist injured from any mechanical accidents. Therefore, this design is implements as an extremely safe corridor.

Design Treatment 4 Site A: the extremely enjoyable treatment of W Colony Rd. (see Figure 3.27)

This design is farmland trail enjoyable area along W Colony Rd. The detailed site location is on the portion of the W Colony Road between the N Grove Road and N Airport Road just as the safe treatment location. The site is chosen because the existence of a bike service store (D&K Bike), and there is the possibility and impact to gathering people to here. On the

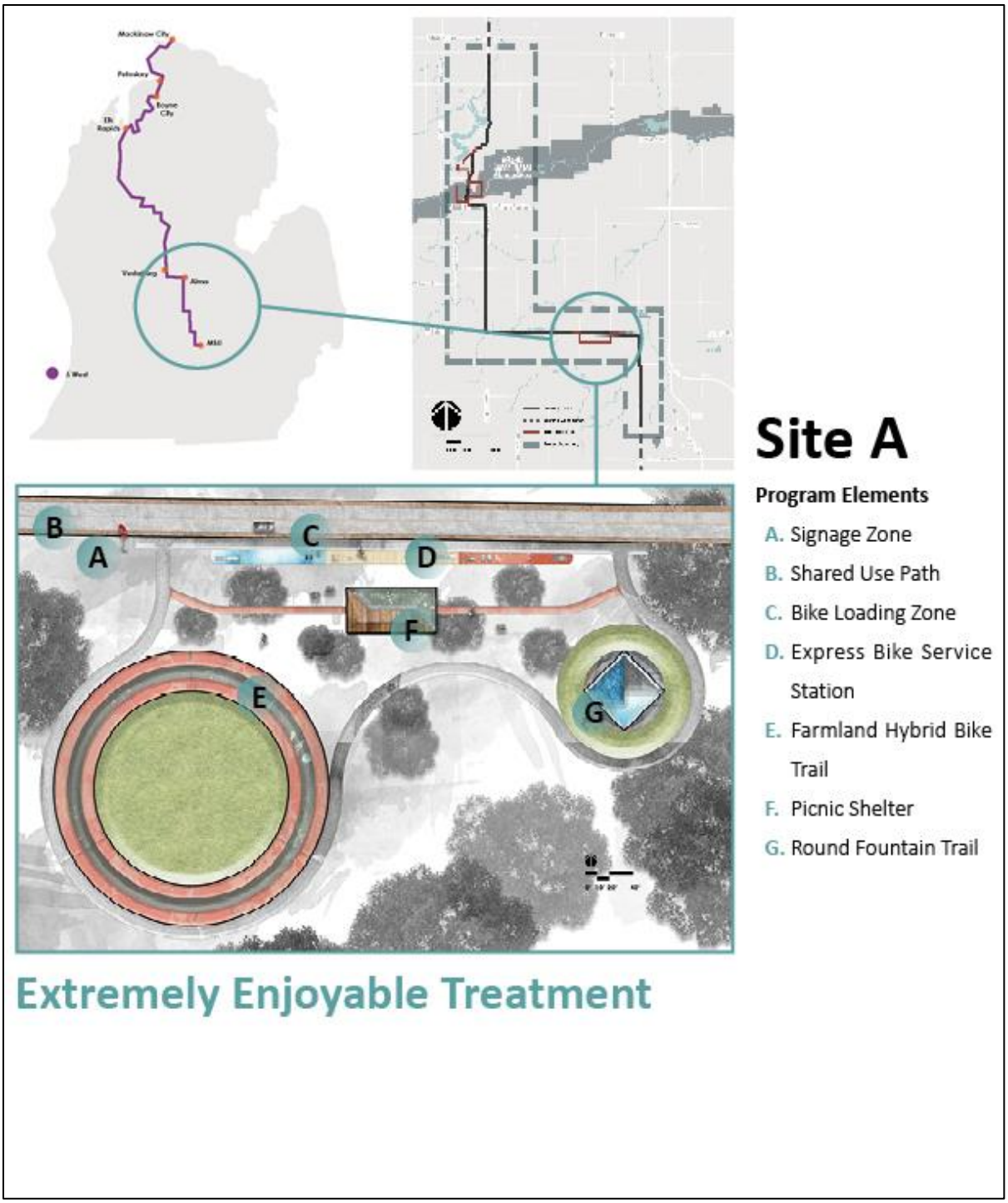

Figure 3.27 The extremely enjoyable treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission

site, there are various interactive elements other than the safe treatments. There is a wider landing zone for bike to turn in, and there is a bike service station highlighted in different color paving for further away visual reorganization. On the enjoyable aspect, there is an

elevated/sloped hybrid farmland loop lies in middle of the farmland, where cyclists can enjoy the view of farmland with their friend and family. There is also a fountain elements on the east of side for expend water feature service and an aquatic elements especially in the summer time. Because of all the installation of new hardscape and structure, there will be certain level of environmental impact and disturbance toward the surrounding natural environments. By having the elements like organized signage zone and landing area, this bike experience will be safer and more enjoyable. However, the site will not match the environmentally friendly aspect.

Design Treatment 5 Site A: the extremely environmental treatment of W Colony Rd. (see Figure 3.28)

This is an environmental treatment follow the pattern of safety intersection. Same as the safety treatment located in the same location, there is a crossing bike way, stop sign zone and treated Dutch intersection on site. The essential elements will be maintained for service. However, in order to treat the segment being more environmental, decorations will only be embedded into ground for wayfinding system. There is no hard structure other than that. There will be no stopping point, the overall design tends to lead people to pass this intersection more safely. In this case, there will be no additional waste treatment. However, the site will maintain the existing planting as possible not only for environmental issue but also have a noise pollution block for the neighborhood. Therefore, the overall site will be safer for riding and be more environmental responsible for the neighborhood; however, the disadvantage will be the lack of interactive enjoyment for cyclists.

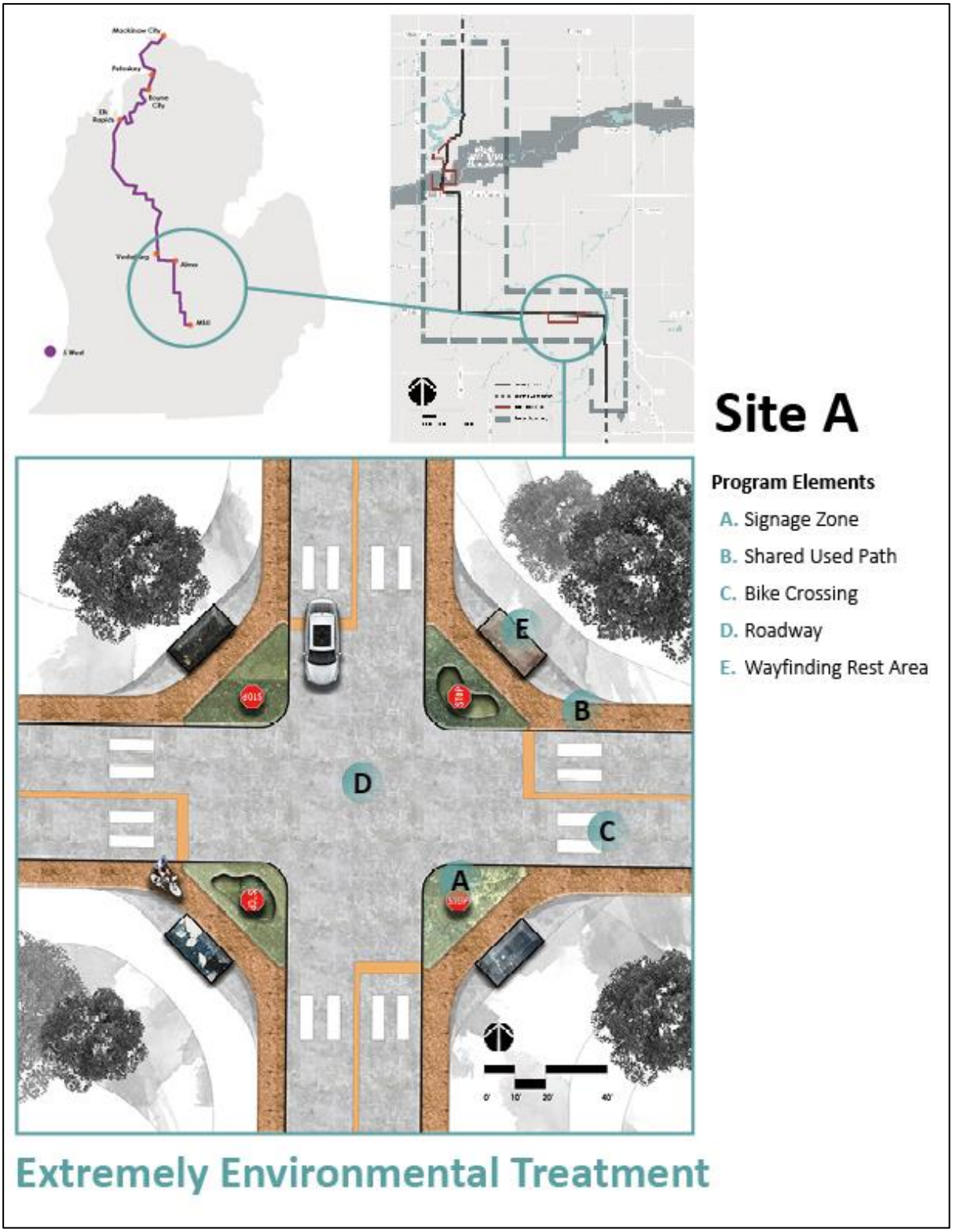

Figure 3.28 The extremely environmental treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission

Design Treatment 1 Site B: the existing conditions in City of Maple Rapid (see Google Mpas, 2018, Figure 3.29)

The city of Maple Rapids is a relatively small township along the DALMAC route, the overall road condition is acceptable for riding. Similar to the W Colony Rd segment, there is no designated bike path, which means the bike users are sharing the road with automobile users in majority of the time. The traffic guiding system is more complete with the installation of traffic lights, turning signs, and pedestrian walk. Due to the poor population

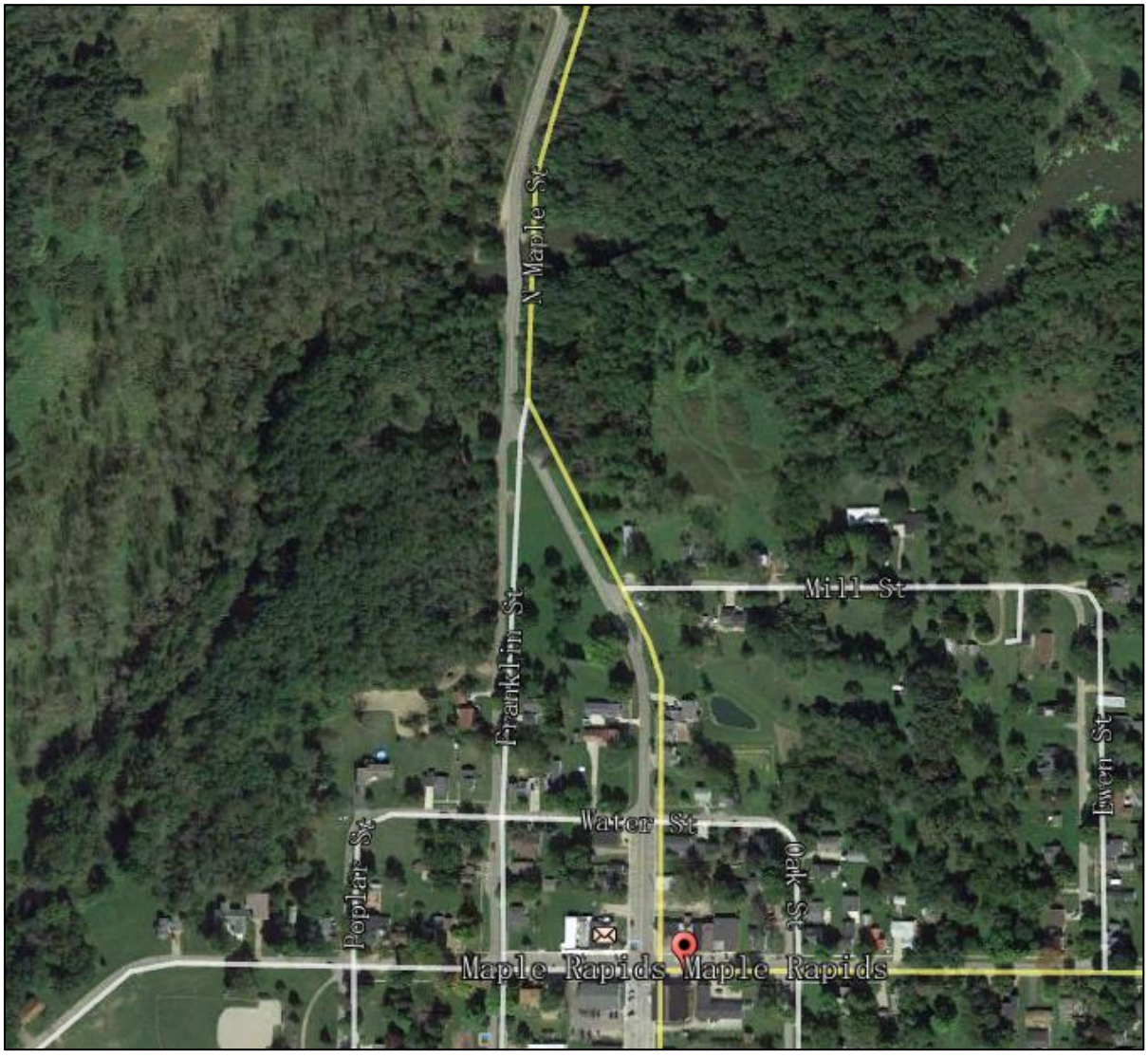

Figure 3.29 The screenshot indicate the plan view along in the City of Maple Rapids. from: "Maple Rapids, Michigan." Map, Google Maps. Accessed on: 2018, April 07. Copyright © 2018 Google, all rights reserved, used by permission.

