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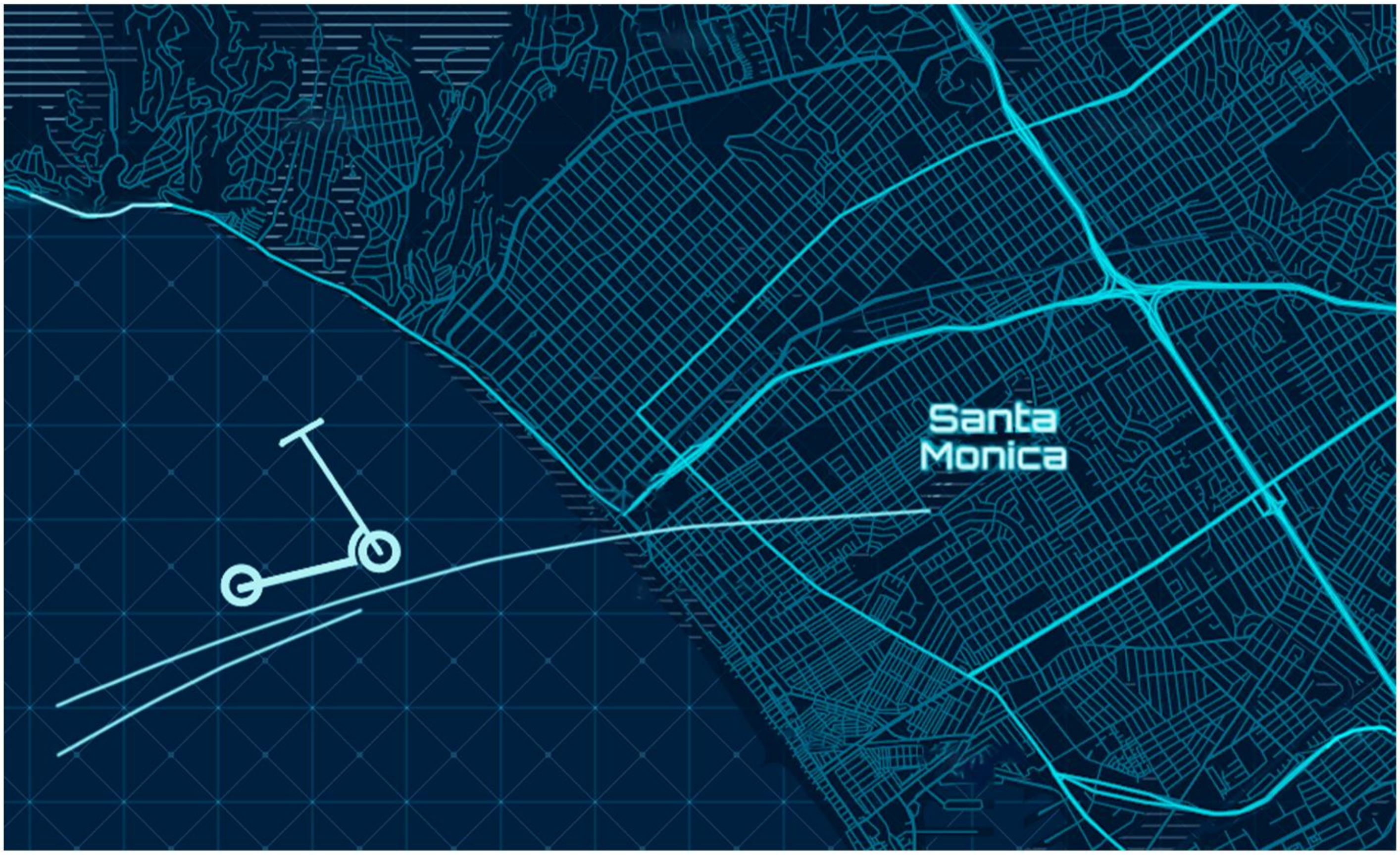

Applied Policy Project

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16. Abstract

The novel nature of shared mobility devices has produced concerns and questions relating to their safety, equity, and environmental sustainability. To determine the extent to which e-scooters might be used to effectively reduce carbon emissions in Santa Monica, California, our team engaged in an extensive review of the relevant literature, conducted interviews with key stakeholders and subject matter experts, and analyzed data representing more than 3 million e-scooter trips in Santa Monica as well as over 6,000 responses to surveys issued to device riders as well as to non-riding members of the community. Ultimately, we recommend two priority options that are immediately actionable, highly effective, and will not worsen safety or equity outcomes: optimizing shared mobility drop zones and encouraging the use of fuel-efficient vehicles employed for e-scooter and e-bike transport. Our priority recommendations as well as the menu of policy options we outline may be adapted to improve e-scooter sustainability in jurisdictions seeking to capitalize on this new mobility mode while curtailing carbon emissions.

