SMART CITY HAWAIʻI: TRANSFORMING OʻAHU'S CITIES

THROUGH SUSTAINABILITY EFFORTS AND URBAN INFORMATICS

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ABSTRACT

Rising to prominence in the early 2000's, smart cities were imagined as the new urban standard built from green design and urban informatics. Since their conception, smart city research has developed tremendously, including the addition of frameworks to classify the types of smart cities that have since emerged and are most prominent, based on the emphasized technologies in smart city plans across the globe. Although Hawai‘i has not formally published a smart city plan, the ongoing developments most prominently seen on O‘ahu, shows initial signs of smart technology adoption and a concern for transitioning towards a more sustainable form of living, which is why the discussion on smart, sustainable developments must happen now.

Provided recent developments, an environmental scan of O‘ahu and Hawai‘i at large was performed to assess the unidentified challenges and opportunities for smart development. Land use laws, the social and cultural landscape, environmental concerns, technological infrastructure, and the potential impacts of an ongoing public health emergency were all reviewed, revealing that while Hawai'i has already taken some initiatives to develop O‘ahu with smart, sustainable technologies, there as barriers that could potentially threaten timely, well-planned development backed by the public. Among these are ambiguous land use laws, lacking public education and civic engagement, and threats of sea-level rise to a significant portion of O‘ahu's urban districts. Based on the results of the environmental scan, four policy recommendations were made that were deemed most beneficial to current and future developments, including a land use law reform, forming a Smart Urban Development and Sustainability Committee, pushing for better public education and civic engagement, and finally, a post-pandemic plan intended to support a self-sustaining economy. This paper ultimately concludes with four future scenarios that demonstrate the necessity for a clear plan to successfully achieve a smart, sustainable O‘ahu.

Table of Contents

List of Tables

List of Figures

Chapter I: Introduction

Around the globe, smart city efforts are taking place to create more efficient cities and improve how they operate. These efforts vary in progress and range from smart energy, smart infrastructure, smart data, smart transportation, smart mobility, and smart Internet of Things (IoT) technology, to a combination of these to achieve a specific goal within the environment (Maddox, 2016). Many of these "smart" categories are heavily interconnected to meet personalized and elaborate "smart city" goals around the globe. The United States is no exception and has taken its own steps in the smart city initiative, paving the way in the country with a Smart City Challenge launched in December 2015 by the U.S. Department of Transportation. American cities across the nation were challenged to develop a smart transportation system plan "that would use data, applications, and technology to help people and goods move more quickly, cheaply, and efficiently" (Smart City Challenge, 2017, para. 1). Although not a participant in this challenge, the state of Hawai‘i, more narrowly the island of O‘ahu, has taken preliminary steps towards integrating smart technology into their urban grid years before the Smart City Challenge.

Given Hawai‘i's central location in the Pacific, isolated over 2000 miles from any remarkable land masses, and its geographic composition as an archipelago with diverse topography, emerging as a smart city presents a rare set of challenges and opportunities for the state to take on. Admittedly, O‘ahu is in its earlier stages of smart implementation and provides two very different urban centers where development may emerge: Kapolei and Honolulu. As a developing city, Kapolei has the potential to be built up with smart innovations while Honolulu may prove more challenging at the implementation stage because of its existing infrastructure. Still, smart development can benefit Honolulu's present urban development. In order to

determine the best approaches for smart city development on Oʻahu, we turn to the Asia-Pacific region and North America for influence, of which Hawaiʻi is a cultural blend unifying the influences from both regions.

In this paper, I will define what a "smart city" is and put this concept into perspective with new insight on types of smart city models that have developed globally. To build a foundational understanding of each model, regional examples (i.e., case studies) are explored that illustrate each of the models and what ought to be considered when determining the model that is best embodied in their development. Case studies will be selected based on the likelihood of Hawaiʻi being able to recreate or sustain a similar project.

Though cost of developing a smart city or integrating smart technology into and existing city is difficult to determine, exploring the value of these other projects can serve as justification for smart city expenditures. As such, rather than budget focus, this paper examines the value of smart implementation and the opportunities and barriers to developing Oʻahu's cities primarily into smart, sustainable developments. This is accomplished through an environmental scan, a research method where existing policy documents, legislation, legislative reports, and other materials identified later are reviewed to assess social, political, cultural, and economic factors impacting smart development. All this comes as a means for establishing the groundwork of why a smart city discussion needs to happen now for the state of Hawaiʻi, taking into consideration the steps that have already been taken, the motives behind these initiatives, and what policy implementations need to come next to transform Oʻahu from now through 2045, a 25-year projection with a multitude of possibilities but with a hopeful end goal of attaining 100% sustainability.

Chapter II: Smart Cities

Before examining the topics lined up in this paper, it is imperative that "smart city" as a concept be defined. This chapter begins by providing a working definition of the phrase "smart city" and continues with a look into a recently published academic article that identifies four smart city models that are identifiable based on the issue most heavily focused on in the smart city proposal. These models indicate that there is no "one size fits all" approach to developing a smart city and project developers must make decisions based on what best fits their society. Included with the four-model examination is an exemplar smart city for each model that the State of Hawai‘i can potentially look towards in their own potential developments should they be seen fit.

Defining "Smart City"

There is no denying the prominence of transitioning today's cities into "smarter" versions of themselves, yet scholars have found that:

> The smart cities movement has been noted to have several limitations including having a one-size fits all, top-down strategic approach to sustainability, citizen well-being and economic development and for being largely ignorant… of urbanism, and of how computers have been used to think about cities since their deployment in the mid-20th century. (Thakuriah, Tilahun, & Zellner, 2017, p. 19).

This begs the question of what "smart" entails, as it is at best ambiguous and does not resonate similarly among developing and planned smart cities.

The term "smart city" is dated around 2000 and was conceptualized as the future's urban centers, fueled by green design and urban informatics (Hall, Bowerman, Braverman, Taylor, Todosow, & Von Wimmersperg, 2000). The understanding of what exactly a "smart city" entails

has since shifted from its conceptual definition at origin, which refers to solving issues in urban design by applying Information Communication Technologies (ICTs) and information processing capabilities to them (Tang, Jayakar, Feng, Zhang, and Peng, 2019). Smart cities are distinguishable by their use of "the Internet of Things" (IoT), a concept that has seen a plethora of definitions since it was first coined.

Common terms associated with IoT as found through these definitions and analyzed by computer scientist and scholar Jeffrey Voas (2016), who has published a number of articles on IoT as part of the National Institute of Standards and Technology under the U.S. Department of Commerce, include: "things, interconnected, Internet, cyber-physical, devices, sensors, smart, physical objects, and virtual world." IoT is indeed inclusive of all these aspects but they are not part of what *should* be a foundational definition of the concept. Voas (2016) proposes that IoT is at it a fundamental level, "about communication, computations, sensing, and actuation," and falls under a larger umbrella he calls the Network of Things (NoT), as IoT does not indicate one singular technology. Rather it implies a "thing" linked to the Internet, a network, hence NoT, under which IoTs exist.

IoT has been used as somewhat of an ambiguous buzzword for marketing technologies that embrace a new standard of being: existing on an interconnected network. Smart city technology is rooted in creating more efficient solutions to operating a city and thus values IoT as the broadly defined answer to empowering cities to reach new limits.

Today, smart cities may be known through a variety of names such as "ubiquitous city", "digital city", and commonly "smart city" among a few others. What remains the same despite the difference in nomenclature is that they each convey this idea of urban informatics, a relatively new technological framework focusing on exploring and understanding urban systems

with generous attention to big data (Thakuriah et al., 2017). Thakuriah et al. (2017) state four areas of research and applications in urban informatics: "(1) improved strategies for dynamic urban resource management, (2) theoretical insights and knowledge discovery of urban patterns and processes, (3) strategies for urban engagement and civic participation, and (4) innovations in urban management, and planning and policy analysis" (p. 1).

Framing smart cities on the principles of urban informatics provides a comprehensible set of goals that can be understood by policy makers and urban developers alike in regulating planning protocols and fulfilling smart city plans.

Smart Cities: A Four-Model Framework

As the geographical and cultural meeting point between two regions, it is sensible that both the smart cities from the Asia-Pacific region and the United States are primary, though not exclusive, points of reference when determining how to proceed with smart city planning on O‘ahu.

Recall that Thakuriah et al's (2017) research depicts the smart city movement as one as having several limitations, one of which is that it is reflective of a one-size-fits all solution. Since their article, however, other researchers have developed a framework that demonstrates recognition from urban and smart city developers of targeted models to resolve goals specific to their city. This is reflected in a four-model framework that takes into account that no two smart cities are alike and there is no one way to plan a smart city when city goals, existing infrastructure, financial resources, and the like are each variable and must be taken into consideration. By examining a respective smart city that fits within the confines of its representative model and narrowing the scope of the region to one of particular relevance, the groundwork for this O‘ahu policy paper is set.

Research conducted by Tang et al. (2019) provides four archetypes for classifying smart cities according to the policies, procedures, and plans that countries around the world rely on when designing a "smart city". They are: (1) the Broad Spectrum Model; (2) the Smart Transportation model; (3) the Essential Services Model; (4) the Business Ecosystem Model. Whereas the Broad Spectrum Model denotes a comprehensive, model smart city, the other archetypes depict more narrow and focused smart city elements. Below, the four archetypes are defined. Note that a city's model is determined by where they place their emphasis in planning and development. Below, each model is explored in greater depth. For each archetype, a regional example that illustrates each model and what the respective city, country, or state's goals are when they decide which model to embody in their development is presented. Note that the case studies presented are selected based on the likelihood of O'ahu's potential to replicate and or sustain similar projects. Consideration for what each model promotes is urged as we look towards a future archetype that suits the state's goals for Kapolei and Honolulu.

Smart Transportation Model

Understandable from its name alone, the Smart Transportation Model is applicable to city plans with a main objective of controlling urban congestion, and is fulfilled with smart public transit, rideshare, and autonomous vehicles (Tang et al., 2019). City profiles commonly fitting this model are those "high-density congested population centers or city states with a history of business activity" (Tang et al., 2019, p. 11).

While Singapore's smart city plan does not exclusively address smart transportation, the Smart Nation initiative, launched in 2014, emphasizes transportation solutions for the nation. A small island nation, Singapore's available land for development is considered scarce compared to other countries with grater land mass, so much so that twelve percent of their land is dedicated to

roads and transportation infrastructure (*Transport*, 2020). Singapore pitches the use of autonomous vehicles as a means of mobility for the elderly and disabled. Autonomy extends to shuttle services, which optimizes land use and reduces reliance on limited manpower (*On-demand shuttle*, 2020).

Related to transportation is hands-free fare payment systems for public transportation like buses and the train system. Fare cards can automatically deduct when passengers pass through fare gates. An alternative-fare option in trial utilizes Bluetooth technology in mobile devices. Additionally, Singapore offers commuters another payment solution, which is to use contactless credit or debit cards to make direct fare payments. A pilot for this option was launched in March 2017 and received over 100,000 sign-ups from commuters. In April 2019, after two years from the successful launch of the pilot program, Singapore's Land Transport Security released the application SimplyGo to manage passengers' contactless card fare payment accounts (*Contactless fare payment*, 2020).

As it stands, Smart Nation Singapore's smart transportation innovations and implementation are fully in motion, with autonomous vehicles in testing since 2015 and contactless fare payment out of its pilot stage. For Singapore, the Smart Transportation Model answers the call of providing a "more efficient, safe, reliable, and enhanced transportation" network, optimizing a nation whose space is limited and congested with over a million vehicles on the road (*Transport*, 2020, para. 1).