density, there is not a lot of traffic conflicts with automobiles users. Moreover, the average speed is around 25 to 35 mph which is a more safe speed zone to travel. The main road has been utilized for the event is N Maple St. One of the main attraction along the road is the Maple Rapids Game Area, which provide participants the opportunities to explore the natural landscape. Additionally, Maple Rapids neighborhood is one of the community willing to provide some sorts of accommodations for participants. This action also make the city of Maple Rapids a potential locations for rest spots. As far as providing extreme weather protections, Maple Rapids is a location that contains more resources such as shading trees and overhead structures.

Design Treatment 2 Site B: the balance treatment of City of Maple Rapids (see Figure 3.30)

This design is greenway rest area located in the north end of Maple Rapids, right before existing the bridge crossing Maple River. The site was selected because of the existing green space. By utilizing the green space, this rest area can be functioned as multi-functional area contains various service. There is the picnic shelter, bike parking space, and internal green bike loop for entertainment and wayfinding service. Another important feature is that this rest area is connected with the existing trail in the Maple Rapids Game Area, which provide DALMAC participants another opportunities to explore the natural and increase their physical exercise quality. Both of the entrance toward rest area are treated with a simple traffic island to enhance the safety level for bike crossing. There are more bike-oriented signage been installed along the major road way. Additionally, due to the characteristics of existing topography, several green spaces can also contributed toward drainage issues as

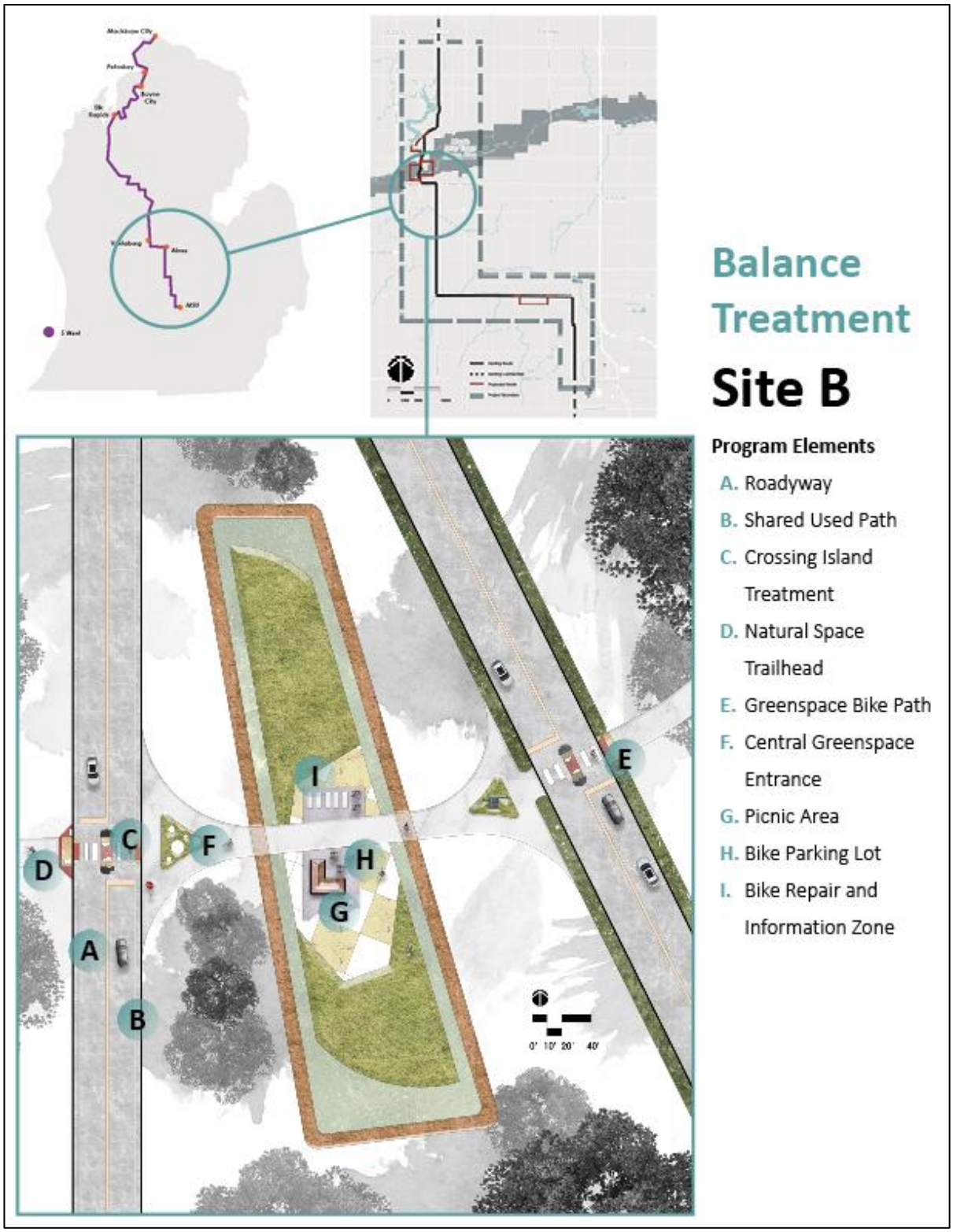

Figure 3.30 The balance treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A.

rain gardens. Due abundant resources on site, the site can potentially accomplish all three promoting concepts. However, due to the existing traffic policies and guidelines, cyclists are

still sharing the road with automobile users by riding on the road shoulder. This is one of the disadvantages toward the aspect of being safe.

Design Treatment 3 Site A: the extremely safe treatment of Maple Rapids (see Figure 3.31)

This design features a bollard crossing treatment to the Franklin St. This site is chosen because its proximity to the unused greenspace and the Franklin St. is also the connection road to the existing trail in the Maple Rapids Game Area. The goal is to encourage cyclists to access the local attractions through the treated route. It will minimize the riding time on the road shoulder. In this case, the road shoulder will also be treated to implement more bike-oriented signage. In example of the bollard crossing system, it is functioned for double ended. There is a traffic island sort of sitting in the middle. It is a more advanced version of traffic lights; when there is automobile passing by, and the cyclists and walkers are in the island area, the bollard will rise up to block people crossing the. The bollard will lower down when the road is free of traffic. At the entrance of the Maple Rapids Trail, there is trailhead area for information and simple seating services for resting. The site design concept address the issue related with safety; then there are still disadvantages toward being enjoyable and being environmental. However, there are not a lot of new construction been implemented onsite expect the installation of bollard crossing system.

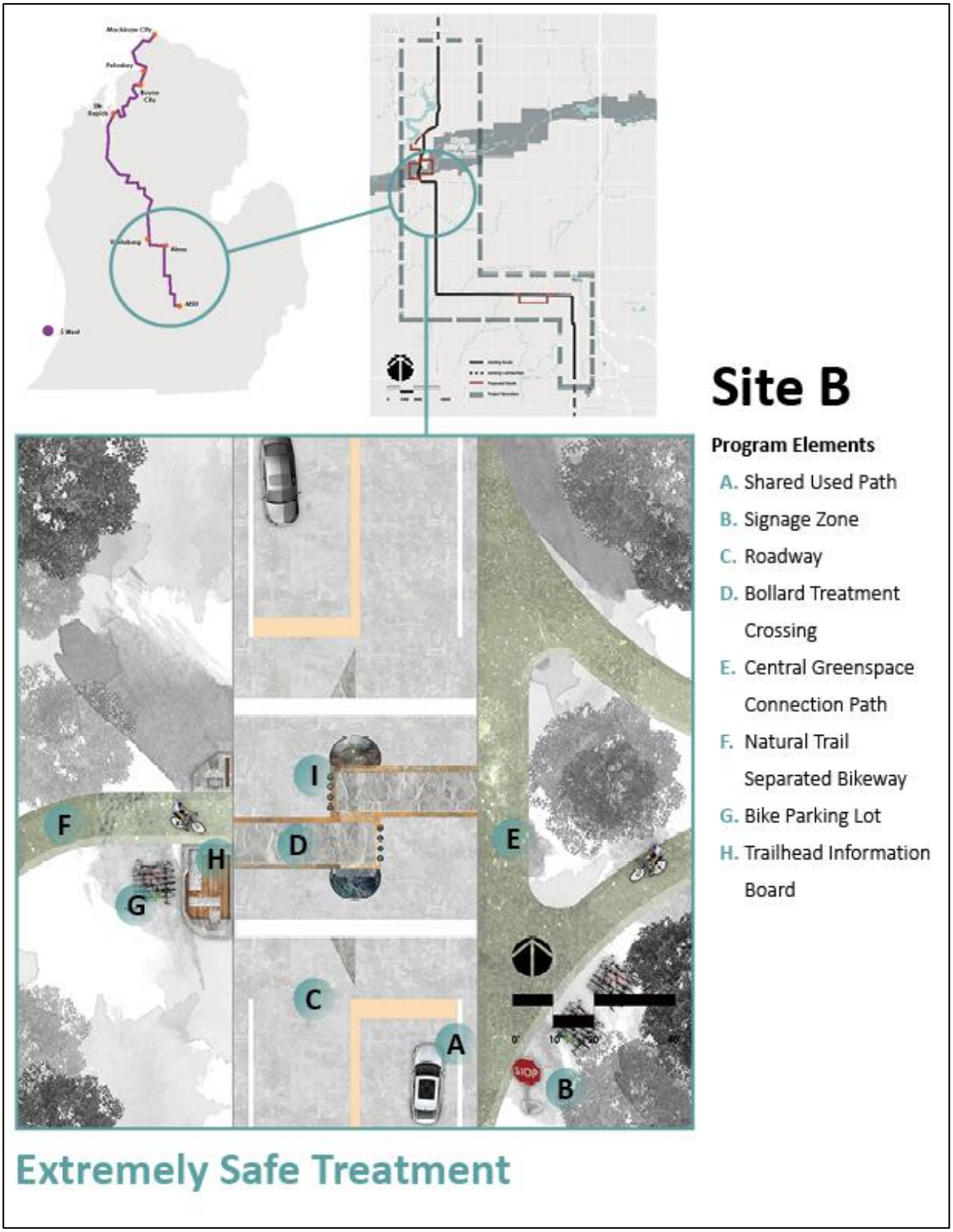

Figure 3.31 The extremely safe treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

Design Treatment 4 Site B: the extremely enjoyable treatment of Maple Rapids (see Figure 3.32)

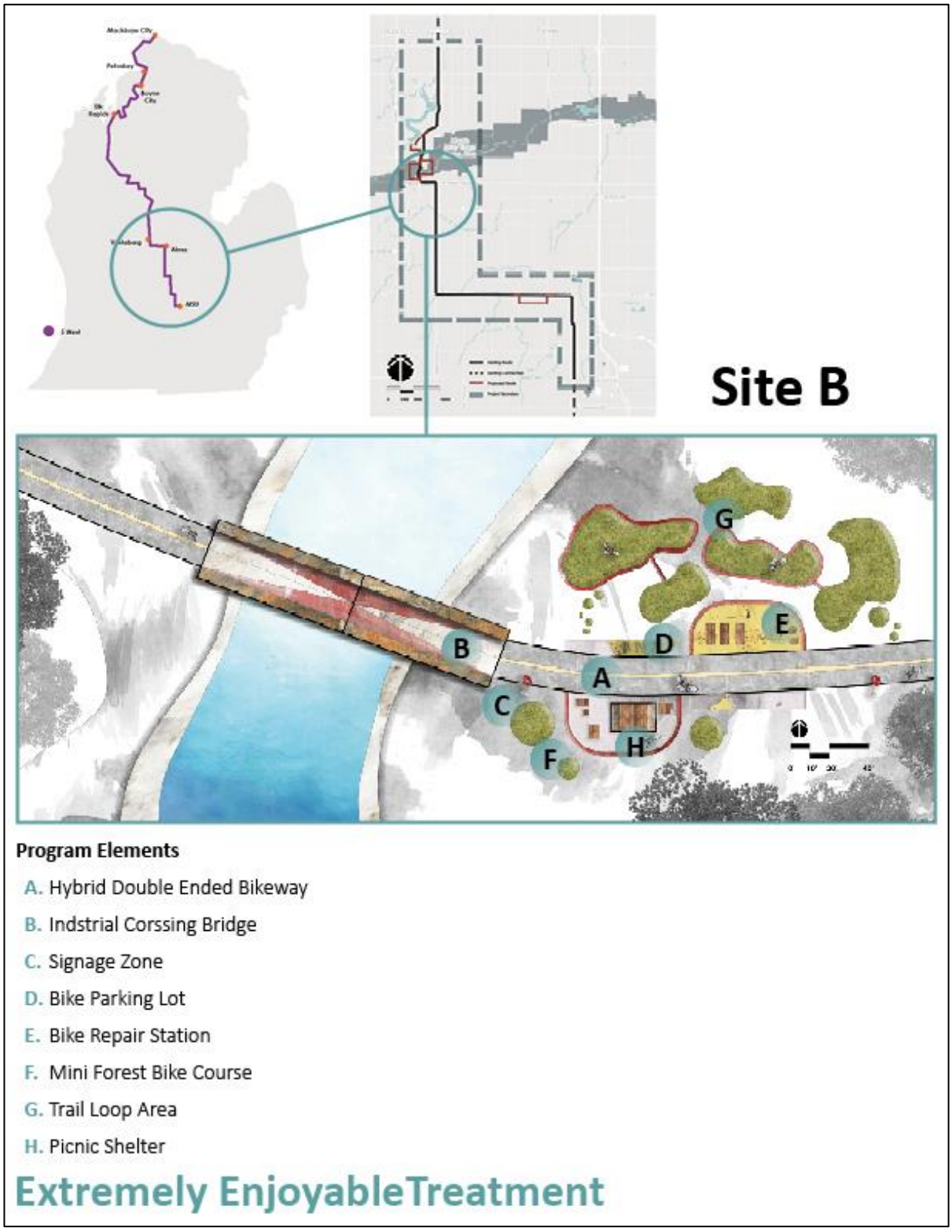

Figure 3.32 The extremely enjoyable treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

This design is a proposed segment for the existing trail. It is located at the bank of Maple River, which is located on the west side of Maple Rapids Township. This design idea take advantage of the existing trail and remains the bridge structure. The newly proposed crossing bridge will maintain the metal material and providing a semi-open shelter like structure for bikers to travel through. The bridge will be safe for both pedestrian and cyclists. In the ideal condition, there are two opposite lanes, and cyclists can ride on the bike lane. For the pedestrian user, they can walk on the raised edge. Additionally, bike users can also walk their bike with their friends/family. Moreover, the bridge will be a great viewpoint to attract to people travel to this hybrid trail. This bridge can also build connection to the existing bridge located right outside of the maple rapids township. Other essential service and facilities such as bike parking lots, repair station, and dining area are still provided. The riding conditions will be generally safe since it is cycling only route, which indicates the overall speed is relatively low. Conflicting with hikers and pedestrian users are less risky than automobiles. However, with all the new implementation, the consideration of achieving environmentally friendly will be less.

Design Treatment 5 Site B: the extremely environmental treatment of Maple Rapids (see Figure 3.33)

This design is a promotion of the concept of ecotourism through improving the quality and quantity through bike –related business along the N Maple Avenue. This is decent location because the existence of retail stores and its proximity to the existing Maple Rapids Game Area Trail. By approaching the ecotourism will not only contribute to the economic

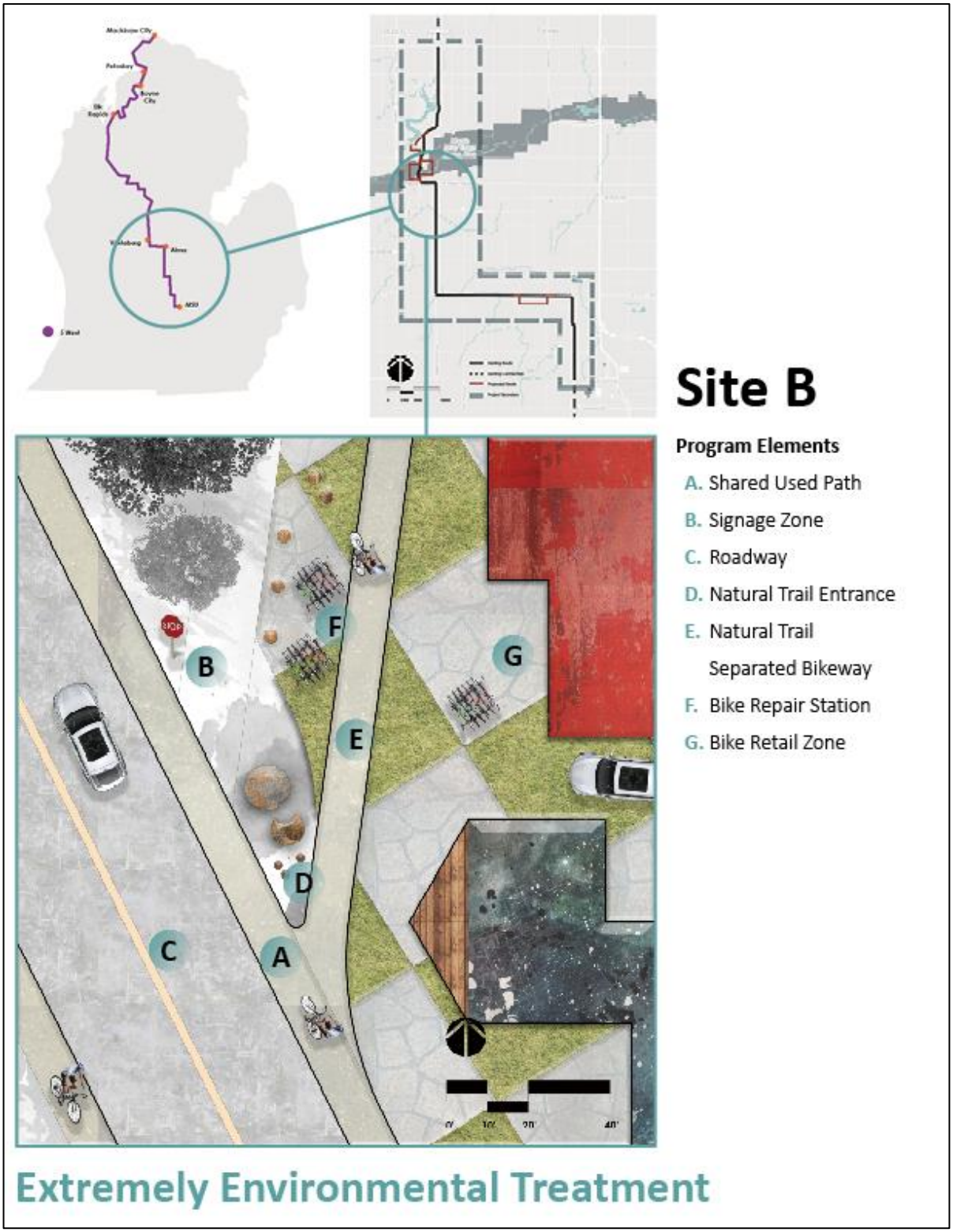

Figure 3.33 The extremely environmental treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

growth of the area, it will also educated DALMAC cyclists to be aware of the environmental projection of the Maple Rapids Game Area trail if they choose to ride. Most importantly,

cyclists can directly enter the trail by turning from on the road shoulder of N Maple Avenue, which makes the overall process more convenient and direct. In order to minimize new construction, the signage and wayfinding system will be provided in a more landscape sculpture which is differently from the classical trailhead sitting. Along the trail, the essential services of bike parking and repair services will be provided. Between the trail and the proposed retail zone, there will be a block of trees proposed to function as the natural noise buffer. Therefore, the retails and surrounding neighborhoods will be free from extreme noise pollution from both cyclists and automobiles. In this case, there is no additional treatment on the safety aspect other than the implantation of bike-oriented signage. As far as the enjoyment aspect, the site doesn't have tons of interactive facilities other the natural beauty in the Maple Rapids Game Area.

Design Treatment 1 Site C: the existing conditions in Rainbow Lake Community (see Google Maps, 2018, Figure 3.34)

Rainbow Lake Community is another a residential complex located on the northwestern of the city of Maple Rapids, it is also regionally close to the town of Perrinton. The major roadway on the west side of the site is S Luce Rd, which is relatively high speed roadway contains multiple turns and curves. It is not a necessary safe route for large group of cyclists. Due to its relatively high population density, there is certain level of conflicts with cyclists and local residents from the entering/exiting traffic flow. Due to the property of residential area, there is definitely limitation of traffic guiding system. In most of the case, people have implemented stop signs to treat potential intersections. There is no sufficient traffic lights

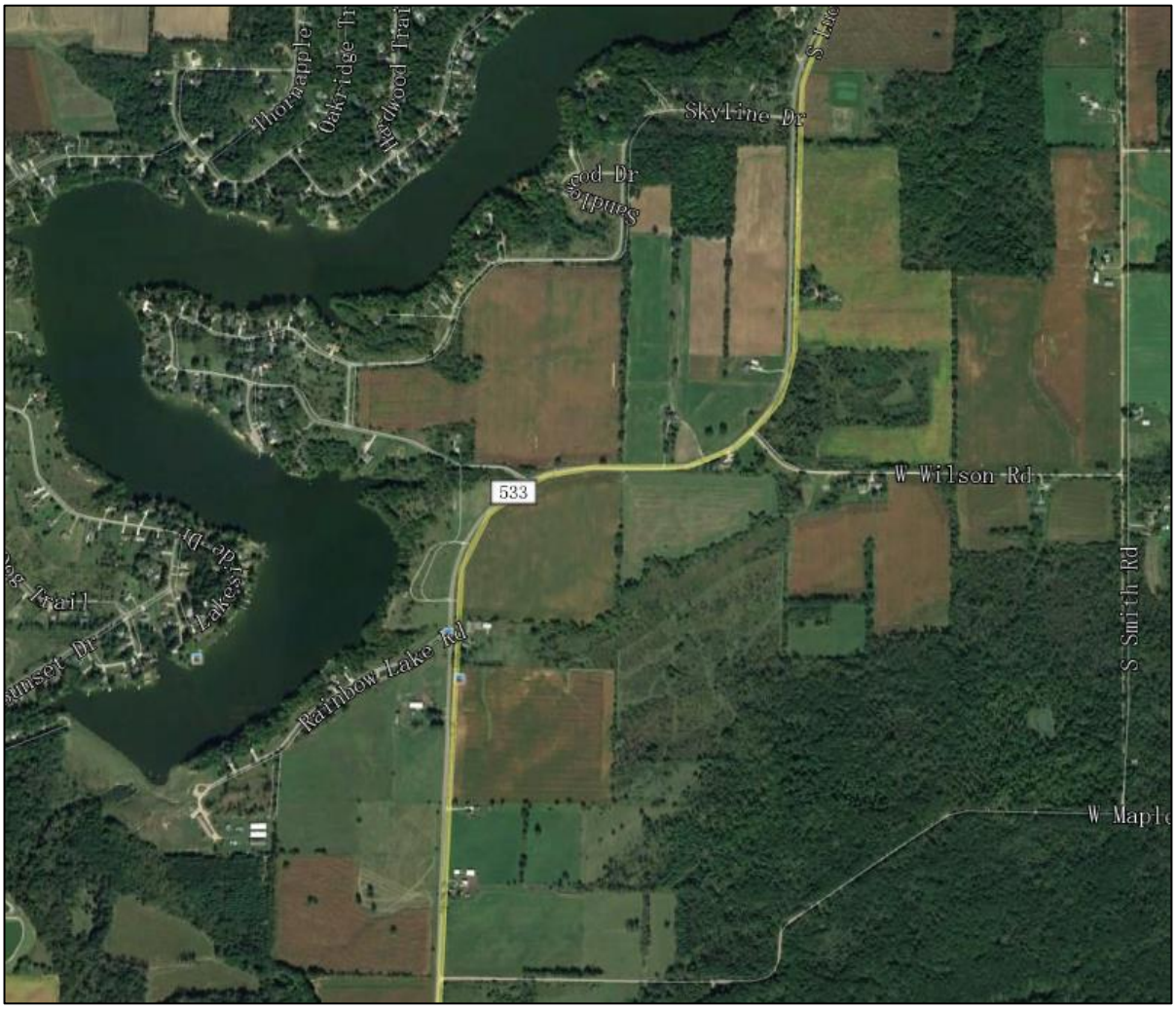

Figure 3.34 The screenshot indicate the plan view in the Rainbow Lake Community area. from: "Rainbow Lake Community, Michigan." Map, Google Maps. Accessed on: 2018, April 07. Copyright © 2018 Google, all rights reserved, used by permission.

and crossing onsite. One of the natural attractions on site is the Rainbow Lake, which brings the potential of water-front riding. Additionally, the existing landscape is a valuable resources for future natural bike route development. According to the research, majority of the Rainbow Lake Communities are cooperating with the DALMAC event, and willing to provide certain levels of the accommodations for the participants.