Essential Services Model

A model with a little less traction on its own, the Essential Services Model depicts a smart city whose concerns lie with "emergency warning and digital healthcare, supported by deployment of mobile networks" (Tang et al., 2019, p. 11). Buzzwords that may apply to this model include

“interoperability”, “first responders”, and pertinent to the United States, “FirstNet”. These terms will be revisited as they pertain to potential future scenarios for O‘ahu. This model is inclusive to disaster preparedness and management, crucial in countries and cities burdened by natural disasters. Though a few cities fit this profile, Tokyo offers a thorough take in their published smart city initiative that can be referenced when developing O‘ahu’s future smart city plans.

At the end of 2016, the Tokyo Metropolitan Government drafted a four-year plan known as “New Tokyo”, slated for completion during the fiscal year of 2020. “New Tokyo” was imagined as a city with three core goals: to be safe, diverse, and smart. The Essential Services Model is best reflected in the “safe city” realization, in which “New Tokyo” states the following: “We will protect the lives and assets of the Tokyo residents from all kinds of disasters, and build a dynamic and bustling Tokyo” (Tokyo Metropolitan Government, 2017, p. 2). The first step to achieving a smart city is to optimize current hindrances that may be a liability to safety and efficiency of essential services.

“New Tokyo” thus tackles concepts like earthquake safety with removal of utility poles to eliminate collapses and obstruction of roads from these events and providing earthquake resistance inspections and optimizations to residences. This is viewed as a step towards disaster-resilient urban development. Disaster management is improved upon further with new community roads to function as firebreaks and rebuilding current structures to be more fire resistant. Countermeasures to support torrential rainfall, an increasingly common issue in Tokyo, include a planned regional reservoir, adding sewage facilities in areas where flooding is more common, and updating the flood risk map to reflect more recent and relevant flood trends (Tokyo Metropolitan Government, 2017).

Tokyo also turns its attention to counterterrorism surveillance measures, utilizing emergency camera image transmission system, which allows private security cameras to be used to assess a situation at the site of disaster. To counter acts of arson, Tokyo planned to implement a new firefighting system in the Fiscal Year of 2019, though they do not disclose exactly what this entails beyond the use of drones and "other tools" to monitor and respond to emergencies. Not to neglect cyber warfare, Japan has also indicated plans to conduct drills with private operators to prepare for potential cyber-attacks. It is worth mentioning that the bulk of counterterrorism measures and other essential services in this plan come as a result of the Tokyo 2020 Games, an opportunity that Japan has capitalized on with the goal of sustainable growth for the nation. At the time Japan's smart city plan was published, they predicted a growth in tourism by 2020 that more than doubled Tokyo's tourism from 2015, which fell just under 12 million then. With the anticipated large influx in tourism expected from the Tokyo 2020 Games, counterterrorism preparation is a natural addition to their smart city plans (Tokyo Metropolitan Government, 2016).

Business Ecosystem Model

The Business Ecosystem Model details the shift from transportation hubs and manufacturing centers to an economy bolstered by investment in digital skills training and business innovation centers, and is identified in their research as smart city projects that highlight "electronic approval of new business permits, encouragement to high tech businesses, [and] high-tech innovation zones" (Tang et al., 2019, p. 7). Findings from Tang et al. (2019) urge a look into North America-based city, Toronto, Canada.

Known as Sidewalk Toronto, Toronto's smart city project (discontinued as of May 2020) was marketed as "a new approach for inclusive [urban] growth" (Sidewalk Toronto, n.d.). In

actuality, Sidewalk Toronto targets elements beyond the Business Ecosystem Model, but much like Singapore, its focus is considerably oriented towards the Business Ecosystem Model, as determined by Tang et al. (2019). Job creation and urban innovation are a part of Toronto's smart city vision.

Part of the vision imagined by the Sidewalk Toronto plan is transforming Toronto into a global urban innovation hub. This is deemed accomplishable through three new major additions to the city in what would be known as the IDEA District: a Google campus, an applied-research institute, and a venture fund for Canadian companies. By relocating Google's Canadian headquarters as part of a new innovation campus, Sidewalk Toronto expects an influx of global business and talent. With the support of all levels of government and the output of academic and research institutions, technology industries are at an advantage in acquiring the support needed to build up Toronto as a smart city (*Outcomes*, n.d.).

Note that Sidewalk Toronto plans to incorporate smart city infrastructure and further develop an already existing city by inducing economic growth. This means that there is an economic presence of some sort already persistent, albeit not as developed as Sidewalk Labs pushes for. At present, the job prospects and GDP remain relatively low from the city, but smart city plans working with a 20-year projection indicate generous growth. By 2040, they project a direct job growth of over 44,000 full-time permanent positions. Additionally, they anticipate an indirect job growth of approximately 30,000 and some 20,000 induced jobs. This adds up to over 93,000 jobs, roughly seven times the amount of jobs currently present. Economic stimulation as a result of industry and job growth shows a similar trend: around seven times the annual GDP contribution than exists today by 2040. Up from $2.1 billion, the growth is estimated at $14.2 billion, a significant increase that showcases the practical value of the Business Ecosystem

Model for cities whose concern is with developing a robust economic hub (*Economic Development,* n.d.).

Broad Spectrum Model

The Broad Spectrum Model as the name indicates, is the most broad and balanced of the four archetypes. This model includes many different aspects of smart city planning and is inclusive of the three former models discussed, capitalizing on no one aspect in particular and driving development in all fields at a relative pace. Tang et al. (2019) indicate Bellevue, Washington as one of the prime examples of a smart city founded on the principles of the Broad Spectrum Model. To begin with, the Bellevue vision statement is as follows:

> Bellevue is a "smart city" with a clean, high-quality environment and excellent and reliable infrastructure that supports our vibrant and growing city, including high-tech connectivity. The city has a connected multi-modal transportation system, which blends seamlessly with its buildings, plazas and parks. (City of Bellevue, 2017, p. iii)

Since 2016, Bellevue has actively worked towards implementing what they call, "elements of a smart city", featuring six narrowly pinpointed target areas in their vision statement to incorporate and enhance smart city features. These include *smart buildings* with goals of reducing waste and integrating emergency first responder systems for safer buildings, *smart connectivity* under which broadband, fiber optic, Wi-Fi, and smart city communications networks are better integrated and accessible, and *smart energy*, including advanced metering, and optimized grid to reduce system outages, and energy conservation and renewability. The City of Bellevue website provides timelines detailing past advances, current projects for the year of 2020, and plans for each respective element of their smart city that they identify.

In addition, *smart public safety* includes the most comprehensive list of objectives and strongly supports the notion of civic engagement emphasized in the Broad Spectrum Model. Bellevue's plan to accomplish smart public safety is through integrating systems to optimize patient care, predictive analyses to prevent crime, implementing FirstNet to provide for a better first responder network, and solving interoperability issues (*Smart City*, n.d.).

FirstNet is the United States' interoperable public safety broadband network and is overseen by the First Responder Network Authority under the U.S. Department of Commerce. FirstNet has priority over Long-term Evolution (LTE) networks (faster than 3G, slower than 4G) and allows first responders to connect with other agencies more immediately to arrange dispatch. Together with IoT, the benefits to first responders promises high potential in smart cities. For example, IoT sensors have the capacity to provide positioning information, and with future developments, these sensors could potentially provide the exact location of traffic accidents to EMS and others. Any requests for additional units for dispatch can be managed through FirstNet (Passanante, 2019).

Moreover, with s*mart transportation*, Bellevue's goal is to increase safety and improve modes of transportation through connectivity of vehicles. Finally, with advanced metering, proactive detection of leaks, and using predictive systems to improve the reliability, capacity, and water quality, Bellevue has the capacity to meet their projection for a *smart water* project, thereby completing their smart city plan (*Smart City*, n.d.).

The Cost and Value of Smart City Transformation

Smart city planning requires that city planners consider both cost and value of a project before approving implementation. The terms cost and value are often used in similar contexts, with more variety to how value is defined. First and foremost, cost is always measured monetarily.

Value on the other hand, is not typically measured in monetary terms. For the purpose of this paper, the working definition for value is derived from Olajide, Lizam, and Olajide's (2016) article clarifying the conceptual definitions of cost, price, worth, and value. In their exploration of various definitions provided for each term, they define cost as "the amount incurred in producing and manufacturing a product," and value as "the utility of a good or service" (p. 55). Building off their definition for value, finding value in smart cities relies on an examination of what benefits smart technology brings to society. Using these definitions, the cost and value of investing in smart cities is explored below.

A major aspect that is not examined in the research conducted by Tang et al. (2019) is expenditures. This is largely because cost varies significantly by the projects undertaken in the various smart city models. It seems reasonable however, to hypothesize that the Broad Spectrum Model, which seeks to provide smart solutions to all aspects of society, will be the costliest of the proposed models as a larger scale operation. Likewise, it is reasonable to say that transforming an existing city into a smart city could run more costly than transforming a developing city or building a new smart city one from the ground up. This can be credited to the existing infrastructure that would require rebuilding at various levels to modernize and restructure older cities. While there are no relevant studies that assess the variations in cost of smart cities globally or even nationally, Smart America (n.d.) anticipates a $41 trillion investment over the next two decades in infrastructural upgrades across the nation's cities. This raises the question of what value is seen that reinforces the need for this expense in the United States.

The Association for Computing Machinery (ACM) Code of Ethics and Professional Conduct states that computing professionals, such as those tasked with bringing smart cities to

fruition, should make contributions benefiting society and humanity's wellbeing. In the case of smart cities, computing professionals within the field of urban informatics must translate their skillset in ethical means to bring forth promising technological developments meant to improve livability for the millions of citizens that live in them (Winter, 2019). In each of the smart city models, there are valuable applications that are meant to fit the demands of the city, such as Singapore's lean towards the smart transportation model, which holds practical benefits for its many residents.

The road to determining value in smart development, however, is hardly straightforward. Advocacy for smart cities is commonly accomplished through marketing specialists, consultants, and city officials, with vague claims to the values of smart city developments. In a similar manner, idealized marketing and policy reports often fail to account for the unique social, technological, and economic environmental factors affecting the deployment of smart cities in the designated locale (Valdez, Cook, & Potter, 2018). This paper seeks to bridge this potential disconnect with potential development on O'ahu through compiling these factors ahead of further consideration from policymakers. However, because smart cities are intended largely to support the community serviced, value is not something that ought to be determined by policymakers alone; civic engagement should be encouraged to determine value to the people, a significant stakeholder in the grand scheme of smart city development.

An issue that may emerge ahead of policy decisions for smart development is that when only certain demographics are involved in civic engagement, they are the few who will see benefit since they are the group(s) voicing their concerns. This means that for those who are rural and those considered disadvantaged, often two groups underrepresented in civic engagement, they are likely to be overlooked where values that might benefit them are concerned. There is

reasonable concern in this that Winter (2019) holds computing professionals accountable to where justice is concerned. Provided that each demographic ought to be represented in civic engagement to gauge the value of each smart initiative, it is reasonable then that the public value in smart city advancements must outweigh the costs to achieve the project in order to deem it a successful investment.