Design Treatment 2 Site C: the balance treatment of Rainbow Lake Community (see Figure 3.35)

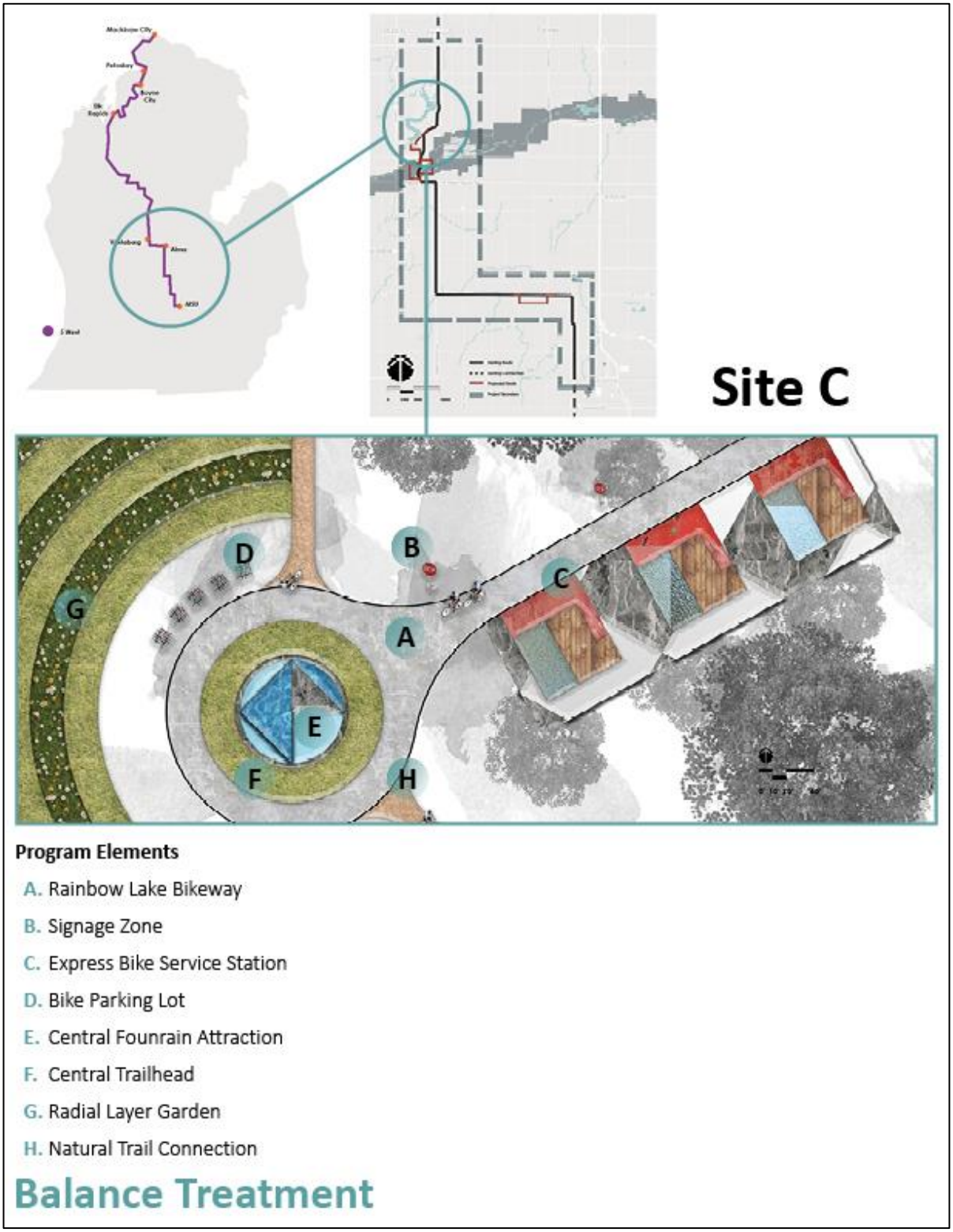

Figure 3.35 The balance treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A.

This design is located on one of the road branch of S Luce Rd at the southeast edge of Rainbow Lake. The site is selected due to its proximity to the water front of Rainbow Lake.

The road branch of S Luce Rd is now proposed to be cycling only; the DALMAC participants can reach a community hybrid trail within the area. The main attraction of the trail is it contains the features of water-front riding and natural forest riding. In the trailhead, there are also multiple services has been applied. There are three express services station have been provided for any kind of bike repair and rest services. At the entrance of trailhead, there is a fountain installed as a welcome landmark. As the backdrop of the trailhead, there are blocks of radial shaped planting strips laid by slopes so it can function as a green filters for rain storm or flooding issue. There are two entrances for the trails, there is wayfinding signage to the trail and the overall DALMAC orientation. Before entering the trails, there are bike parking lots provided if the DALMAC participant's decide to enjoy the hybrid trail by foot. In the future, when the site is not utilized by DALMAC, the trail can also be access by the local residents in the Rainbow Lake Community which can contribute toward the aspect of ecotourism. As far as from the safety consideration, it is still dangerous for cyclists to turn in on S Luce Rd in a relatively high speed zone. In this case, the entrance paving will be treated in a highlighted color to remind incoming automobile. The overall consideration for this side is more toward being enjoyment, and less on achieving being safe and environmentally friendly.

Design Treatment 3 Site A: the extremely safe treatment of Rainbow Lake Community (see Figure 3.36)

This design a separated bike lane improvement compare with the existing site design along the S Luce St. The reason the site was selected is because S Luce St is the major

roadway throughout the Rainbow Lake Community. The traffic light in the area are limited.

The overall speed is relatively high, and there are numerous of sloped surface, curved road,

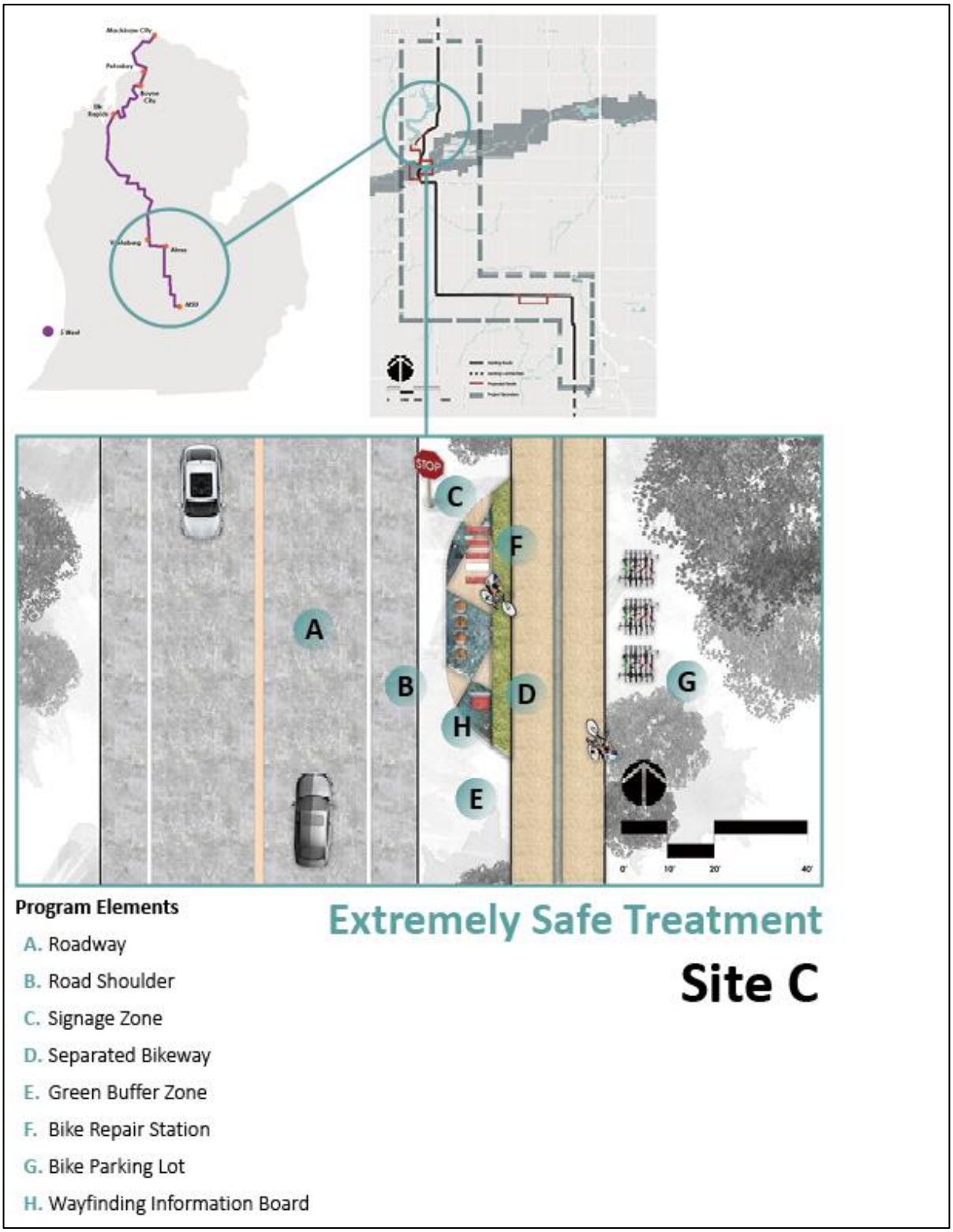

Figure 3.36 The extremely safe treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

and turns. Therefore, the design idea is to propose a completely separated bike way along the S Luce St. As what have planned, it is a double bikeway with express bike repair station on the side. By having a 10’ green buffer zone, the bikeway is completely protected from the roadway which minimize the risk of incoming traffic. In the buffer zone, series of bike-oriented signage will be installed according to the road condition. When there is curves or sloped surface, groups of cyclists has relatively comfortable space to be prepared and be actually separated from the automobile users. In this case, the site maximize its use and advantage toward the aspect of being safe. On the other hand, there isn’t much interaction with the natural features, such as Rainbow Lake. There is certainly no opportunities for implementing facilities that can contributed to the environmental considerations.

Design Treatment 4 Site C: the extremely enjoyable treatment of Rainbow Lake Community (see Figure 3.37)

This design is an innovative and elevated bike trail. It is located at the road branch of S Luce Rd in the dense forest area. The site is chose because of the vegetated area, which will provide enough shading in the direct sun exposure. Most of the essential bike facilities are included such as bike parking lots and express service station. Additionally, there are free-formed picnic area with the central loop of bike route for people to sit and eat. Speaking of the route, the larger loop on the outside is a simple route for entry-level cyclists and younger age group to enjoy. Based on that, there is four entrances to the inner loop which is an elevated route interacted with the small boardwalk route. Elevation change and texture of different route will enhance the excitement level for experience cyclists group. Therefore, it

will also be an attraction for people travelling through DALMAC. Speaking of the safety

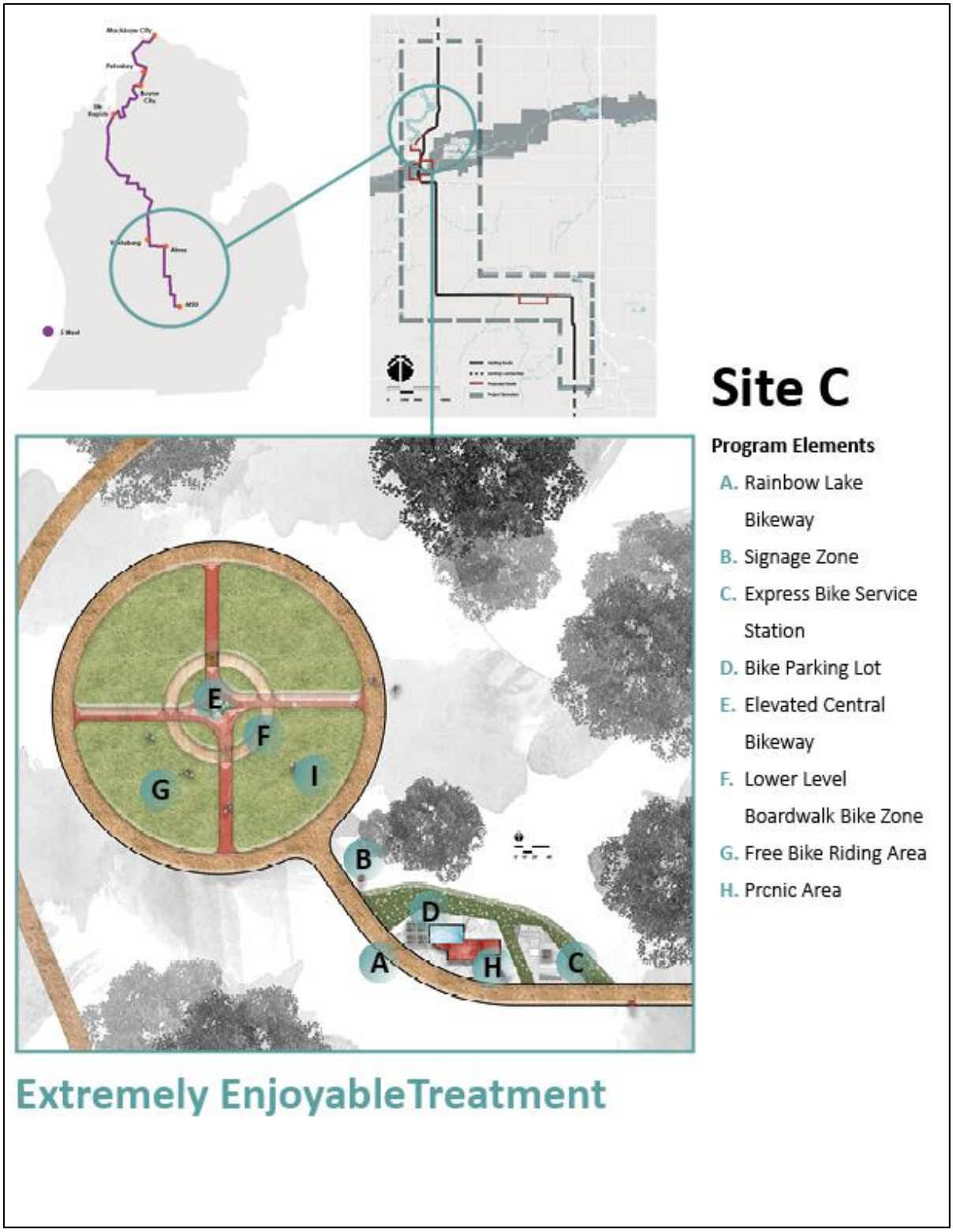

Figure 3.37 The extremely enjoyable treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

consideration, the elevated route are surrounded with soft-paving material will be decrease

the damage while there is falling accident. The overall riding experience entering the site will be safer since it is cycling designated route. However, due to the installation of new bike course and routes, the site will be less achieving the aspect of environmental.

Design Treatment 5 Site C: the extremely environmental treatment of Rainbow Lake Community (See Figure 3.38)

This design proposed a green type of green infrastructure in the middle of housing complexes. The detailed the location is within the Sky Line Dr., it is one of most loosely distributed housing complexes on site. There is more value to maximize the use of the space. The side work and parallel parking on site will be maintained. However, in the middle of wide roadway, there will be an area carved out to implement a greenway trail. When the topography is applicable, the greenway portion will be skunked in the middle to function as a rain garden to help with the water infiltration processes. When there is extremely slope applied, the sunken area will be protected by fences. In most of the case, the DALMAC cyclists or other user can walk or riding on the hard surface on the edge of the greenway. Additionally, overhead structure such as shelters and express bike station will be provided. It is an ideal location for DALMAC cyclists who want to take a fast rest; as well as a great opportunities for the cyclists from the community to have a riding experience. This is an enjoyment promotion but has the value can contribute to the environmental issues. However, the safety issue are still under concerned, since there is no physical buffer protect bikes from the roadway other that stop signs and other bike-oriented signs.

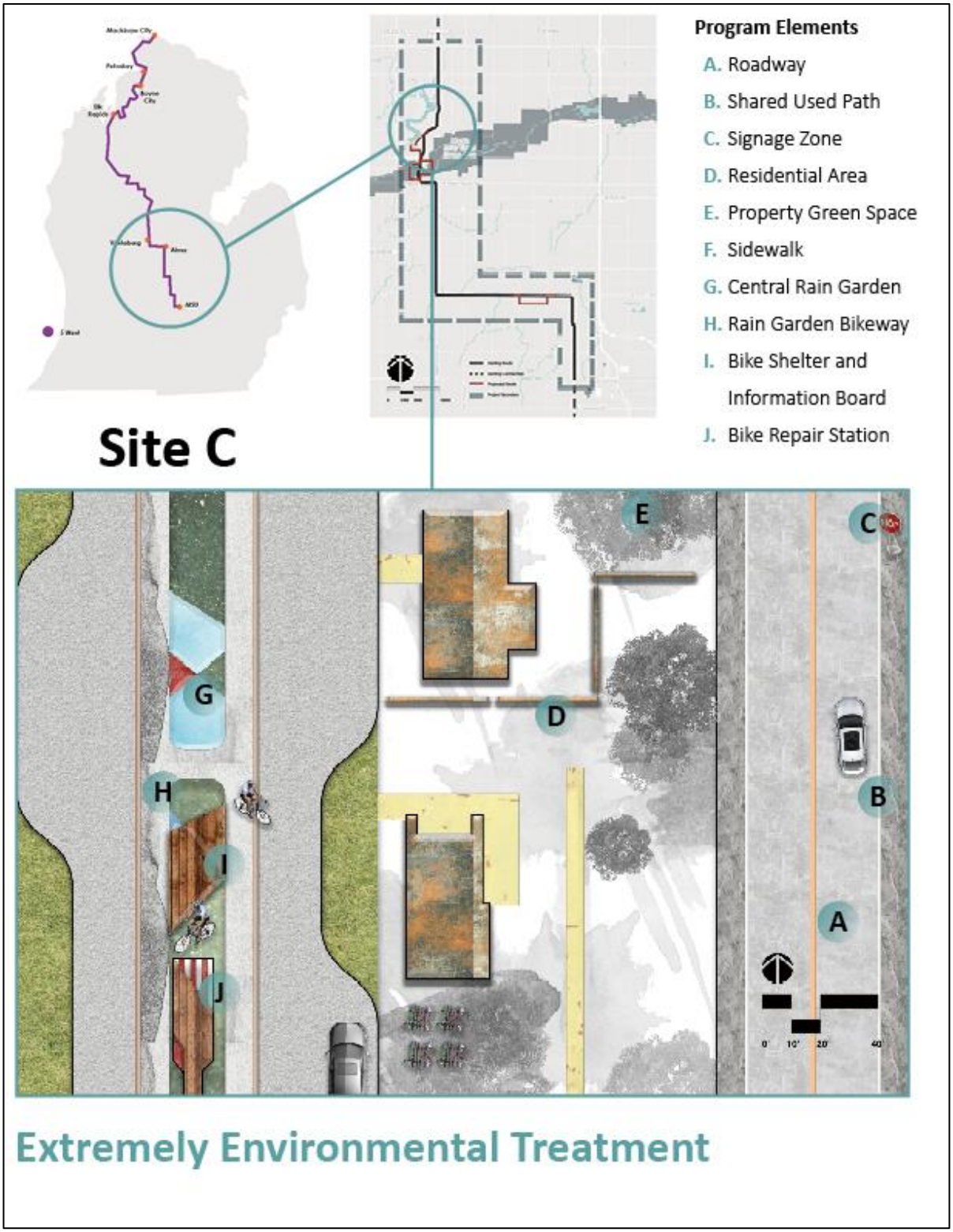

Figure 3.38 The extremely environmental treatment plan of DALMAC bikeway, the design display include key map, location map, and program elements for Site A. Copyright © 2018 Yinliang Li, all rights reserved, used by permission.

3.3 Define Criteria

The next step is to define criteria for a scoring system that can properly transfer the perception of design deliverables to a numeric evaluation system. The criteria questions started with three objectives, then branched out five categories under each objectives. In the aspect of being safe for cycling, the five categories are addressed as surface, wayfinding, speed, buffer, and traffic. In the aspect of being enjoyable for cycling, the five categories are addressed as adventure, rest, thermal, interaction, and landscape. In the aspect of being environmental for cycling, the five categories area are addressed as vegetation, construction, waster, noise and wildlife.

The descriptive questions can be found as following:

Safe-Surface-Question 1: Is the bike path surface smooth (without physical obstacles) for cyclists to during the event?

Safe-Surface-Question 2: Is the bike path accessible for surface maintenance (repair, detour, and reinstallation) when it is required?

Safe-Wayfinding-Question 1: Is there a wayfinding system (such as an information board, signages, or any other interactive facilities) to guide the participants along the event route?

Safe-Wayfinding-Question 2: Is the wayfinding system accessible to read and find (located in the 5’-10’ range from the designated bike path) along the event route?

Safe-Speed-Question 1: Is the bike path located in a relatively safe speed zone (35mph or less) in case there is a conflict with automobiles?

Safe-Speed-Question 2: Is the bike path free from extreme slope change (greater

than 5%)?

Safe-Buffer-Question 1: Is there a buffer zone (dimension measures from 5’ to 10’) to protect cyclists from the unexpected accident or incoming traffic?

Safe-Buffer-Question 2: Is there a buffer zone to protect bike fall from elevation change (greater than 4’ above the ground)?

Safe-Traffic-Question 1: Is the bike path being separated from the roadway (in this case, the bikeway is individual, not presented in a shared-use bikeway)?

Safe-Traffic-Question 2: Is the traffic flow being controlled by some safe treatment (traffic light, signage, intersection treatment, and crossing treatment)?

Enjoyable-Adventure-Question 1: Is the portion of the route has any form of elevation change so that the cyclists can address the feeling of maximal exercise?

Enjoyable-Adventure-Question 2: Is the segment of the route include different type of bike courses (by providing different road surface, bike riding environment, and bike related activities)?

Enjoyable-Rest-Question 1: Is there a rest area along the event route?

Enjoyable-Rest-Question 2: Is the rest area sufficient for 50 and more people?

Enjoyable-Thermal-Question 1: Is there a shading area along the event route to protect cyclists from extreme sun exposure?

Enjoyable-Thermal-Question 2: Is there a shelter structure along the event route to protect cyclists from extreme weather (raining, windy or typhoon)?

Enjoyable-Interaction-Question 1: Is there any interactive site design elements (such as the information board for people to read, the pathway for people to walk, and

signage for people to follow) along the event route for the cyclists to experience?

Enjoyable-Interaction-Question 2: Is there an attraction designed/existed (both natural and artificial attractions) for cyclists to explore along the event route?

Enjoyable-Landscape-Question 1: Is there a scenery spot (the natural feature of a landscape) that can be visited along the event route?

Enjoyable-Landscape-Question 2: Is the route passing the natural/proposed area filled with ground cover, shrub, tree and any other plants (the overall plant quantities are larger than 20)?

Environmental-Vegetation-Question 1: Is the existing vegetation along the event free from external damages (meaning there is no tree removal, ground disturbance or any other negative change made the overall vegetated terrain)?

Environmental-Vegetation-Question 2: Is the existing vegetation been buffered through any form of physical structure (fence, railing or signage)?

Environmental-Construction-Question 1: Is the portion of the route free from new construction?

Environmental-Construction-Question 2: Is the construction process designated to be unaffected to the existing features along the event route?

Environmental-Waste-Question 1: Is the event route free from waste (or any sort of contamination)?

Environmental-Waste-Question 2: Is there a waste treatment/recycle system implemented along the event route?

Environmental-Noise-Question 1: Is the event route free from noise pollution

caused by the cyclists?

Environmental-Noise-Question 2: Is there any form of noise pollution buffer been implemented along the event route?

Environmental-Wildlife-Question 1: Is the event road free from unexpected wildlife interaction?