Something else to consider where civic engagement and the success of smart city services is concerned, is providing citizens education on those services to improve understanding on both existing and future services to the public (Lee, Lee, & Lee, 2019). In the same study, it was determined that those who have an interest in innovative products, have more familiarity with "high technology", or are familiar with smart cities, are better aware of the services provided within a smart city. To curve the discrepancy in knowledge and the lack of civic engagement from the rural and disadvantaged populations, education is imperative, especially pre-emptively to account for these demographics in the developmental phases of projects (Lee et al., 2019; Winter, 2019).

In the following chapter, a background of O‘ahu’s current smart and sustainable city projects is featured. While reading, consider how O‘ahu’s own rural and disadvantaged populations may benefit or be ostracized in the current developments. Chapter IV, which introduces the challenges and opportunities to consider in ongoing and future developments, seeks to weigh in on the value of smart city development on the island. Beyond the potential to simply attain new technology, I urge you to continue to consider the public benefit for these identified demographics in this chapter too.

Chapter III: O‘ahu at Present

As it stands, O‘ahu hosts two cities with potential for smart city planning and growth. Current efforts on the island have emphasized a Smart Transportation Model, with state support for hosting testing of autonomous vehicles and eventually welcoming them onto local roads. Furthermore, the Honolulu Authority for Rapid Transportation (HART), with local, state, and federal support, has worked on constructing an electrically powered automated rail system that will run from Kapolei to Ala Moana in Honolulu when completed. Current projects on O‘ahu however, are not limited to just smart transportation, but also smart energy as part of the state’s sustainability initiative. Below, these transportation and energy developments are discussed.

Support for Autonomous Vehicle Testing

In November 2017, Governor David Ige of Hawai‘i signed Executive Order 17-07. He issued the following statement in the order:

> WHEREAS, in recent years, our island state, with its conditions conducive to introducing electric vehicles—including Hawai‘i’s ideal battery-friendly temperature ranges, Hawai‘i’s contained market, Hawai‘i roadways offering short commutes, and Hawai‘i’s favorable government policies—has seen international auto manufacturers include Hawai‘i as one of their first rollout markets for Zero Emission Vehicles. (para. 6)

Further offering that Hawai‘i similarly offers “ideal conditions for the testing and rollout of connected autonomous vehicles”, Governor David Ige calls for autonomous vehicle testing in the state of Hawai‘i (Haw. Exec. Order No. 17-07, 2017). The order addresses multiple facets of concern and relief as they apply to the state and who will regulate autonomous vehicle testing, including the University of Hawai‘i engineering department, Hawai‘i’s new car dealerships, and companies that specialize in connected automated vehicles (CAVs) and 5G deployment. The

most immediate implementation deals with shuttle buses at the Consolidated Rental Car Facility at the Daniel K. Inouye International Airport. The order also states vehicular autonomy as a safer alternative that may be more efficient in saving time and alleviating the overall traffic in the state, common in both freeway and metropolitan roads (Haw. Exec. Order No. 17-07, 2017). Ige ultimately requested establishing a Hawai‘i CAV contact in the Office of the Governor who is to "provide the highest level of attention and support to companies seeking to test self-driving vehicle technology in Hawai‘i" and that:

> The Hawai‘i Department of Transportation, the Hawai‘i Department of Public Safety, and the Hawai‘i Department of Business and Economic Development and Tourism shall take steps to work with companies seeking to do self-driving vehicle testing and development [sic] business in Hawai‘i, through policies and as otherwise needed, in the interests of the public. (Haw. Exec. Order No. 17-07, 2017, para. 8)

There has been no recent update on this order's operational status and beginning of testing in the state remains to be fulfilled. However, in 2019, House Bill No. 1183 (2019) was introduced with the purpose of authorizing the operation of CAVs for testing purposes, further supporting Executive Order 17-07. HB1183 was most recently carried over to the 2020 Regular Session (*HB1183*, n.d.). Pending enactment of this bill, the Department of Transportation will be required to have autonomous vehicle manufacturers who intend to test in the state provide a satisfactory safety record, their insured or bonded status, a list of the vehicles safety features including a manual override feature, and lastly satisfactory proof of the ease an autonomous vehicle's operator can enable and disable the self-driving technology (Haw. H.B. No. 1183, 2019). This indicates a concern for policy and the expectation that safety will be upheld as Hawai‘i takes on smart transportation on roads that will be shared with humans and computers alike.

HART and The Rail

Hawai‘i’s venture into smart transportation does not terminate with automobiles and buses. The Honolulu Authority for Rapid Transportation’s (HART) sole project is the Honolulu Rail Transit Project. Reflected in HART’s mission statement is a push for the Smart Transportation Model and states the goal with the Rail is “to provide an efficient and reliable transportation alternative for Honolulu’s congested urban corridor” (*About Us,* n.d.). The Rail Transit project was established in 2005 and is set to be run on as a fully automated electrically powered system. Construction on the Rail began in 2011 and is anticipated to continue beyond 2025. However, the first section of the Rail, running from Kapolei to Aloha Stadium, is slated to become operational in March 2021. The remainder of the route, from Aloha Stadium to Ala Moana Center, is planned to begin operating by 2026, though it may take longer, pending land procurement, changes in political will (i.e., mayoral changes), and possible delays or stalls that arise from project funding source mismanages, occurrences that together have tarnished public opinion on the project.

At its anticipated completion, the Rail will thereby connect O‘ahu’s second city to Honolulu and will service the island’s most populated communities. The overall project completion to date sits at just over 55%, according to HART (2020). When completed, the Rail is estimated to cost more than $6.7 billion at completion. $1.55 billion of this budget was awarded under the federal Full Funding Grant Agreement (FFGA). Since 2007 and through 2027, a half-percent surcharge on goods and services purchased on O‘ahu has been and will continue to be collected to cover $4.8 billion of the project total. To cover the remainder of the project, funding will come from alternative federal programs and locally generated revenue from interest on funds or deposit (*Rail Facts,* n.d.).

It should be noted that by 2030, HART aims to take more than 40,000 vehicles off O‘ahu roads. As such, HART is generally targeted towards O‘ahu’s residents, current riders of public transportation and those who travel with private modes of transportation all the same. Based on HART’s commitment to this, Rail stations feature a variety of options to accommodate and encourage ridership. This includes park-and ride lots, automobile drop-off and pick-up (kiss-and-ride) zones, bicycle parking and storage, and TheBus and TheHandi-Van boarding areas. By doing so, the Rail makes itself readily available towards the general public to provide an efficient, reliable service that does not interfere with road congestion from its elevated construction (*Station Design and Features,* n.d.).

Smart Energy for Sustainable Living

Hawai‘i prides itself in having an optimal geographic composition that allows the state to meet its renewable energy goals. One project known for its smart sustainability is the Kapolei Sustainable Energy Park, which became operational in 2011 and provides clean electricity to thousands of homes. It consists of some 4,200 photovoltaic modules on five acres of land located near the Campbell Industrial Park. This energy park services close to between 150 and 250 homes annually and over the course of 25 years, is expected to have reduced greenhouse gas emissions significantly with the elimination of over 38,000 tons of carbon dioxide emissions (*Kapolei Sustainable Energy Park,* n.d.; *Solar Power,* n.d.). Oil consumption will be minimized too, saving 120,000 barrels over this timeframe.

At present, HECO is contracted to purchase power from the Kapolei Sustainable Energy Park until late 2031 (*Kapolei Sustainable Energy Park,* n.d). Similar projects have seen become operational on the leeward side of the island, with the Kalaeloa Renewable Energy Park and Kalaeloa Solar Power II servicing Ewa Beach. Furthermore, in 2019, a massive 20-megawatt

solar plant—Kapolei Sustainable Energy Park a 1-megawatt plant for comparison—was proposed, known as the Kalaeloa Solar Energy Project (Innergex). It is possible that this large solar plant may be a part of the Hawaiian Electric Company's (HECO) plan to replace some of the energy that will be lost when Campbell Industrial Park's coal-fired power plant providing 180 megawatts of power, AES Hawai'i, ceases operations in 2022 (Hawai'i State Energy Office, n.d.)

By 2045, Hawai'i hopes to achieve their goal of 100 percent renewable energy. Tactics proposed to accomplish this according to HECO are modernizing each islands' power grid to a smart grid, which "allows for two-way communication between the utility and its customers… to respond digitally to our quickly changing electric demand" (*The Smart Grid,* n.d., para. 2). Additionally, HECO promotes shifting to electric vehicles and powering the islands through 100% green energy (*Our Vision and Commitment,* n.d.).

Looking towards the Future

Up to this point, brief case studies on the four smart city archetypes have been provided as well as an analysis of O'ahu's present state. The remainder of this paper proceeds to provide future projections for O'ahu's smart cities, applying urban informatics in the development of this plan. Future projections will look at O'ahu in the next three decades and will consider where O'ahu's cities stand now in their smart city initiatives and what additional challenges and opportunities may emerge. This will be a comprehensive examination of the variety of smart initiatives that can be taken. Provided a 25-year projection, we will determine the archetype that is most suitable based on the goals Honolulu County has set for its respective cities.

Chapter IV: An Environmental Scan

The purpose of environmental scanning is to "to find early indications of possibly important future developments to gain as much lead-time as possible" (Gordon & Glenn, 2009, p. 1). In other words, this method involves examining persisting issues and room for opportunity to be considered ahead of informed policy decision making. Environmental scanning offers a preliminary examination of stakeholders, climate change, land use, and social, economic and technical factors that must be considered ahead of smart city planning. The goal in this is to highlight areas of uncertainty, barriers, and challenges presented by the current state of affairs beyond what is already underway.

Using the environmental scanning method, this paper examines a variety of source material to set the framework for smart city development on Oʻahu. The theoretical framework set forth pre-emptively in this paper was sourced from journal articles and exemplified through relevant case study resources, including city project official sites, governing organizations, and city urban planning reports. Moving forward, policy groundwork is laid primarily through government publications, industry reports, and examination of news archives to deliver relevant historical data important to consider ahead of Smart City Oʻahu, highlighting areas for opportunity, barriers and challenges, and areas of uncertainty.

In assessing the potential for smart city development on Oʻahu, major areas of concern highlighted in this chapter are:

1. Geographical concerns, with special attention to state land use laws and the built environment.
2. The social and cultural landscape of Hawaiʻi, including demographic information and a traditional Hawaiian value affirming sustainable practices.

3. The natural environment, with a strong focus on the impact of climate change on the state and the state's sustainability mission.
4. The state of technological infrastructure and its ability to support smart project developments.
5. And the potential impacts of an ongoing public health emergency with the COVID-19 pandemic.

The issues brought forth in this paper are a culmination of examining work from the following groups and organizations: the Hawai‘i 2050 Sustainability task force, the Hawai‘i Climate Change Mitigation and Adaptation Commission (Hawai‘i Climate Commission), Hawaiian Electric, Hawaiian Telcom, O‘ahu Transit Services, and various departments under the State of Hawai‘i at large.

Because no two smart cities are alike, it is important to realize that the emerging challenges and opportunities that each smart city faces and those presented in this examination are unique to O‘ahu. Figure I (below) presents a SWOT analysis summarizing the main issues identified in this environmental scan:

Figure I. SWOT Analysis of O‘ahu's Potential for Smart Development

Strengths	Weaknesses	Opportunities	Threats
• Aligning cultural and environmental goals on sustainability • Transpacific appeal	• Unclear land use laws • Public education • Economic dependence on tourism	• Revised land use laws • Modernized technological infrastructure to support smart grid • Public education on smart and sustainable development	• Climate change impact on rising sea-level and current infrastructure and urban centers • COVID-19 • Civic unrest

While these points might seem largely vague at this point, this chapters serves to provide the greater context of the significance of each of these aspects ahead of any policy recommendations, beginning with land use laws in Hawai‘i.