Environmental-Wildlife-Question 2: Is there any form of signage/alert been implement to notified cyclists about the existing wildlife conditions?

3.4 Measure Variables

This step is going to score the variables developed by the criteria.

There are two questions asked for each category, thus, there are total of 30 questions. The descriptive questions are designed to answer with “yes” or “no”. If the answer is “yes”, the site with specific treatment earns 1 points; on the other hand, if the answer is “no”, the site with specific treatment earns 0 point.

Through comparison, the highest score with specific treatment within one region is supposed to be most comprehensive design in the selected location.

3.5 Statistical Calculation

In this case, the Freidman’s test of variance is suitable. The Freidman’s test is a nonparametric analog of the parametric two-way analysis of variance, in other word, this test allows comparisons of more than two treatments or groups, such as design treatments (Daniel, 2000). By calculating through the Freidman test of variance and multiple-comparison procedure, the final comparisons and results are provided to explore the

differences, practicalities, and possibilities among various treatments. In brief, the first statistical calculation will use the Freidman two-way analysis of variance by ranks, and followed by the Multiple-comparison procedure through the Friedman Test as the second portion (Daniels et al., 2017; Feng et al., 2017; Lin et al., 2017; Wang et al., 2015; Lin, 2013., Burley, 2003; Burley, 1996; Burley et al., 1988).

a. The Freidman Two-way Analysis of Variance by Ranks

In the first portion of the calculation, the experiment approach from the statistic aspect to find out if there is a true difference between each treatment through the Freidman's test of variance. The test is different from the Kruskal-Wallis test. The Friedman test ranks observations with induvial blocks completely separated. Thus, a set of observation data is going to rank smallest to largest, and each block are also contains separate set of k ranks (Daniel, 2000).

For this specific experiment, the blocks are the three concentrated area which means *b = 3*; the treated observations are the five treatments for the bike improvement plan, which means *k = 5.* The ranking follows the smallest to the largest, for example, the lowest score will receive the first rank; on the other hand, the highest score will receive the fifth rank (Daniel, 2000).

Afterward, the step is to calculate test statistic by first obtain the sums the ranks in each column. The following step is to statistically proven the sum of tanks, whether it is proving or rejecting the hypothesis. Usually, there are two hypotheses can been assumed:

"H_0: The population within a block are identical.

H_1: At least one treatment tends to yield values than at least one other treatment."

Theoretically, if H_0 is stated ture, the expecatation is that the sums from ranks should be fairly close in size which is applicable for attributing difference to change. If the H_0 is false, which means H_1 is proven, the expecataion is that there is at least one sum from tank is sufficiently different in size from which it can not reasonably attribute as sampling varaibility. Particulally, when H_0 is rejected, difference among rank sums should computed through statistic calculation to prove the magnitude is sufficently large enough for rejection (Daniel, 2000, p.225).

The computational formula for the test statistic is:

Equation 1: $X_r^2 = \frac{12}{bk(k+1)} \sum_{i=0}^{k} R_j^2 - 3b(k+1)$

In the situation of a tie, the tied observations are addressed as the mean of the rank positions for which they are tied, and the computational formula should be adjusted through following formula:

Equation 2: $X_r^2 = 1 - \sum_{i=1}^{b} T_j \,/ bk(k^2 - 1)$

"As for decision rule after statistic calculation, when the value of b and k are not given, we compare computed X_r^2 for significance with tabulated values of chi-square with *k - 1* degrees of freedom. Reject H_0 at the α level of significance if the X_r^2 computed from the data is greater than or equal to the tabulated value of $X_{(1-\alpha)}^2$ for *k – 1* degrees of freedom (Daniel, 2000, p.226)."

b. Multiple-comparison Procedure for Use with Friedman Test

In the second calculation part, a multiple-comparison procedure with Friedman test has

applied to find out which treatment statistically stood out among all the treatments (Daniel, 2000).

When comparing all possible differences between pairs of samples, when the experiment wise error rate is α, and when the number of blocks is large, then it is declared R_j and $R_{j'}$ significantly different (R_j and $R_{j'}$ are the rank totals of the *j*th and *j'*th treatment), through the following formula:

Equation 3: $\left|R_j - R_{j'}\right| \geq z\sqrt{\frac{bk(k+1)}{6}}$

Additionally, we can find value of z through the following, the value of can be find through the giving table corresponding to $\propto/k(k-1)$, as well as the following equation:

Equation 4: $z = \frac{\alpha}{(k-1)}$

3.6 Conclusion

Through series of procedures (Create Scenarios, Define Criteria, Measure Variables, and Statistic Calculation), different treatments with various concepts toward DALMAC are resulted in scores. The result section is going to present in tables and explaining paragraphs address the scores from design criteria questions and statistical calculation.

CHAPTER 4 RESULT

4.1 Variables Measurements

Site A: W Colony Rd							
Concept	**Category**	**Criteria Questions**	**Treatment**				
			1. Existing	*2. Balance*	*3. Extremely Safe*	*4. Extremely Enjoyable*	*5. Extremely Environmental*
Safe	*Surface*	1) Is the bike path surface smooth (without physical obstacles) for cyclists to during the event?	0	1	1	1	1
		2) Is the bike path accessible for surface maintenance (repair, detour, and reinstallation) when it is required?	0	1	1	1	1
	Wayfinding	1) Is there a wayfinding system (such as an information board, signages or any other interactive facilities) to guide the participants along the event route?	0	1	1	1	1
		2) Is the wayfinding system accessible to read and find (located in the 5'-10' range from the designated bike path) along the event route?	0	0	1	0	1
	Speed	1) Is the bike path located in a relatively safe speed zone (35mph or less) in case there is a conflict with automobiles?	0	0	1	0	1
		2) Is the bike path free from extreme slope change (greater than 5%)?	1	1	1	0	1
	Buffer	1) Is there a buffer zone (dimension measures from 5' to 10') to protect cyclists from the unexpected accident or incoming traffic?	0	0	1	0	1
		2) Is there a buffer zone to protect bike fall from elevation change (greater than 4' above the ground)?	0	0	0	1	0
	Traffic	1) Is the bike path being separated from the roadway (in this case, the bikeway is individual, not presented in a shared-use bikeway)?	0	1	1	1	1
		2) Is the traffic flow being controlled by some safe treatment (traffic light, signage, intersection treatment, and crossing treatment)?	0	1	1	1	1
Enjoyable	*Adventure*	1) Is the portion of the route has any form of elevation change so that the cyclists can address the feeling of maximal exercise?	0	0	0	1	0
		2) Is the segment of the route include different type of bike courses (by providing different road surface, bike riding environment, and bike related activities)?	0	1	0	1	0
	Rest	1) Is there a rest area along the event route?	0	1	1	1	0
		2) Is the rest area sufficient for 50 and more people?	0	1	0	1	0
	Thermal	1) Is there a shading area along the event route to protect cyclists from extreme sun exposure?	1	1	0	1	0
		2) Is there a shelter structure along the event route to protect cyclists from extreme weather (raining, windy or typhoon)?	0	1	0	1	0
	Interaction	1) Is there any interactive site design elements (such as the information board for people to read, the pathway for people to walk, and signage for people to follow) along the event route for the cyclists to experience?	0	0	1	1	0
		2) Is there an attraction designed/existed (both natural and artificial attractions) for cyclists to explore along the event route?	0	1	0	1	0
	Landscape	1) Is there a scenery spot (the natural feature of a landscape) that can be visited along the event route?	0	0	0	1	0
		2) Is the route passing the natural/proposed area filled with ground cover, shrub, tree and any other plants (the overall plant quantities are larger than 20)?	1	1	0	1	0
Environmental	*Vegetation*	1) Is the existing vegetation along the event free from external damages (meaning there is no tree removal, ground disturbance or any other negative change made the overall vegetated terrain)?	1	0	0	0	1
		2) Is the existing vegetation been buffered through any form of physical structure (fence, railing or signage)?	0	1	1	1	1
	Construction	1) Is the portion of the route free from new construction?	1	0	0	0	0
		2) Is the construction process designated to be unaffected to the existing features along the event route?	0	1	1	1	1
	Waste	1) Is the event route free from waste (or any sort of contamination)?	0	0	0	0	0
		2) Is there a waste treatment/recycle system implemented along the event route?	1	1	1	1	0
	Noise	1) Is the event route free from noise pollution caused by the cyclists?	0	0	0	0	0
		2) Is there any form of noise pollution buffer been implemented along the event route?	0	0	0	0	1
	Wildlife	1) Is the event road free from unexpected wildlife interaction?	0	0	0	0	0
		2) Is there any form of signage/alert been implement to notified cyclists about the existing wildlife conditions?	1	1	1	1	1
Individual Treatment Total Score			***7***	***17***	***15***	***20***	***14***

Table 4.1 Criteria measurements and detailed scores for Site A: W. Colony Rd.

Site B: City of Maple Rapids								
Concept	**Category**	**Criteria Questions**	**Treatment**				
			1. Existing	*2. Balance*	*3. Extremely Safe*	*4. Extremely Enjoyable*	*5. Extremely Environmental*
Safe	*Surface*	1) Is the bike path surface smooth (without physical obstacles) for cyclists to during the event?	1	1	1	1	1
		2) Is the bike path accessible for surface maintenance (repair, detour, and reinstallation) when it is required?	1	1	1	1	1
	Wayfinding	1) Is there a wayfinding system (such as an information board, signages or any other interactive facilities) to guide the participants along the event route?	0	1	1	1	1
		2) Is the wayfinding system accessible to read and find (located in the 5'-10' range from the designated bike path) along the event route?	0	0	0	0	1
	Speed	1) Is the bike path located in a relatively safe speed zone (35mph or less) in case there is a conflict with automobiles?	1	1	1	1	1
		2) Is the bike path free from extreme slope change (greater than 5%)?	1	1	1	0	1
	Buffer	1) Is there a buffer zone (dimension measures from 5' to 10') to protect cyclists from the unexpected accident or incoming traffic?	0	0	1	0	1
		2) Is there a buffer zone to protect bike fall from elevation change (greater than 4' above the ground)?	0	0	0	1	0
	Traffic	1) Is the bike path being separated from the roadway (in this case, the bikeway is individual, not presented in a shared-use bikeway)?	0	1	1	1	1
		2) Is the traffic flow being controlled by some safe treatment (traffic light, signage, intersection treatment, and crossing treatment)?	0	1	1	1	1
Enjoyable	*Adventure*	1) Is the portion of the route has any form of elevation change so that the cyclists can address the feeling of maximal exercise?	0	0	0	1	0
		2) Is the segment of the route include different type of bike courses (by providing different road surface, bike riding environment, and bike related activities)?	0	1	1	1	1
	Rest	1) Is there a rest area along the event route?	0	1	1	1	1
		2) Is the rest area sufficient for 50 and more people?	0	1	0	1	0
	Thermal	1) Is there a shading area along the event route to protect cyclists from extreme sun exposure?	1	1	1	1	1
		2) Is there a shelter structure along the event route to protect cyclists from extreme weather (raining, windy or typhoon)?	0	1	0	1	1
	Interaction	1) Is there any interactive site design elements (such as the information board for people to read, the pathway for people to walk, and signage for people to follow) along the event route for the cyclists to experience?	0	1	1	1	0
		2) Is there an attraction designed/existed (both natural and artificial attractions) for cyclists to explore along the event route?	1	1	1	1	1
	Landscape	1) Is there a scenery spot (the natural feature of a landscape) that can be visited along the event route?	1	1	1	1	1
		2) Is the route passing the natural/proposed area filled with ground cover, shrub, tree and any other plants (the overall plant quantities are larger than 20)?	1	1	1	1	1
Environmental	*Vegetation*	1) Is the existing vegetation along the event free from external damages (meaning there is no tree removal, ground disturbance or any other negative change made the overall vegetated terrain)?	1	0	0	0	1
		2) Is the existing vegetation been buffered through any form of physical structure (fence, railing or signage)?	0	1	1	1	0
	Construction	1) Is the portion of the route free from new construction?	1	0	0	0	0
		2) Is the construction process designated to be unaffected to the existing features along the event route?	0	1	1	1	1
	Waste	1) Is the event route free from waste (or any sort of contamination)?	0	0	0	0	0
		2) Is there a waste treatment/recycle system implemented along the event route?	1	1	1	1	1
	Noise	1) Is the event route free from noise pollution caused by the cyclists?	0	0	0	0	1
		2) Is there any form of noise pollution buffer been implemented along the event route?	0	0	0	0	0
	Wildlife	1) Is the event road free from unexpected wildlife interaction?	0	0	0	0	0
		2) Is there any form of signage/alert been implement to notified cyclists about the existing wildlife conditions?	1	1	1	1	1
Individual Treatment Total Score			***12***	***20***	***19***	***21***	***21***

Table 4.2 Criteria measurements and detailed scores for Site B: City of Maple Rapids.