Land Use Laws

As an island state surrounded by thousands of miles of Pacific Ocean, land in Hawai‘i is notably limited. Even smaller still is O‘ahu, which comprises of almost 600 square miles, making it the third largest of the Hawaiian Islands and the most densely populated. The most recent census release in 2010 indicated a population of 950,000 on O‘ahu, comprising of over 70 percent of the state’s population (Hawaii State Data Center, 2013), most of which is concentrated heavily along O‘ahu’s south shore. Land use laws and designated districts contribute to where urban development is permissible, with the added barrier of consent for development controlled mostly by O‘ahu’s consolidated landowners.

Competition for land, a rather unique issue in the state, presents a contrast in a deeply rooted cultural perspective that does not align with the notions of land ownership. Despite this, the market approach had dictated value in ownership of land, much of which is highly concentrated. On O‘ahu alone, the most prominent consolidated land ownership is attributed to five entities: the state government, the federal government, Kamehameha Schools, Castle & Cooke, and the county government (Wallace, 2015). From Kapolei to Waikiki, following the island’s most urbanized developments, land ownership sits largely between the state and federal government. This consolidated ownership controls the rate at which land is released for developing, meaning that planning and land use is susceptible to delays and hinderances as plans go through the process of approval. By law, despite land ownership titles, what one is allowed to do with their land that is either constructive or entrepreneurial, cannot be executed without the

consent of a variety of parties, including the City Council, the State Legislature, the courts, and the land use law administering body, the Land Use Commission (Hawai‘i 2050 Sustainability Task Force, 2007).

From 1960 through the 70s, a variety of land use plans emerged, providing the islands with the groundwork for land use development. However, the State Land Use Law in 1961, which was the nation's "first instance of state control and land use," has remained among the most influential regulatory land use documents (Hawai‘i 2050 Sustainability Task Force, 2007, p. 94). This law is responsible for the creation of four land classifications in the state: urban, rural, agricultural and conservation lands, all with varying control between state and county jurisdictions (Hawai‘i 2050 Sustainability Task Force, 2007). In 2007, the State Land Use Law in 1961 saw its most recent amendments. Table I (below) provides an overview of the land use guidelines designated in Hawai‘i Revised Statutes Chapter 205 (2007) as it pertains to the four identified districts:

Table I. Current Classification of Lands

District	Definition	Inclusions	Governance
Urban	Lands now in urban use and reserved land in areas with foreseeable urban development	Activities and uses dictated by county ordinances and regulations	County jurisdiction
Rural	Lands comprised of small farmlands and low-density residential lots	Golf courses and related facilities; residential lots at least one-half acre	Joint state-county
Agricultural	Lands with high potential for intensive cultivation efforts	Agricultural parks; aquaculture; cultivation of crops; energy production; farming; open-air recreational facilities	Joint state-county
Conservation	Lands consisting of forest and water reserve zones	Parks, wilderness, and beaches; scenic and historic areas	State Department of Land and Natural Resources

Note that the Department of Hawaiian Home Lands is exempt from county zoning. Furthermore, the distinction between rural and agricultural considers topography, soils, and other geographic differences that make the land more suitable for one use over the other, as seen with the inclusion of golf courses as rural zones rather than agricultural. Note however that there is no classified rural land in on Oʻahu, which calls into the question the validity of these working definitions and distinctions as an isolated example. This one example among other cases that highlight the discrepancies in current land use law, highlights the need for reviewing the law at present.

In 2014, the State of Hawaiʻi Office of Planning released a five-year boundary review. This comprised of two phases, a review of HRS205 without pursuing boundary amendments and phase two, consisting of recommendations to the commission, the governor, and the legislature on how to improve the land use law without compromising its initial intent. Following the completion of Phase 1 and Phase 2, the Hawaiʻi 2017 legislative session introduced HB1321 Relating to Land Use. This bill called for establishing an advisory committee tasked with reviewing the State Land Use Law to clarify discrepancies resulting from amendments and systemic loopholes that have caused confusion in what is permissible in the different districts (Haw. H.B. No. 1321, 2017). In this bill, the proposed committee would have required this advisory committee to submit reports to the legislature and included a write-in sum of appropriated funds to support the act proposed. Although HB1321 died in committee and thus garnered no immediate action on land use revisions, it is still worth examining the efforts of the proposed land use revisory committee under this bill, which are as follows:

> (1) Review the evolution of the land use law since its enactment and the reasons for the various amendments to the law; (2) Review conflicts that have arisen because of ambiguities in the law and the judicial remedies that have been rendered;

> and (3) Revisit the recommendations of the various commissions, task forces, and working groups that were created to investigate different components of the land use law, such as the land evaluation and site assessment commission and the rural working group. (para. 7)

Provided climate change concerns discussed further below, it is reasonable to consider the need for a land use advisory committee once more ahead of potentially changing demands in urban development to accommodate evolving environmental conditions discussed later in this chapter.

Society and Culture

This next section is comprised of two elements: a demographic examination of Honolulu County and a review of a traditional Hawaiian value promoting sustainable living that is still largely practiced today. Through identifying both demographics and cultural relevancies, there is potential to gauge how society could benefit from smart and sustainable developments and how the state and other organizations can proceed with educating and informing the public in community matters of concern with ongoing and upcoming developments. A development that is supported by the community presents a better likelihood for achieving at-large goals where community involvement is required.

Recall that the recorded Census population for Honolulu County in 2010 was slightly over 953,000. However, the most updated population estimate provided by the United States Census Bureau on July 1, 2019, indicates an increase in population from the 2010 Census by 2.2%, at over 974,563 (*QuickFacts Honolulu County, Hawaii*, n.d.). In addition, QuickFacts, operated by the U.S. Census Bureau provides estimated demographic information for the county. The estimates provided below is for demographic categories deemed most informative for smart and sustainable development on O‘ahu. These identified demographic categories are home

broadband internet access, education, living arrangements, income and poverty, and transportation.

From a 2014-2018 timeframe, the average O‘ahu household has three persons. Approximately 85.3% of these households have a broadband internet subscription. Median household income in 2018 was an estimated $82,906. Of the estimated population, approximately 7.7% are in poverty. Relative to the percent of population age 25 and older, approximately 91.7% are high school graduates or higher and 34.3% hold a bachelor’s degree or greater (*QuickFacts Honolulu County, Hawaii*, n.d.). As for transportation, in 2013, the U.S. Census Bureau reported that the in Honolulu County, 64.7% of people drove alone, 14.7% carpooled, and 8.1% relied on public transportation. The demographics for public transportation users comprised most significantly of those 55 years and over at 25.9% with females comprising over 58.4% of public transportation ridership. The most popularly reported occupation of public transportation-dependent citizens was in the Service industry (Hawaii State Department of Business, Economic Development and Tourism, 2015).

Broadly, these statistics above can be examined alongside those elements identified in figure I to make future projections on community adoption of new technology and sustainable systems. Income for example, might be considered in gaging probability of investment into solar systems and electric cars. Similarly, the ever-declining population and overwhelming reliance on POVs versus public transportation when factoring in health concerns, calls to question the willingness of residents to ultimately adapt to a new public transit system able to thrive and accomplish the reduction of greenhouse gas emission goals set forth by various stakeholders. Proceeding through this chapter with demographics in mind should raise questions that may not have been previously asked or were otherwise tentatively answered assuming an agreeable and

adaptable island population. This is not to say that residents will be disagreeable, as traditional Hawaiian values urging sustainability and taking care of the land still remain strong, but demographic categories residents are personally a part of are a very real factor to account for that may hinder progress without proper policy and community education.

Historically, Hawai‘i embraced the idea of the land as a communal resource, with one of the Hawaiian values, *malama ‘aina,* meaning ‘to care for the land’. It is generally expected that every member of the community observes this value, which is ultimately embedded in caring for and showing respect for the land by partaking in sustainable practices. This value maintains that as a steward of the land, an individual should use only what they need and nothing more. Years ago, this would have consisted of not over-fishing in ponds, not over-plucking feathers from birds for elaborate cloaks worn by kings and being savvy with materials harvested for construction purposes, among others.

Today however, in modern society, these practices translate to the ways in which citizens interact with technology and invest in more sustainable alternatives. Minimizing water use and turning to smart water meters, transitioning to public transportation and electric vehicles, and investing in home photovoltaic (PV) systems are all ways to continue the practice of *malama ‘aina* at an individual level. At the state level, implementing legislation and pushing for more sustainable practices statewide afford a similar effectiveness that enables each island to invest in new projects and developments with wide-reaching benefits. Current sustainability goals contributing to the Hawaiian value of *malama ‘aina* established by the state are introduced below.

Hawai‘i’s Sustainability Goals

Green Magazine Hawai‘i, the state’s designated magazine for informing consumers about sustainable living practices across the island, identified three environmental goals for the state in their 2020 issue. These four goals are as follows (Hawaiian Electric, 2020):

1. By 2030, reduce vehicle miles traveled through alternative transportation options.
2. By 2030, minimize negative impacts of land use on environment and people.
3. By 2030, achieve 30% energy efficiency and have 40% renewable energy.
4. By 2045, have 100% clean and renewable energy.

In chapter III, O‘ahu’s solar farm projects and transportation solutions were introduced. These listed goals serve to inform what has driven the initiative to move towards a more sustainable and smarter way of living. This section addresses how Hawai‘i has gradually taken steps towards these goals and the challenges and opportunities that have emerged in the smart model context altering the progression towards these four goals set forth by the state.

Hawai‘i’s move towards sustainability over the next decade is part of the United Nations 2030 Sustainable Developmental Goals. In 2017, Hawai‘i became the first state to sign on to the Paris Agreement, indicating the intent to produce net-zero greenhouse gas emissions by 2050. Approved by Governor David Ige in 2017, S.B. 559 recognized Hawai‘i’s need to reduce activities contributing to global warming and to work towards reducing the impacts of climate change on the state, emphasizing a concern on rising sea levels on the state, a concerning long-term issue this paper later addresses (2017).

Meeting 2030’s and 2045’s goals of energy efficiency and clean and renewable energy is largely reliant on the local community’s initiative to go paperless, invest in photovoltaic home systems, and making the switch to electric vehicles and environmentally conscious public

transportation alternatives. Most recently, in the 2019-2020 Sustainability Report published by HECO, Oʻahu rated at 25.2% renewable energy, with customer-sited solar comprising of 12.9% of the total percentage. Biomass was second most prominent, producing 6.3% if the renewable energy. Grid-scale solar (i.e., solar farms) followed with 3%, with wind and biofuels completing the remaining percentage at 2.3% and .8%, respectively (2020). This leaves Oʻahu with 25 years to achieve an additional 74.8% of renewable energy. If increased at a steady rate, Oʻahu would only require a 2.9% increase per year until 2045 to attain 100% clean and renewable energy. This is closely in line with the pace at which the entire state is progressing, with a 2020 end goal of 30% renewable energy, as noted by HECO. In 2019, Hawaiʻi reached 28% renewability, requiring a 2.8% increase in renewable energy per year to stay on track for the 2045 goal.

In the effort to sustain a 100% renewable energy state, public cooperation is a necessity. The above statistics indicate that Oʻahu is steadily increasing and retaining community investment into sustainable technology, but it is important to remember that participation is only possible provided the financial security to invest in sustainable alternatives by 2045. This is a generous timeframe that aligns with those for goals set in countries leading the sustainability charge, but the cost of living and Hawaiʻi's isolated position in the Pacific poses uncertainties that are unaccounted for in this timeframe, including consumer behavior and the after-effects of adopting clean energy vehicles.

In 2018, 1,267,136 vehicles were registered across Hawaiʻi, including passenger cars, public service vehicles, trucks, and motorcycles. Of this number, 793,379 were registered on Oʻahu (Hawaii State Department of Transportation, 2019). While Hawaiʻi currently proposes no bans on sales or ownership of gas emitting vehicles by any given year, the hopeful phase-out by 2045 as indicated by HECO (2020), which would require widescale public cooperation to

achieve, raises concern of another issue: procedures for phased out gas emitting vehicles. Accomplishing sustainability goals does not end at the eventual switch to more efficient methods of energy production and the reduction of greenhouse gas emissions. In the case of the latter, phasing out gas emitting vehicles means that over 1,200,000 vehicles will be out of commission that must be responsibly dealt with in ways that enforce the mission of sustainability locally and globally. This is not an issue that can be solved through vehicle dumping in developing countries, wherein environmental impacts like deforestation may occur to accommodate new infrastructure that will support the increase in vehicles on the roads. The result of deforestation is a release in carbon dioxide, contributing to global warming, an issue that could have particularly detrimental consequences on O‘ahu’s urban centers over the next few decades. These issues are examined in depth in the next section.

Environmental Examination

In a report published by the state in 2017 and later updated on November 27, 2018, the impact of climate change on coastal flooding from sea level rise was examined. In this report—which identified an approximate 3.2 feet of hazardous sea level rise during the mid and latter half of this century, based on one of four futures scenarios provided by the Intergovernmental Panel on Climate Change (IPCC)—it was revealed that this rise would render more than 25,800 acres of land unusable across the island in sea level rise exposure areas. Flooding types were classified into three categories, all of which are presumed plausible for O‘ahu: (1) passive flooding; (2) annual high wave flooding; (3) coastal erosion. From this acreage, an estimated 34% is anticipated to be from the urban district, 25% from the agricultural districts, and 40% of this from conservation lands across the main Hawaiian Islands (Hawai‘i Climate Change Mitigation and Adaptation Commission, 2017).

Across the islands in these compromised exposure areas, over 6500 buildings are anticipated to be affected, including hotels, malls, small businesses, churches, schools, and community centers. From this sea level rise, businesses are susceptible to interruption in normal operations, relocation, or business closure. Meanwhile, residents would be left vulnerable to displacement in the 3.2 feet sea level rise scenario.

As the state's most urbanized waterfront area, Honolulu is considered the most significant hotspot for economic loss, potentially contributing to over 65% of the economic loss for the state. Table II (below) summarizes the potential impacts of chronic flooding at 3.2 feet increase in sea level as provided by the Hawai'i Climate Commission (2017):

Table II. Potential Impacts of Chronic Flooding on O'ahu

Potential Impact of Flooding	**Anticipated Total Loss**
Land flooded	9,400 acres
Economic loss due to structure and land loss	$12.9 billion
Residents displaced	13,300 residents
Structures flooded	3,880 structures
Major roads flooded	17.7 miles

This table does not account for other financial loss related to impacted critical infrastructure, which includes: (1) roads; (2) airports; (3) harbors; (4) electric and telecommunication infrastructure; (5) wastewater ponds; (6) and other public service facilities. Provided critical infrastructure is impacted, other losses could be incurred by the community including loss of commerce, convenient transportation routes, and access to public services (Hawai'i Climate Change Mitigation and Adaptation Commission, 2017).

Though we cannot be fully certain the exact point at which chronic flooding will become an issue, we can anticipate these loss trends in the next 30 to 70 years as a best-case scenario (Hawai'i Climate Change Mitigation and Adaptation Commission, 2017). Scholars at the School of Ocean and Earth Science and Technology (SOEST) at the University of Hawai'i at Manoa

project that by mid-century, a sea-level rise of at least one foot is probable (n.d.). This means that potentially by 2050, O‘ahu could see a $4.1 billion structure and land loss, 650 structures flooded, around 2,000 residents displace, 5.5 miles of major road flooded, and an undetermined value of critical infrastructure lost. Given that these numbers are projected for only 20 to 30 years out, we must consider this a harbinger of the economic upset this could cause before the state continues its developments along O‘ahu’s compromised shores.

Note that on O‘ahu, there is no designated rural land, which means that all land is divided into the other three districts. At present, almost a third of O‘ahu is designated urban land, but this percentage can grow as land use demands change. One of the catalysts for this change is the rise in sea-levels discussed in the previous section. In the last 50 years alone, 7% of agricultural land was converted to urban land amid the growing demand for housing. As most urban land is located along the coast in future sea-level rise exposure areas, both agricultural and conservation lands may face use conversion should further inland urbanization be sought to avoid more urban land loss detailed in table III (Hawai‘i Climate Change Mitigation and Adaptation Commission, 2017).

Table III. Distribution of O‘ahu Land Districts Impacted by 3.2 Feet Sea-Level Rise

District	**Lost Acreage**	**Percentage**
Urban	5,527.2	58.8
Agricultural	1485.2	15.8
Conservation	2387.6	25.4
Total:	9400	100

It must be noted that by the end of the century, a sea-level rise greater than six feet is not improbable, which could severely increase the acreage of land lost to chronic flooding. In just the 3.2 feet scenario, it is anticipated that four of the HART Rail stations running between the Daniel K. Inouye International Airport and Ala Moana will be flooded, with portions of the Rail footprint similarly affected (Hawai‘i Climate Change Mitigation and Adaptation Commission,

2017). The impacts of chronic flooding on major infrastructure with both main roadways and the anticipated Rail route leaves much to consider for the long-term success of ground and Rail transport.

Potential Impacts on Smart Development from COVID-19

With the onset of COVID-19, in March 2020 in the Hawaiian Islands, O‘ahu has encountered prevalent issues exposing an economy heavily reliant on tourism. As of 2020, the pandemic in tandem with other normal operational issues, has delayed the Honolulu Rail Transit Project’s operational start date from Kapolei to Aloha Stadium to March 2021, with the latest projected completion of the project in March 2026 (Pang, 2020; Dayton, 2020). In a conservative projection by HART, it was estimated in July 2020 that COVID-19 could cause a $450 million loss to the project and has delayed its construction by around eight weeks. The large sum comes as a result of the economic shutdown in a tourism-reliant industry, where excise and hotel tax revenue have suffered (Dayton, 2020).

The shortfalls to the HART Rail project extend beyond budgeting, however. In April 2020, IBM conducted a survey on U.S. consumer behavior plans post COVID-19. In this study, 25,000 individuals were polled and opinions on public transportation and rideshare showed a dramatic shift, with rideshare being hit hardest. Over 50% of the surveyed population indicated a reluctance to use rideshare or stop using it altogether. This mean that companies like Uber and Lyft could see a drastic loss of consumers when operations resume ‘as normal’. For public transportation, more than 20% of participants indicated that they would no longer use public transportation, including buses, subways, and trains. An additional 28% shared that they were more likely to use public transportation less often than they used to (IBM, 2020).

To date, there are no provided statistics on ridership for the Rail since it has yet to begin operations. However, the Monthly Performance Reports published by TheBus offer insight into the local effects the COVID-19 pandemic has had on public transportation ridership on O‘ahu. These reports include a fiscal year monthly ridership comparison that can be referred to see how FY20 ridership compared to FY21 ridership, focusing specifically on the months where COVID-19 actively affected ridership. Figure II and figure III, sourced from the Oahu Transit Services Inc. (OTS, Inc.) Monthly Performance Reports (2020) depict the weekday and monthly ridership trends for the months of February, March, April, and October. These months were selected to reflect pre-pandemic ridership, ridership at the onset of quarantine in the state, effective in mid-March 2020, the first full month under quarantine, and the most recently reported month to date under the ongoing pandemic. Note that February 2019 and February 2020 show a statistically insignificant decrease of around 15,000 riders monthly or roughly 5,000 less weekday ridership.

Figure II. TheBus Monthly Ridership 2019-2020

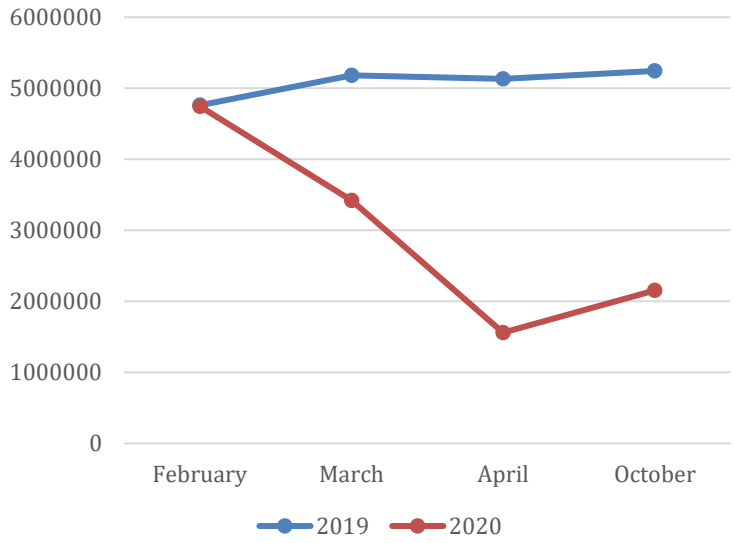
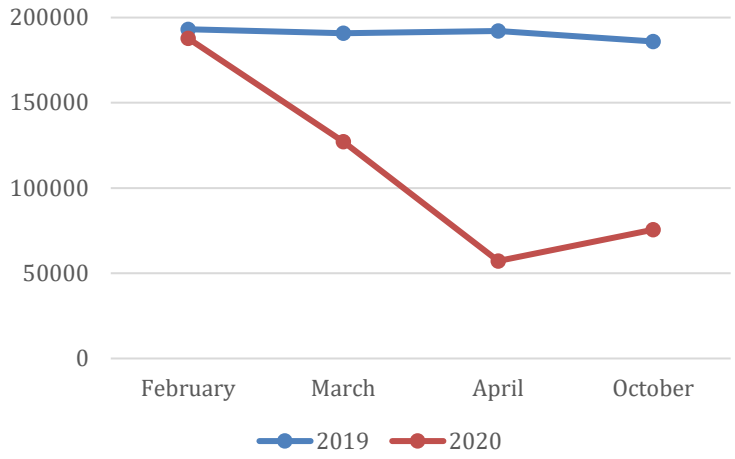


Figure III. TheBus Average Weekday Ridership 2019-2020



As of October 2020, TheBus weekday ridership continues to sit between 50,000 and 100,000 as it has since April 2020, the first fully observed month under the stay-at-home order. At its highest since the onset of the pandemic on O‘ahu, ridership reached around 81,000 in July 2020 (Ramos, 2020). Most notable however, are the year to date (YTD) statistics between the FY2020 and FY2021, in the respective month of September. The YTD September FY2021 total monthly ridership is over 12.3 million less than YTD September FY2020, which was recorded at over 20.5 million (Oahu Transit Services, 2020).

As it stands, TheBus never shut down operations throughout the ongoing pandemic, but the sharp decrease in passengers made it notably easier for passengers to social distance. Decreased ridership also led to a reduced schedule, meaning the wait time between buses were made longer than before COVID-19. Presently, OTS monitors the fluctuation of ridership and adds more buses to busier routes accordingly to account for those passenger numbers. Overall, however, the most notable takeaway is that despite a slight increase to public transportation usage, COVID-19 is taking a toll on a decades long trend of decreased ridership. From 1993 to 2018 alone, the decrease in ridership sits at over 12 million, down from an estimated 76.14 million (Ramos, 2020).