Site C: Rainbow Lake Community								
Concept	**Category**	**Criteria Questions**	**Treatment**				
			1. Existing	*2. Balance*	*3. Extremely Safe*	*4. Extremely Enjoyable*	*5. Extremely Environmental*
Safe	*Surface*	1) Is the bike path surface smooth (without physical obstacles) for cyclists to during the event?	1	1	1	1	1
		2) Is the bike path accessible for surface maintenance (repair, detour, and reinstallation) when it is required?	0	1	1	1	1
	Wayfinding	1) Is there a wayfinding system (such as an information board, signages or any other interactive facilities) to guide the participants along the event route?	0	1	1	1	1
		2) Is the wayfinding system accessible to read and find (located in the 5'-10' range from the designated bike path) along the event route?	0	0	1	0	0
	Speed	1) Is the bike path located in a relatively safe speed zone (35mph or less) in case there is a conflict with automobiles?	1	1	1	1	1
		2) Is the bike path free from extreme slope change (greater than 5%)?	0	0	1	0	0
	Buffer	1) Is there a buffer zone (dimension measures from 5' to 10') to protect cyclists from the unexpected accident or incoming traffic?	0	0	1	0	0
		2) Is there a buffer zone to protect bike fall from elevation change (greater than 4' above the ground)?	0	1	0	1	1
	Traffic	1) Is the bike path being separated from the roadway (in this case, the bikeway is individual, not presented in a shared-use bikeway)?	0	1	1	1	1
		2) Is the traffic flow being controlled by some safe treatment (traffic light, signage, intersection treatment, and crossing treatment)?	0	1	1	1	1
Enjoyable	*Adventure*	1) Is the portion of the route has any form of elevation change so that the cyclists can address the feeling of maximal exercise?	1	1	0	1	1
		2) Is the segment of the route include different type of bike courses (by providing different road surface, bike riding environment, and bike related activities)?	0	1	1	1	1
	Rest	1) Is there a rest area along the event route?	0	1	1	1	1
		2) Is the rest area sufficient for 50 and more people?	0	1	0	1	0
	Thermal	1) Is there a shading area along the event route to protect cyclists from extreme sun exposure?	1	1	1	1	1
		2) Is there a shelter structure along the event route to protect cyclists from extreme weather (raining, windy or typhoon)?	0	1	0	1	1
	Interaction	1) Is there any interactive site design elements (such as the information board for people to read, the pathway for people to walk, and signage for people to follow) along the event route for the cyclists to experience?	0	1	0	1	1
		2) Is there an attraction designed/existed (both natural and artificial attractions) for cyclists to explore along the event route?	1	1	1	1	0
	Landscape	1) Is there a scenery spot (the natural feature of a landscape) that can be visited along the event route?	1	1	1	1	0
		2) Is the route passing the natural/proposed area filled with ground cover, shrub, tree and any other plants (the overall plant quantities are larger than 20)?	1	1	0	1	0
Environmental	*Vegetation*	1) Is the existing vegetation along the event free from external damages (meaning there is no tree removal, ground disturbance or any other negative change made the overall vegetated terrain)?	1	0	0	0	0
		2) Is the existing vegetation been buffered through any form of physical structure (fence, railing or signage)?	0	1	1	1	1
	Construction	1) Is the portion of the route free from new construction?	1	0	0	0	0
		2) Is the construction process designated to be unaffected to the existing features along the event route?	0	1	1	1	1
	Waste	1) Is the event route free from waste (or any sort of contamination)?	0	0	0	0	0
		2) Is there a waste treatment/recycle system implemented along the event route?	1	1	1	1	1
	Noise	1) Is the event route free from noise pollution caused by the cyclists?	0	0	0	0	0
		2) Is there any form of noise pollution buffer been implemented along the event route?	0	0	0	0	1
	Wildlife	1) Is the event road free from unexpected wildlife interaction?	0	0	0	0	1
		2) Is there any form of signage/alert been implement to notified cyclists about the existing wildlife conditions?	1	0	1	1	1
Individual Treatment Total Score			***11***	***20***	***18***	***21***	***19***

Table 4.3 Criteria measurements and detailed scores for Site C: Rainbow Lake Community.

4.2 Statistical Calculations

		Treatment				
	b = 3 ; k = 5	1. Existing	2. Balance	3. Extremely Safe	4.Extremely Enjoyable	5. Extremely Environmental
Concentrated Area	A. West Colony Road	7	17	15	20	14
	B. Maple Rapids Township	12	20	19	21	21
	C. Rainbow Lake Community	11	20	18	21	19

Table 4.4 Comprehensive results from all 5 treatments across 3 sites through criteria measurements.

By using the above equations, result from criteria measurements (Table 4.4 and Table 4.5), and referencing factors for Chi-square calculation through provide tables in the book (Daniel, 2000), we have:

$$X_r^2 = \frac{12}{3(5)(5+1)}(479.5) - 3(5)(5+1) = 63.93333$$

Since we have a tie, we adjust X_r^2, we have $T_2 = 2^3 - 2 = 6$ and $\sum T_i = 6$, so the adjustment factor is:

$$1 - \frac{6}{5(3)(5-1)} = 0.983333$$

Finally $X_r^2 =$ adjusted for ties is *63.93333/0.983333 = 65.01695.*

With reference of Chi-square table valued in 14.86, $X_r^2 = 65.01695 > 14.86$, with *k-1 = 4* degrees of freedom show that the probability of obtaining a value of X_r^2 as large as *65.01695* when H_0 is true is less than *0.005*. Moreover, with reference of Chi-square table valued in *18.467*, $X_r^2 = 65.01695 > 18.467$, with *k-1 = 4* degrees of freedom show that the probability of obtaining a value of X_r^2 as large as *65.01695* when H_0 is true is less than *0.001*. Consequently, both results reject H_0, and the descriptive conclusion is that at least one

		Treatment				
	b = 3 ; k = 5	1. Existing	2. Balance	3. Extremely Safe	4.Extremely Enjoyable	5. Extremely Environmental
Concentrated Area	A. West Colony Road	1	4	3	5	2
	B. Maple Rapids Township	1	3	2	4.5	4.5
	C. Rainbow Lake Community	1	4	2	5	3
Friedman Test Statistic	Total for Indvidual Rank (R)	***3***	***11***	***7***	***14.5***	***9.5***
	Square	***9***	***121***	***49***	***210.25***	***90.25***
	Sum of Square	***479.5***				

Table 4.5 The rank of final measurements from sites with various treatments, and statistic calculations include total for individual rank, rank square and sum of square for later calculations.

treatment is different from another result. The P value is less than *0.005* or *0.001*. For the specific experiment of bike experience improvement treatments, this results means at least one treatment is significantly different than another treatment across the 3 concentrated area.

Since H_0 is rejected, the next question is which treatment(s) is statistically different from other treatments.

In this case, we choose an experiment wise error rate of $\alpha = 0.05$. With $k = 5$ and $\alpha = 0.05\ (0.05/5=0.0025)$. Then, through the calculation: $0.5 – 0.0025 = 0.495$, we state that *z* score is a one sided test, a *50%* test, or a test with *0.5* probability. Afterward, by referencing to the table, $z = 2.81$. Alternatively, we also choose an experiment wise error rate of $\alpha = 0.1$. With $k = 5$ and $\alpha = 0.1,\ (0.1/5=0.005)$. Then, through the calculation: $0.5\text{-}0.005 = 0.495$, we state that *z* score is a one sided test, a *50%* test, or a test with *0.5* probability. Afterward, by referencing to the table, we gather the result that $z = 2.48$.

Following with the above mentioned equation (the right-hand side of inequality from equation 3), we have:

Plug in *z =2.81*,

$$2.81\sqrt{\frac{3(5)(5+1)}{6}} = 10.883084$$

Plug in *z = 2.48*,

$$2.48\sqrt{\frac{3(5)(5+1)}{6}} = 9.604999$$

Treatments	Comparison	Absolute Value Difference	Difference > 9.604999 ?	Difference > 10.88308 ?
1: Existing 2: Balance 3: Extremely Safe 4: Extremely Enjoyable 5: Extremely Environmental	R1-R2	8	no	no
	R1-R3	4	no	no
	R1-R4	11.5	yes	yes
	R1-R5	6.5	no	no
	R2-R3	4	no	no
	R2-R4	3.5	no	no
	R2-R5	1.5	no	no
	R3-R4	7.5	no	no
	R3-R5	2.5	no	no
	R4-R5	5	no	no

Table 4.6 Multiple-comparison result from the Freidman test.

The final result of comparison will be find in Table 4.6.

As what Table 4.6 presented, the comparison between the Existing treatment and Extremely Enjoyable treatment are statistically proved different. Therefore, the conclusion here is that among all 5 treatments, Extremely Enjoyable treatment performed best against the existing treatment and potentially has value toward future bicycle development of DALMAC.

CHAPTER 5 DISCUSSION

5.1 Discussion

a. The Surprise of Extremely Enjoyable Treatment

From what I anticipated in the earlier stage, I believe safety considerations is always the primary issue toward the topic of bikeway design. Abundant research articles has also addressed the safety concerns as the primary topics. Numerous experiment action has done to test the accident rate and practicability of innovative bike facilities. Therefore, I focus my literature review mainly toward the topic of safety issue of bikeway, for example, toward the concept of “Sharing the Road”, protective bikeway guidelines, and perception of cyclists to accept of bike safety policies. Additionally, I have conduct a corridor study toward existing bikeways in central Michigan area to visually address my considerations of this topic. Until now, I still believe in the importance of bicycle safety, and it is a more accessible approach to conduct evidence-proved design.

Surprisingly, the experimented results indicate a statically difference between treatment 4: extremely enjoyable and the treatment. Therefore, the result expressed value of extremely enjoyable treatment inspired me to a new perspective. Therefore, I am curious and decide to purse the reason behind this result. Meanwhile, I am rethinking about the value of improving bikeways through an enjoyable approach.

Among three of the main objectives, I consider the concept or the guideline of bicycle enjoyment is definitely the most complicated one to stipulate. Most of the professional knowledge toward bicycle enjoyment are not comprehensive enough for real-world practice. People all have different perceptions while deciding if it is an enjoyable cycling

infrastructure. Thus, it is possible that one of the idea might be favored by majority of the people, but it is not acceptable for the rest of the group. Related to the design ideas I present earlier, the enjoyment treatments might not address completely enough for every single cyclists. It is hard to define the level of acceptance without empirical data support. In this case, there is more potentials to clarify the enjoyable treatments designs. Potential solutions include but not limit to implementing innovative cycling infrastructure, gathering public's ideas, or visually addressing details associated to design for more accessible understandings.

b. Innovative Bicycle Enjoyment Elements and Their Possibilities with DALMAC

One the other hand, there are also many innovative bicycle oriented facilities and treatments I consider can be categorized in the topic of bicycle enjoyments. In the following paragraph, I would like to discuss the several bike oriented treatments and its possibilities toward DALMAC.

The first topic is bicycle sharing system. As what Dell'Olie (2011) stated, bicycle sharing schemes have been implemented in multiple European countries where dense bicycle network is occurred. In detail, bicycle sharing system as a public bicycle rental system is an accessible way to promote automobile alternatives. As a mutated public transport category, bike sharing system are featured with the characteristics of being practical, fast, and flexible as a mobility solution.

Firstly, I consider it will be incredible to build a comprehensive bike sharing system for DALMAC throughout Lower Michigan. However, this ideal might not be practical because

this specific bike sharing system will be built in a massive scale. The development of bike sharing system usually has limitations toward funding and maintenance issues. Moreover, a detailed bike sharing plan requires layers of analysis about participant rate, choices of bicycles, payment system, legal issues, and so on. Therefore, it is more reasonable for DALMAC to connect with potential bike sharing systems from different townships along the routes. As the result, there will be more opportunities to expand the route so DALMAC participants are able to explore more about Michigan. In this case, there are more future attractions for cyclists to stop and explore; yet, the focus here is to encourage people to experience the route more instead of reaching destination. On the other hand, if there is the connection between DALMAC and local bike-sharing system, it will increase the community cohesion as well as the level of convenience and accessibilities for DALMAC cyclists.

The second category is about usage of E-Bikes. As what Fishman and Cherry (2015) stated, the term E-bikes refers to electric bicycles which is a newly invented bicycle form in the transport market. Many researched stated the existence of E-bike help people maintain the speed of bicycles with less effort; yet people believe the usage of E-bike contribute to cycling promotion. However, there is controversial topics toward whether E-bikes are able to replace the conventional bicycles due to several safety considerations. Through analyzing naturalistic GPS data, Langford et al. (2015) stated that riders of E-bike typically travel in a higher speed than regular bikes and both users of conventional bicycles and e-bikes adopt the similar safety behaviors.