While these numbers cannot accurately portray changes in the Rail ridership as it has yet to be operational, these numbers do suggest that usage, especially among those who are not public transportation dependent, may be negatively impacted in that true ridership from voluntary public transportation users will not meet the ridership trends envisioned by HART (see chapter III). Most notably, HART's 2030 goal of decreasing the number of vehicles on O'ahu roads by 40,000 along the Rail's immediately serviceable area are brought into question. As a result, we must consider what long-term effects waves of infectious diseases, not just COVID-19, has on the community's trust in public transportation, specifically with the Rail Transit project, may directly impact unfulfilled carbon dioxide emission reduction goals, an issue that jeopardizes the state's push for sustainability.

In addition to the potential long-term effect that COVID-19 could have on the Rail's success is the pandemic's detrimental toll on employment, or more so, the lack thereof, an added impact of the economic distress faced. Already, Hawai'i's high cost of living and economy is largely responsible for the departure of many residents in past years. While there is no certain way to measure how the COVID-19 may increase migration from the state, it is anticipated that the state of the economy and the long recovery process to come may sooner drive out residents who can no longer make a living in Hawai'i because of unemployment, less job openings, and prices for homes and rent costs (Jung, 2020).

In June 2020, the Department of Business, Economic Development and Tourism (DBEDT) published a report on the populations made economically vulnerable due to COVID-19. Both vulnerable workers and vulnerable households were examined. This report determined that roughly 47.5% of all workers in Hawai'i could be considered economically vulnerable (i.e., at risk of job loss) either by occupation, industry, worker characteristics (e.g., young, part-time,

low-wage, self-employed), or a combination of those three (Hawaii State Department of Business, Economic Development and Tourism, 2020). In just seven months, the year-to-date initial unemployment claims to October 31, 2020 are 654% higher than they were in 2019, with an increase of 216,948 claims in Honolulu County. As of September 2020, the unemployment rate in Honolulu County is 13.6%, with a statewide unemployment rate (Hawaii State Department of Business, Economic Development and Tourism, 2020). Recall that the estimated population in 2019 is just over 974,000, which means that well over a quarter of all residents of O‘ahu were left unemployed at some point since the onset of the pandemic locally in March 2020.

As for households, for those whose housing cost exceeds 30% of the household income, those classified as low-income households, and a single-parent household, they were also considered economically vulnerable, given the higher risk of housing-cost burden from the recession due to job loss (Hawaii State Department of Business, Economic Development and Tourism, 2020). Provided continuous years of hardship in job recovery for most households, with an anticipated return to less than 5% unemployment no sooner than 2023 or 2024, affording the cost of living may be too far off for some households. On one hand, it is possible that the reliance on public transportation and complimentary internet services may be more frequently utilized to compensate for additional household vehicle and broadband expenses, but on the other hand, relocating to the mainland could be deemed a more pragmatic alternative. Interestingly, should residents lean towards remaining on O‘ahu and adjusting to smart and sustainable transportation alternatives, progress on sustainability goals can still be met without requiring the financial capacity to invest in expensive electric vehicles and home PVC systems, just some of the few smart initiatives currently existing.

Broadband

As the most isolated collection of land masses on the planet, Hawai‘i faces a unique set of challenges in broadband infrastructure that continental land masses and nearby islands are less impacted by. Making sure Hawai‘i has proper access to broadband is pivotal in developing a smart, interconnected city. Transpacific and interisland submarine fiber connectivity is a costly solution to enable the state with Internet access, and recent exhaustion of previously laid cables demands additional and updated fiber lines to support connectivity of a growing grid.

Broadband is supported by seven different systems across the state: (1) cable; (2) Digital Subscriber Line (DSL); (3) fiber; (4) terrestrial microwave; (5) satellite; (6) cellular or mobile wireless; (7) and wireless wide area network (WWAN). While these seven systems exist, a fiber optic system generally provides the best bandwidth and is the most reliable in providing broadband to the islands and is the most effective for inter-island connectivity. As the names suggest, the first three systems are wirelines technologies and the latter four are wireless technologies. Despite the distinction, it is worth noting that almost all systems are connected to a fiber system (State of Hawaii Department of Commerce and Consumer Affairs, 2012). This means that the fiber optic system is perhaps the most important as the foundation on which other systems are connected for transmitting data transnationally in the context of Hawai‘i.

In August 2017, Hawaiian Telcom completed the SEA-US fiber cable system, a state-of-the-art submarine fiber system stretching over 9300 miles, providing Hawai‘i a direct connection to Southeast Asia. The system runs from Indonesia to the continental United States in California, with connection points in the Philippines, Guam, and Hawai‘i. The completion of this fiber system was especially crucial for two main reasons.

First, of three transpacific fiber cables running from the continental U.S. to Hawai‘i, two are more than halfway through their lifespan and are forecasted to be unable to meet the bandwidth demand for the state (Hawaiian Telcom, n.d.). This includes the Southern Cross Cable Network (SCCN), ready for service from November 2000 and the Japan-U.S. Cable Network (JUSCN), ready for service from September 2001. Both cable networks have landing sites on O‘ahu, with SCCN having an additional landing site on Hawai‘i Island (State of Hawaii Department of Commerce and Consumer Affairs, 2012). For reference, both fiber optic systems have a life expectancy of 25 years, meaning that in the next half decade, these two cable networks could be retired.

Second, with technological advances, newer systems will no longer have value in landing in Hawai‘i. As the SEA-US cable system is routed to bypass earthquake-prone regions, Hawai‘i can count on more stable connectivity with a 20 terabit per second (Tbps) capacity and 100 Gigabit per second (Gbps) technology (Hawaiian Telcom, n.d.). However, while the benefits for Hawai‘i from the continental U.S. may be limited, from this addition to Hawai‘i’s fiber optic network, we can predict that other transpacific fiber systems will be attracted to the islands as a potential hub and landing site to compensate for the rapid increase in data usage across the globe (Hawaiian Telcom, n.d.). A recent addition to the transpacific submarine fiber system with a landing site on Hawai‘i is the Hawaiki Transpacific Cable Network. This system connects Australia and New Zealand to the United States’ West coast with a landing site in Hawai‘i. The Oregon to Hawai‘i segment was completed in 2017 and the full system was completed in April 2018, with a ready for service date in June 2018 (Reichert, 2018). In addition to the transpacific cable systems that Hawai‘i connects is the interisland fiber system, which also possesses room for expansion that could make for a more efficient broadband network (Hawaiian Telcom, n.d.).

Although fiber optic systems are sufficiently relied upon for much of Hawai‘i’s connection, a newer wireless network is emerging on island that compliments the predominantly 4G network system: 5G. Commercial 5G mobile networks are well under way across the globe. Although 5G is not readily available across all the main Hawaiian Islands, O‘ahu has already taken steps towards deploying the beginnings of 5G along the island’s major urban concentrations as far west as Waipahu and into Waikiki. Unlike with 4G and other technology, which will continue to run in tandem with 5G networks, 5G enhances the efficiency of IoT technology (strongly associated with smart cities) by providing low-latency, secure communications previously unseen in earlier networks. 5G has a wide range of applications for smart city developments, including improving interoperability between emergency services, broadly enhancing the healthcare industry’s teaching, diagnostic, and data management practices, support smart metering, and potentially reducing carbon dioxide emissions. Under Hawai‘i’s presently identified smart initiatives, future CAV testing in Hawai‘i can benefit from 5G’s ability to precisely interconnect communications between vehicle and road networks to improve the reliability of CAV technology (GSMA, 2019).

As an alternative to wireline technologies, 5G fixed wireless access (FWA) can provide internet access to homes quickly and cost effectively where wireline technologies may not reach without sacrificing broadband speeds comparable to fiber optic networks (GSMA, 2019). This alternative allows an opportunity to narrow the digital divide in underprivileged household by providing a lower cost broadband solution without sacrificing quality. Note that this is only possible so long as mobile is readily available, and the incentive is not yet there to cover the growing disparity between class and social divide. Furthermore, while there is no guarantee that the current broadband infrastructure can support either of the four smart city models identified in

chapter II, there is opportune room for growth in broadband technologies beyond that can further transform and connect not just Kapolei to Honolulu, but the other population centers scattered across O‘ahu.

Final Analysis

At the beginning of this chapter, I provided a SWOT analysis as a primer for the contents examined in this environmental scan, with special attention to the current and emerging issues and opportunities for O‘ahu’s potential smart and sustainable development. This included a look into the state’s land use laws, society and culture, sustainability efforts and goals, the effects of climate change on urban development, COVID-19’s potential impact on future developments, and broadband. Below, the key points to consider for policy consideration are listed as a recapitulation of the content in this chapter:

1. Ambiguous land use laws and climate change impacts on urban centers and transportation infrastructure require activity from the Land Use Commission or other entity to revise Land Use Law to best reflect on O‘ahu’s evolving demands.
2. Public education on smart solutions and civic engagement, including from rural and disadvantaged populations, allows for informed discussion and consideration of public concerns ahead of smart city developmental policy, a concept intended to benefit society’s wellbeing.
3. Sustainability goals and the societal practice of *malama ‘aina* are steadily attainable but side effects such as a gas-emitting vehicle phase-out requires a responsible plan consistent with the mission of 100% clean and sustainable energy.
4. The impact of infectious disease on public transportation ridership can persist beyond the active months of the COVID-19 pandemic and lower ridership turnout for an extended

period, prolonging the time it takes to remove POVs from the roads and ultimately reduce carbon dioxide emissions.

5. Increasing fiber optic networks or mobile 5G networks can increase O‘ahu’s ability to sustain a smart city and continue to integrate unexplored smart technology.

Provided these identified challenges and opportunities, the next chapter outlines a set of policy recommendations to address issues and create solutions.

Chapter V: Policy Recommendations

In the last few chapters, I have provided a background into smart cities, the model types, the current establishments on O‘ahu, and the presented challenges and room for opportunity to develop O‘ahu’s cities smartly and sustainably. The multiple layers examined and, in particular, O‘ahu’s projects to date and its threats and opportunities reveal two major observations: (1) O‘ahu has at least a partial drive to accomplish smart and sustainable projects for the betterment of society; (2) and there is not enough collaborative effort to effectively accomplish projects with maximum efficiency and consideration for all outliers. Regardless, as it stands, O‘ahu shows clear potential for adopting the Broad Spectrum Model as the basis for their smart city, exhibiting characteristics in various smart developments versus focusing on a singular development to have excel. However, to accomplish this, there must be efforts made to improve upon current methods and regulations for development on O‘ahu. In this chapter, four policy recommendations are laid out for consideration that target the identified issues and strengthen the efforts towards opportunity. They are:

1. Reform land use laws to fit the needs of developing society.
2. Form a smart urban development and sustainability committee composed of experts in all fields.
3. Educate the public on smart and sustainable projects and encourage civic engagement to better meet societal needs.
4. Create a post-pandemic plan that supports a local self-sustaining economy with growth in business sectors pertinent to infrastructural and technological demands.