One of the original sprit for DALMAC is to promote cyclists to challenge themselves physically, as well as encourage bicycle fitness. In this case, both statements seems to set on

the opposite side of E-bike usage, since E-bike are known for achieving cycling behaviors with less effort. Furthermore, DALMAC as a bicycle event traveling through dozens of Shared Used Path, there is the potentials that E-bikes riders involve with accidents more frequently due to the high speed. However, I still consider E-bike usage in DALMAC as an interesting thoughts toward bikeway design. There is the possibilities that bikeway design targeted to electric bicycles can be planned differently, which could be an interesting topics for future studies.

c. The 3D Model Envision for the Extremely Enjoyment Treatment

Through researches of bicycle usage and cycling in couple European countries, Hull and O'Holleran (2014) stated, a qualified bikeway design are likely to promote behavior of cycling from the positive perspective. There are few statements from the result section I found quite inspirational. Those statement can be associated with the development of DALMAC, especially the development of Extremely Enjoyment Treatment. In detail, the statements include details of building wider cycle lane installation, introducing cycle lane segregation, enhancing connection of bikeway, installing protective cycling infrastructure in low-visual quality environment. Based on those concepts, I have accomplished some designs in 3D models rendering in Lumion software to visually address the modifications to the Extremely Enjoyable primarily, as well as other treatments.

The important elements here is have a wider cycle lane, which is similar solutions I have applied to majority of my design ideas. Wider cycle lanes can increase the buffer distance between automobiles and cyclists, thus, it is possible that wider cycle lanes can lower both

cyclists' and drivers' emotional stress.

The article also mentioned about the segregation among cycle lanes, trunk roads and busy center roads (Hull and O'Holleran, 2014). For the DALMAC route, majorities of the roads are overlapped with major commute roads locally which might increase the potential accident rate. If possible, it is more idea to lead the route in a separated cycle lane with buffers or protections. In the Extremely Enjoyment Treatment design, the idea of a wider landing area is introduced (see Figure 5.1).

Figure 5.1 This diagram show the details of advanced bicycle landing area and an express bike service station. The brick pattern indicate the area for landing. For the express bike station, colorful pavements indicate different functions of the repair service on Site A. Therefore, cyclists can observe further away to decide if there is a need for services, the turning in action will be safer and smoother with the wide landing zone.

Hull and O'Holleran (2014) also stated the importance of direct route connecting all land uses. In the development of DALMAC, the original idea is to address the linking and sharing of bicycles throughout the event. For a large scale, the linking of DALMAC is addressed in the connection between each townships along the route. Therefore, I believe in the future,

there are going to be more townships added the routes which is an outstanding way to unity communities together. In a smaller design scale, I think the segment from Extremely Enjoyable Treatment should build the regional connection with local attractions, such as an industrial crossing bridge (see Figure 5.2).

Additionally, the article also proved the importance of installing bicycle safety infrastructures (Hull and O'Holleran, 2014). There are several practical protective infrastructure have been mentioned in the bicycle safety literature review section. From my

Figure 5.2 This diagram show the details of crossing bridge in Site B. This industrial bridge modified on the existing bridge structure is going to be a main attraction onsite. In detail, the design encourage cyclists to walk their bike so the bridge can provide surface of both cyclists and hikers. The slow travelling speed will provide visitors more time to enjoy the natural landscapes.

understanding, I think the priority criteria for safety bicycle infrastructure is usability and clarity. In my design, I have implemented a Dutch intersection which is a protected infrastructure build at the intersection to orient the flow of bicycles (see Figure 5.3).

On the other hand, the article also stated the usage of bicycle parking lots (Hull and O'Holleran, 2014). Same as vehicles, it is essential to build bicycle parking lots for proper storage. Delicate to the DALMAC, most of my design have introduce the idea of bicycle parking lots associated with express bike stations which I consider is a multi-use, convenient, and space saving cycling infrastructure (see Figure 5.4). Moreover, due to the dimensions of bike racks, it is also applicable to add the aesthetics value in the bicycle parking lots. From my understanding, one of the disadvantages of building a bike parking lot is the possible miscounting of bike racks number. Excessive bike racks group might decrease the accessibility of cycling.

Figure 5.3 This diagram show the details of a Dutch intersection in an intersection along DALMAC 5 West Day 1 Route. The color paved route indicate the boundary for cycle lanes, and there are also crossing have provided for cyclists to travel the street in a safer environment. In addition, there is also the orientation panels to navigate cyclists during in the event.

Inspired by the above-mentioned guidelines and knowledge, I transformed featured design elements from extremely enjoyable treatment on each sites in Lumion perspectives. Therefore, the design concepts of bicycle enjoyments can be visually addressed in a more

understandable approach with the support of design perspectives.

Figure 5.4 This diagram show the creative design of bike racks in bike parking lots on the way in Site C. Rows of irregular bike racks as a scene will provide visitors sense of arrive, thus, it will encourage people to stop and take a look to the sites. Additionally, it is also a functional elements that will provide people the convenience of parking and storing bicycles.

d. Future Research Recommendations

All in all, I have analyzed and researched through several aspects of bicycle enjoyment. Now I consider approaching of bikeway design from the enjoyable aspect should never be an individual topic. In fact, bicycle enjoyment is the complex of all above-mentioned major objectives (being safe, enjoyable, and environmental). In another word, the statement means the concept of bicycle enjoyment is strongly involved with bicycle safety and cycling environmental factors. The following paragraphs is going to illustrate my thinking processes to support this idea.

First of all, public's attention and acceptance of bicycle enjoyment has raised. For example, as what indicated on the DALMAC official website ("DALMAC 2018 Handbook",

2018; “DALMAC 2017 Handbook”, 2017), the 2017 version of handbook propagandized mostly toward routes schedule and bicycle safety gears. There was less content about accommodation and bike-relevant services. However, in the 2018 version of handbook, there is more space showing cyclists interacting with different elements along the route. Meanwhile, there is more content toward services like school playground accommodation, bike carriage service, and cyclists massage options. From my understanding, the fullness of advertising through accommodations and services is another perspective state increased public’s attention toward bicycle enjoyment. In this case, it has proved that bicycle enjoyment is not always directly related to bikeway design details.

Secondly, under most of the situation, the process of analyzing the attributes from DALMAC accommodations and services appears to be a statement related with bicycle enjoyment. However, I consider focusing about accommodations and suggestions of bicycle enjoyment activities can count as another perspective to approach the overall cycling environment of DALMAC being safer. In detail, as a common agreement, cyclists who rest well are likely to be recovered faster; thus it will result in a more controllable riding experience. On the other hand, in the aspect of building environmental cycling, it usually refers to ride in a more green and natural environment without excessive further artificial expansion and pollution. In this case, cyclist who are looking for natural exposure will find the cycling experience become more enjoyable. Therefore, the improvement of environmental bikeway design can count as another sort of contribution toward bicycle enjoyment.

At this point, I would like to state that enjoyments of DALMAC is not only provided from

the qualities of cycling infrastructure, it is also evolved with DALMAC organization management, attractions along the way, and so on. The joy of family and friends riding together can define as enjoyable; the joy of professional cyclists doing maximal practice can also define as enjoyable. As a landscape architecture major students, I think bicycle enjoyment is defined as whether cyclists are able to have a continuous riding experience along with series of attractions. The objectives of bicycle enjoyment and relevant factors are hard to define. In fact, the goal can target to make cyclists feel the nature, encourage people achieve physical experience through cycling, feel the spirit along the DALMAC route as well as many other positive goals.

In conclusion, I think gathering community input and public perception through methods like surveys are definitely important toward controversial properties of cycling and bicycle usage. For example, the result for the criteria section can result completely different if it was graded by people who know less about bicycles. If the survey data indicate disadvantages and weaknesses toward bicycle promotion, the design treatments and solutions will be managed under a different approach.

On the other hand, I consider cyclists have different perception while adopting ideas of bicycle enjoyment. Thus, people have bicycle professional background are likely to have different opinions compare with regular cyclists. As a result, I think there is the possibilities to study different perceptions between cyclists and professions when implementing cycling infrastructure in the future. In these case, the similarities and varieties opinions from these groups will indicate the public acceptance level of bicycles. The result will be more effective and contributive toward the professional field of bikeway design.

5.2 Result Debrief

Improving the overall quality of cycling environment is always a complicated projects for professions in this field. My intent of this thesis is to explore whether there are difference among various treatments toward bikeway design. Across three selected study sites from DALMAC through five treatments, the result indicate that there is a difference among all treatments ($p \leq 0.005$ or $p \leq 0.001$). Furthermore, among all treatments, extremely enjoyable treatment statically appeared most promising ($p \leq 0.05$).

5.3 Limitation of the Methodology

According to the statement from the earlier section, the result indicated there is a difference among all three treatments toward selected DALMAC site through the Freidman two-way analysis. Furthermore, among all five treatments, the extremely enjoyable treatment statistically stood out. This specific result implies the potential value of improving the existing cycling environment from the enjoyment and entertainment aspects.

The experiment answered my curiosities, however, there is another question raised whether the result from this methodology can become part of empirical studies. In this methodology, the logic design and thinking processes might be inspirational, however, this methodology to explore the differences between various treatments toward selected DALMAC route is definitely limited due to the study durations and properties. In conclusion, I would like to address the limitation of this specific methodology from the aspects of specimen quantities, treatments variety, and statistic calculation choices.

The first concern is about lack of variable quantities. There are only three concentrated

sites summarized from the spatial analysis processes (sites include: W. Colony Rd, City of Maple Rapids, and Rainbow Lake community). Therefore, theses specimen result in total of 15 results compare among 3 sites. The result is limited when thinking about the massive scale and range of DALMAC, thus, the result of promoting extremely enjoyment treatment of cycling environment seems only applicable between these 3 sites. In addition, as the result indicated, there is the possibility for failing completely (as tested, the P value is less than 0.005 or 0.001) among all 15 results. From a comprehensive perspective, the result is inspirational, but it might not be widely acceptable or applied for the complete 5 West route from DALMAC.

In order to increase the variables quantities, the solutions here is to expand the design ranges. Thus, if it is possible, we can apply the same methodology toward rest of the DALMAC route (according to the 2017 DALMAC handbook, there is 5 routes). According to the newer version of DALMAC handbook, the organization is expanding the choices of routes which means there are more availabilities while choosing specimen. Once the attributions and quantities of specimen changed, the result might be varied dramatically. The research will be more empirical and inspirational as one of the articles in the field of bikeway design.

The second concern is the limitation of treatments' varieties. In the methodology, there are only 5 treatments include approaches of existing (non-input), balance, extremely safe, extremely enjoyable, and extremely environmental. In the end, the restricted treatments leads to 15 results which is probably not a competitive amounts compared with DALMAC due to the scale and size. In many cases, the concept of various treatments are conflicted with each other due to the limitation of funding, policies, and public's acceptance.

However, there are the possibilities of approaching the bikeway design very differently, such as improving the bikeway by achieving both aspects of enjoyable and environmental (for example, expending new cycling infrastructure in natural area for cyclists' enjoyment can counts as a double-faced solutions). In conclusion, I think expanding the varieties of treatments is a good solution to fix the second concern. Moreover, if possible, the treatment topic might be extremely innovative in the future. For example, in the future, there can be the treatment with topics with unlimited budgets; there can also be the treatment where traffic policies can be overwritten. At that time, the result might be dramatically different than the existing one. All in all, the quantities and qualities improvement of treatment categories will result in advanced meaningful contribute toward to field of bikeway design.

The third limitation is about the choices of statistic calculation. In the methodology, the choice of statistic calculation is the Friedman test of variance by ranks which is a sort of test treated properties of specimen within induvial block separately. As what Danial (2000) indicated, the Friedman test is unlike other test toward variances; yet in the text, the author introduced the Kruskal-Wallis test, which is also a non-parametric method, but it treated properties of specimen within the same range of distributions.

This statement inspired me that choice of different calculations method can impact the results differently. Originally, the Friedman test allows me to compare the difference between treatments across all 3 selected sites. If I chose the use Kruskal-Wallis test in the beginning, the difference might be find in the same range, in this case, the difference can be only approved in the same sites. Therefore, the results, even the hypotheses might be different.

From another stand of point, the application of various statistic calculations are likely to enhance the qualities of the result data. It methodology contain both sets of calculation, the compassions among one sites or among all three sites might result in a more precise thinking process and inspirations while implementing cycling faculties. Therefore, the result might contribute the overall topic of bikeway design from a unique perspective.

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