Recommendation I. Reformed Land Use Laws

Following the Land Use changes proposed by the Hawai‘i Climate Change Mitigation and Adaptation Commission, and in HB1321, revisiting Land Use Laws is more crucial now more than ever. Revisions are key in clarifying inconsistencies that arose most prominently in the Chapter 205 amendments to the Land Use Law of 1961. As proposed in HB1321, there should be a land use law review committee to review current law and potentially propose more sensible changes that better define the four land districts with particular attention to rural and agricultural land divisions, the inclusions of each, the limitations of each district, and the appropriate permissions that grant exceptions to land use district use.

Reformed land use laws need to consider how to make land use less bureaucratic so that the state can move forward with developments at an efficient rate. O‘ahu’s consolidated land owners must provide permission to developments on or over their lands, but for projects concerned with community-level developments, this is a barrier that sacrifices the efficiency at which projects acquire permissions and can begin developments. The revised state land use laws should be able to regulate the requesting procedure for building permits and land use law exemptions that meet the modern needs of society and restrict the ability for any one agency to receive case-by-case permissions that reinforce bureaucratic tendencies.

Lastly, on O‘ahu, concerns of rising sea level within this century are anticipated to have the most significant impacts on the urban districts, with nearly 60% inundated within the century. Being mindful of conservation lands, the Department of Hawaiian Home Lands’ exemption from land use county zoning, and agricultural preservation of mineral-rich soils, urban district expansion away from coastlines and clear of immediate impact zones for the decades to come will allow for urban development in less compromised areas of the island. The land use law

revision and reform should account for district re-zoning that alleviates costly and wasteful development along sea-level rise impact zones that are likely to displace upwards of 13,300 Oʻahu residents, damage 3,880 structures, flood 17.7 miles of roadways, and cause at least $12.9 billion worth of damages. Existing structures and roadways will remain in jeopardy, but the state can assure that no further costs and damage is incurred by encouraging future developments to move further inland.

If this recommendation is implemented, bureaucratic tendencies with less public interest at heart may be discouraged and sustainable efforts that benefit society will be granted more leverage to excel. Local businesses will be given the chance to thrive and smart transportation efforts can be better accounted for to have longer term success without environmental interference.

Recommendation II. Oʻahu Smart and Sustainable Development Committee

The largest reason for a multidisciplinary committee it to unite all projects on common ground. Each activity currently taking place on the island and the opportunities for growth with bandwidth and the local economy, show initial signs of falling into the spectrum of a smart city. In order to maximize efficiency and unify all organizations and regulating bodies working towards smart and sustainable projects, the State of Hawaiʻi should form a Smart and Sustainable Development Committee comprised of representatives from the state government, the University of Hawaiʻi's relevant school and colleges, the Department of Defense, Hawaiian Electric, HART, and other stakeholders committed to and interested in partaking in smart development. At the highest level, this committee will be tasked with mediating across the various stakeholders on urban development as it pertains to smart technology and sustainability.

This committee's core responsibilities would be establishing communications and raising awareness on shared challenges and opportunities to capitalize on. This committee operates with the mindset that common interests mean common goals and decisions are mutually agreed upon based on informed decision making. An interdisciplinary committee allows for open discussion that can educates all present parties on core issues affecting the future development of O'ahu's main cities, including awareness of sea-level rise and the need to build in areas exempt from chronic flooding further inland, an issue that vastly threatens many developments. In working towards a collective sustainable effort, this committee must consider how ongoing and upcoming developments in areas potentially jeopardized by sea-level rise are ineffective and wasteful for long-term function. Not only is this committee responsible for open communication within the group but also developing a joint smart and sustainable urban development proposal that accounts for the projected rise in sea-level, the rezoning of lands to minimize slow-downs in future developing by securing permissions now, halting major construction in urban and infrastructural development that is planned within sea-level rise impact zones hurts the longevity of these developments, and slowing down urban development in the Honolulu-Waikiki area while increasing efforts in Kapolei, a more elevated city with lower threats from anticipated sea-level rise.

Going hand in hand with Recommendation I, the re-routing of discontinuation of the Rail's unbuilt track further inland could help avoid economic loss brought on by the pandemic, alleged mismanagement because of sea water's corrosive effects on concrete, the resulting increase in public perceptions of unreliability and decreased usage, and the potential of autonomous vehicles and rideshare alternatives making the rail obsolete by 2050, as projected by University of Hawai'i civil engineering professor, Panos Prevedouros (Grassroot Institute of

Hawaii, 2020). This is one example of an issue that can be brought forth to the committee that they may jointly consult over and make an informed decision on, since the effects of saltwater on soil and untreated concrete is enough raise questions about the integrity and longevity of the structure, an issue of public safety (Anupoju, n.d.). Other areas this committee could be tasked with reviewing is civic engagement and public concern for projects whose benefits fall short of rural and disadvantaged population needs.

Ethical considerations will also fall into the hands of this committee, where the potential effects or sustainable and smart city decision making are also considered prior to establishing a reputable plan. This might mean considering adopting an ethical approach to gas emitting vehicle phase-out. Given Hawai‘i’s promising push towards 100% clean and sustainable energy by 2045, it is imperative that the state propose a responsible solution for what happens with these phased out vehicles over the next three decades. It is easy to suggest that vehicles be shipped off to foreign markets as a second party sell-off, but in doing so, there is a redundancy in claiming support for sustainable efforts when the issue of dealing with greenhouse gas emissions is left at the discretion of the receiving country. This proposed committee must therefore be proactive in determining how this island state will handle issues of disposal or recycling ‘dated’ technology before it becomes an unaccounted-for issue.

Ultimately, the proposed Smart and Sustainable Development Committee should be tasked with considering professional research insight to make decisions that may spare economic loss from unsuccessful projects, acting in the public’s interest, and arranging public educational forums for two-way conversation that raises trust and reliance in the government’s actions.

Recommendation III. Public Education and Civic Engagement

The traditional Hawaiian value of *malama ʻaina* highlights long-standing values of sustainable methods of living and a respect for the environment. This value encompasses and should be used in the most sustainably efficient ways. Of course, not every member of society is familiar with this traditional value, but as with *aloha* and *mahalo*, embedding this phrase into every day usage with promotion from the Hawaiʻi Tourism Authority, local television and radio advertisements endorsed by the state, and in public spaces where printed advertisements are authorized, and educational curriculum at every level educational institution to forge understanding of this concept and increase community interest in participating in more sustainable alternatives that they can afford to adopt.

Taking progressive steps towards educating the public might aid in reducing the negative stigma around public transit. The most frequent consumers are students, low-income household members, and senior citizens, unlike in other major cities and island nations like New York City, Japan, and Singapore, where white collar workers have no issue with using public transportation. Hawaiʻi's residents have built a reliance on POV's that makes it otherwise difficult to imagine successful adoption of public transportation alternatives to meet sustainability goals in the allotted time or make the switch to electric vehicles. Providing education on the environmental and societal benefits of smart transportation and clean energy may provide the cognitive shift needed to assure sustainability goals be met.

Civic engagement means that the public engages with policy makers and regulatory bodies to input their concerns with developments that both indirectly and directly impact them. As it stands, civic unrest is not uncommon on Oʻahu with current smart developments and the slow progression on the path towards completion. Should the state apply this recommendation,

there is reasonable chance that residents will feel more secure in the government for listening to their concerns and holding open discussion for education and feedback. This includes public skepticism in data privacy protections, which may challenge the state's push for smart efforts when the public is hesitant to trust the technology enabling smart cities.

Recall the ACM Code of Ethics mentioned in chapter 2, which states that computing professionals should have the good of the public at heart in their developments. With smart cities, collected data must be used responsibly, such as with smart meter reading, traffic monitoring, and for public safety. As such, there needs to be enforceable privacy protections that Hawai‘i residents are comfortable with. Providing a data privacy law that allows the public the ability to see how data is being collected and what it is being used for will be an important factor in gaining public trust. Critical to this is determining what entities should own data and what data protections are offered to ensure data access is not used unethically or abused. The State of Hawai‘i must be sure to reach agreement with private companies to release their data or find another alternative solution that can be used in big data applications without selling off personal information. Should the state consider establishing a privacy law, it is beneficial to raise awareness that collected data is being used for the public good.

Furthermore, one of the greatest issues where civic engagement is concerned is equity, which is making sure that all demographics have proper representation and receive fair and impartial treatment. Already, rural and disadvantaged populations are excluded from realistic adoption and or use of the state's proposed projects and investments to move towards a smart sustainable city, with socioeconomic class making it harder for the latter to adopt newer technologies. Under this recommendation, the state must find a way to, at minimum, push for equity in its development to maximize societal benefit. The University of Hawai‘i's social

scientists and computing professionals can perform collaborative research to assist in the creation of a smart, sustainable urban plan that can best serve public interest and the global community effort to slow the effects of climate change and become better interconnected.

Following this recommendation means building trust between the government and society. By gaining community support and focusing on open communication of new developments and potential policy implementations, the State of Hawai‘i can better design its smart and sustainable urban plan to meet the unique demands of O‘ahu’s residents.

Recommendation IV. Self-sustaining Economy

The COVID-19 pandemic exploited the weaknesses in Hawai‘i’s economy and the overreliance on travel, tourism, and hospitality sectors. In the months since the onset of the pandemic locally, the state has seen how many of Hawai‘i’s residents lost their jobs from the steep crash in tourism. This has highlighted the need for competitive, local economic development to expand job sectors that are profitable for Hawai‘i and lower the reliance on one dominating industry and outsourced labor. This policy recommendation thus highlights the need for the state to establish a plan for a locally self-sustaining economy, one that has potential to develop O‘ahu into a smart and sustainable island.

On September 11, 2020, the University of Hawai‘i President, David Lassner, released a statement on post-pandemic Hawai‘i supporting the notion of a self-sustainable state island ecosystem with the aid of the university. Four ‘imperatives’ are identified, including engaging more local residents in post-secondary education, preparing more residents to fill local job needs, expanding economic sectors and transforming old ones, and strengthening the university’s research operations into a major economic and intellectual driver (Lassner, 2020). While the University of Hawai‘i is not an exclusive entity in accomplishing these goals, they are an

important driver as the state's only public research university and significant stakeholder in informing and supporting many of Hawai‘i's policy decisions.

One of the areas emphasized in Lassner's statement is construction, design, and the built environment. This is a call for construction engineers, managers, skilled laborers, and thoughtful designers who can contribute to a sustainable built environment. In the tech industry, this is bringing up strong, local computer scientists and engineers who can minimize the need for outsourcing and maximize the potential to develop a strong local computer and engineering economic sector (Lassner, 2020). Building the local presence of specialists in data science and artificial intelligence/machine learning can empower smart development with local agencies and organizations fulfilling the island's requisites in establishing a smart grid that allows progress tracking on sustainable efforts and responsible use of urban and residential data to provide feedback identified in Recommendation III.

Given the University of Hawai‘i's stance on supporting these initiatives to develop post-pandemic Hawai‘i, the underlying recommendation is that policy support the notion of local economic developing by building up the local business environment to be more apt to self-sustain without the need for expensive outsourcing. This support can be acted on by bidding for foreign and mainland technology agencies or providing support for the growth of local small businesses and the educational workforce with a sustainable variety of local technology to initiate the push for onshore technological development and reduce the offshore agency dependence.

Chapter VI: Future Scenarios

Policy implementation supporting the efficiency of smart and sustainable development can substantially alter O‘ahu’s landscape. The previous chapters show that stakeholder support is there where actions are perceived to be viable solutions. The first signs of potential for a smart and sustainable development is there, too. What is needed now is policy implementations that effectively unify efforts and raise a common goal of development meant to benefit and positively serve all demographics, and an effective plan of smart, sustainable technology implementation to continue development in a responsible, sustainable manner that can serve the community for the decades to come. In this chapter, four futures are explored that allow visualization of O‘ahu’s future under a variety of directions that the State of Hawai‘i can take, that impact a smart and sustainable island model.

Hawai‘i’s sustainability goals have a desired accomplishment year of 2045, 25 years from now. In line with this timeframe, these scenarios are provided for 2045, when Hawai‘i plans to achieve 100% clean and sustainable energy goals. The scenarios presented explore O‘ahu with no policy recommendations adopted, with all policy recommendations implemented, with only some policy recommendations implemented, and an exclusive focus on attaining sustainability over smart solutions.

Scenario I. No Change to Policy

The year is 2045, over three decades since sustainability and smart design proposals were first explored on O‘ahu. In the years since, the Rail saw its completion, clean energy farms soared, and broadband connectivity has improved despite the lack of policy implementations. These few accomplishments, however, are outweighed by poor planning and disregard for evidence-based recommendations made by researchers.

While the Rail exists, ridership sits lower than what planners had hoped for, the preference for POVs and the lack of public education on the benefits both deterrents for ridership. The multi-billion-dollar project is considered unsuccessful because of the cost to build, sustain, and operate versus the value it holds to all demographic levels. Slow progress in its developmental years discouraged the public early on and altered perceptions to the beneficial aspects of the Rail. Furthermore, residents refuse to switch to public transportation because of lack of interest in public transportation, doubt and unrest from tedious years of extensions to the project, the COVID-19's influence on social distancing and hygiene that are hard to maintain on public transit.

Land use laws remain unclear and unchanged, and consolidated landowners and major developers continue to exercise bureaucratic efforts that make it difficult to attain community benefit. Public service companies refuse to share data that is beneficial to measuring how city systems are operating. Bureaucratic tendencies extend into data collection that fills many residents with a low sense of trust for how their data is used. Moreover, the lack of educating the public has reinforced skepticism in new technology. In addition, failure to enforce privacy laws that protect the public fuels mistrust since transparency is foregone.

Sea-level rise has not yet made any significant impacts to O'ahu but concerns of its anticipated effects loom now more than ever. Many are frustrated by the financial implications with structural loss, infrastructural loss, and business and residential displacement caused by flooding. Many more question why certain projects like the Rail and new residential complexes were developed in areas expected to become inaccessible when roadways flood and first levels of many buildings are rendered useless. Residents fear eventual property loss and feel the weight of making a decision to relocate outside of O'ahu.

With no behavioral change, O‘ahu manages to achieve a few goals: sustainability, an alternative transportation option, expansive broadband, and more urbanization. But unlike the promising benefits these all present, the ineffective management to reach them is more damaging and inhibits the ability for these new developments to thrive. To the dismay of local economists and researchers, the lack of economic diversification continues to limit the economic growth potential for the islands and has contributed to the departure of many residents over the decades who struggled to make a living with limited industries and rising cost of living where alternative economic industries could have been pursued to encourage retention.

Scenario II. All Policies Implemented

After two and a half decades of constant policy implementations to meet the sustainability goal of 2045, residents of O‘ahu see their efforts rewarded, making significant progress towards their goal while maintaining economic, environmental, and community satisfaction. A joint smart and sustainable development committee proves beneficial in uniting efforts and making more informed planning and policy decisions. Among their accomplishments is the addition of a 25-year plan to responsibly phase out gas-emitting vehicles and encourage the transition to 100% clean energy.

Reformed land use laws provide clarity to older amendments, regulates bureaucratic tendencies, and allow for a formal course of action to rezone districts so that new urban lands are reserved away from future sea-level rise impact zones. Kapolei saw dramatic urban development over Honolulu as a result of future sea-level rise concerns, increasing the scale of the city sizably as the island’s second main urban center. Because of its location and significant room for development in the surrounding acreage, developing Kapolei proves more cost effective since infrastructural developments and smart grid integration is less invasive to pre-existing structures

and grids. Kapolei's wide roads and traffic system also makes it the preferred city for initial automated vehicle testing.

As a result of public education and the push for civic engagement, residents are generally happier with decision made, feeling more assured that their voices were heard as developments occurred over the years. Openness to smart and sustainable transportation alternatives increased, though adoption of technology was considerably difficult because of cost barriers, especially in the earlier years between 2020 and 2045. Comparatively rural island regions like Haleʻiwa and Kaʻaʻawa are serviced by electric buses, but otherwise have no change in transportation alternatives, though efficiency is improved based on ridership and traffic trends gathered from publicly reported data. Citizens also feel more assured about their data privacy with enforceable privacy protections in place that allow them to see what data is collected and reported.

Mobile wireless and fiber optic broadband allow for an interconnected island grid that supports IoT. The digital divide is narrowed by widespread access to networks, both public and private, enabling those who at bear minimum, own a device, to always be connected at a lower cost with mobile broadband. Public safety and traffic concerns see improvement from the near instantaneous data feedback to keep Oʻahu and its residents updated with the latest information. Public services benefited from FirstNet and interoperability improvements, granting improved emergency response times and more effective solutions to dealing with crises situations.

Heeding the economic concerns caused by the COVID-19 pandemic in Hawaiʻi beginning 2020 and opportunity to capitalize on new economic ventures supported by the University of Hawaiʻi, the state was able to minimize reliance on the tourist economy. Supported by grant funding, local computing professionals, engineers, and urban designers affiliated with the university were granted potential to initiate locally based efforts to contribute to the smart

and sustainable city mission. Job outsourcing was minimized as a result of maintaining a local workforce distributed among tech, engineering and urban planning firms backed by policy support at the state level.

Despite the geographic isolation, Hawai‘i remains remarkably connected within the transpacific because of its local initiatives and proves to be self-sustaining. The broad ecosystem model is successfully implemented due to the wide array of goals set forth from becoming both a smart and sustainable hub.

Scenario III. Some Policies Implemented

In the 2020’s, the City and County of Honolulu successfully organized the O‘ahu Smart and Sustainable Development Committee. The committee succeeded in unifying developments across O‘ahu under common guidance and ensured that developments considered environmental factors to make informed project decisions, even having some pull in land use law revisions. The committee assessed the value ongoing projects to society, cost concerns and projections with slow progress and delayed projects like the Rail, and created a smart, sustainable plan that was more pragmatic long-term.

However, public education and civic engagement did not receive significant attention to onboard support from citizens on smart and sustainable developments in the decades. Instead, developers referred to public trends to deduce solutions that served in the public’s interest most. Without civic engagement, residents question some of the decisions that are made and wonder the benefits offered to them. Rural and disadvantaged populations feel unaccounted for and widespread concern over data privacy is expressed by the public who may not be familiar with privacy laws or do not have any added enforceable privacy protections to regulate what their data is collected for and used in.

O‘ahu in 2045 thus feels divided between public interest and the state’s actions towards smart, sustainable development. Adopted practices by citizens is more dependent on what benefits their household most and the financial implications with less regard for what benefits the environment and sustainability goals. This comes as a result of an undereducated public on matter of smart technology and sustainable practices. Without high engagement, the state is unable to justify new advancements in technology, how they are intended to benefit society, and encourage the public to join the initiative for the community benefit to see goals met by the designated year.

Scenario IV. Sustainable Advancement, Smart Abandonment

Although sustainability is often supported by smart developments, the City and County of Honolulu was conflicted over cost implications of smart city technology. As a result, the state outlined a sustainable approach that used only the necessary technologies to advance sustainability. By 2045, Hawai‘i can advance sustainability goals, reducing carbon dioxide emissions produced locally. Although O‘ahu did not develop a committee that supported both smart and sustainable development, the state adopted plans for a sustainability committee tasked with decision-making and public advocacy on clean, renewable energy adoption.

While financial limitations interfered with some households’ ability to invest in electric vehicles and customer-sited solar, residents are environmentally conscious and are inclined to make informed decisions on their energy use and practice sustainable methods where they have control. To their benefit, the extent of renewable energy coverage provided by state-owned energy farms provides electricity to thousands of residences, servicing low-income households and public facilities all the same. The state’s push for sustainability extends further, mandating the new vehicles sales of non-gas emitting vehicles by 2030, allowing only electric vehicles to be

sold on the market. Household appliances sold on island are also limited to energy efficient and water saving appliances, another mandate to support sustainable alternatives.

A stronger push for public education and civic engagement proves beneficial to the state. To incentive public transportation, low-income would-be passengers (i.e., those whose housing costs are over 30% their household income) can ride at lower cost. To encourage ridership post-pandemic, the state pushed for proper sanitation and bus maintenance to make public transportation a more pleasant rider experience. In addition, public transportation route schedules are improved to maximize efficiency and promise timeliness and reliability for passengers, two issues the public identified that impacted their likelihood to use public transportation for commutes. Although the Rail phased out some of TheBus routes, TheBus fleet transitioned fully to electric, contributing to the reduction in carbon dioxide emissions and highlighting a Smart Transportation Model.

In the 25 years between 2020 and 2045, the state is able to focus their attention on issues of sustainability and garner widespread public support, thanks to public education and regulation of clean and sustainable solutions. A wider population is served beyond residents of O‘ahu. The narrowed sustainability scope also allows them to develop a responsible gas-emitting vehicle phase-out plan that promotes recycling and repurposing of vehicles and their parts, which neither results in an abandoned vehicle graveyard on the islands, nor relies on exporting secondhand vehicles to other countries for their use, thereby increasing deforestation and enabling continued gas-emissions. Overall, Hawai‘i upholds their end of the Paris Agreement that they signed onto in 2017.

Chapter VII: Conclusion

Smart cities have emerged in the 21st century as the anticipated norm as technology continues to emerge, networks evolve, and civilization moves towards a new standard of living. Smart city proposals must be tailored to fit the needs of the respective state or nation's people as there is no one-size-fits-all approach that is applicable to each developing city. However, recent research indicates that today's smart city projects can be classified into one of four smart city models depending on what smart development is most prevalent in the given plan. Applying this framework to the state of Hawai‘i, we can determine that the Broad Spectrum Model best encompasses what O‘ahu's various agencies are working towards, though there is no universally developed plan for the state that clearly indicates this, a concerning reality that requires collective efforts to bring to fruition.

In recent years, interest in smart development and transitioning to clean and sustainable energy has become more prevalent in the state of Hawai‘i. As early as 2005, the State of Hawai‘i saw benefit in implementing smart systems to connect urban sectors and promote economic growth. Now, in 2020, initially proposed efforts like the Rail and Kapolei as O‘ahu's second city are underway, with challenges and opportunities emerging as the projects continue to develop further that must be accounted for as early as possible to allow for steady progress with minimal project delays. The potential for smart and sustainable growth is dependent upon collaboration from state agencies with post-secondary education institutions, tech developers, and affiliated project developers to most effectively implement smart, sustainable design on O‘ahu.

Regardless of policy efforts, O‘ahu is on a pathway to adopting sustainable energy alternatives and continuing development that most heavily impacts urban concentrations. However, without collaboration from stakeholders, a clear regard for concerns expressed by the

public, and project plans that pose benefits to society, development may run more risks of economic, social, and technological losses explored in the environmental scan in chapter IV, making smart, sustainable development a high stakes operation that must be thoroughly planned to see maximum benefit. For this reason, it is imperative that policies proposed within this paper and identified beyond it be seriously considered as O‘ahu and its neighboring islands continue to develop substantially in the coming decades, working towards a 100% sustainable and clean energy goal by 2045.

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