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DISCLAIMER

This report was prepared towards fulfillment of the requirements for the Master's in Public Policy degree in the Department of Public Policy at the University of California, Los Angeles. It was prepared at the direction of the Planning & Community Development Department in the City of Santa Monica as a policy client. The views expressed herein are those of the authors and not necessarily those of the Department, the UCLA Luskin School of Public Affairs, UCLA as a whole, or the client.

CLIENT

This report was prepared for the Mobility Division of the Planning & Community Development Department of the City of Santa Monica. The Mobility Division oversees transportation policy and programs in Santa Monica. Their responsibilities include management of parking operations, maintenance of the traffic signal system, and execution of transportation elements relating to specific plans, action plans, and the City's General Plan.[1] The Mobility Division also administers Santa Monica's public bikeshare system and, beginning in 2017, was tasked with regulating the private provision of e-scooters and e-bikes within the City. Ultimately, the Mobility Division's mission is to guide efforts that fulfill one of the City's five strategic goals: creating a "new model of mobility" for Santa Monica and its citizens.[2]

[1] Santa Monica. Planning & Community Development. Mobility Division. "About Us." Retrieved from https://www.smgov.net/Departments/PCD/About-Us/Mobility/.
[2] Santa Monica. "City Council Meeting Agenda Item: 3.R." April 26, 2016, 3.

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EXECUTIVE SUMMARY

Almost two-thirds of carbon emissions in the City of Santa Monica can be attributed to the transportation sector.[3] As the overarching goal of its Climate Action and Adaptability Plan, Santa Monica hopes to achieve carbon neutrality by 2050. The City aims to accomplish this, in part, by converting solo automobile trips to shared mobility transportation modes such as e-scooters.[4] However, without a comprehensive understanding of the environmental sustainability of e-scooters, the City cannot adequately regulate or balance externalities associated with the private market provision of such shared mobility devices. The novel nature of shared mobility devices has produced concerns and questions relating to their safety, equity, and sustainability. In this context, the Mobility Division of the City of Santa Monica has asked our team to address the following policy question:

"How can the City of Santa Monica Utilize E-Scooters to Reduce Carbon Emissions Attributable to the Transportation Sector?"

To answer this question, we engaged in an extensive review of the relevant literature, conducted interviews with key stakeholders and subject matter experts, and analyzed data representing more than 3 million e-scooter trips in Santa Monica as well as over 6,000 responses to surveys issued to device riders as well as to non-riding members of the community. Our research revealed several key findings, which we categorize based on whether they affected the average life-cycle emissions of, or the substitution effect caused by, e-scooters. We identified e-scooters' average life-cycle emissions and their substitution effect on travel other modes as the two primary factors that constitute the net carbon emissions attributable to the devices. Considering these two factors and their corresponding findings, we concluded that e-scooters reduce transportation-related carbon emissions in Santa Monica. Also, we find that e-scooters' net carbon impact could be further limited through public-sector intervention that will improve e-scooter life-cycle emissions or continue to facilitate the substitution effect of e-scooters.

According to our findings, we envisioned policy guidelines to help address six current e-scooter

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[3] Garret Wong. Santa Monica. Office of Sustainability and the Environment. "City of Santa Monica Climate Action & Adaptability Plan." May 2019. Retrieved from https://www.smgov.net/uploadedFiles/Departments/OSE/Climate/CAAP_SantaMonica.PDF, 14.

[4] Ibid, 7.

inefficiency areas: 1) Collection and Deployment; 2) Charging; 3) Durability; 4) User; 5) Location; and 6) Infrastructure. Using our policy guidelines, we crafted and evaluated twelve specific policy options that might reduce carbon emission. Our policy option evaluation consisted of first determining their political, administrative, and financial feasibility. Secondly, we assessed each option based on its potential effectiveness toward reducing carbon emissions and its potential impact on community safety and equity.

Ultimately, we recommended two priority options that are immediately actionable, highly effective, and will not worsen safety or equity outcomes: optimizing shared mobility drop zones and encouraging the use of fuel-efficient vehicles employed for e-scooter and e-bike transport. Optimizing drop zones would result in a net carbon emissions decrease of 13.4 percent and it would also potentially improve equity and safety outcomes for both riders and non-riders. Encouraging providers to use fuel-efficient vehicles for device transport would be even more effective at reducing CO_2 levels. It would result in a 22.0 percent decrease in net carbon emissions impact, while having a negligible or neutral effect on equity and safety.

GLOSSARY OF TERMS

AI Index: Allocative Inefficiency Index is a measure of allocation compared to utilization of e-scooters in a particular area.

CAC: The Community Advisory Committee is an appointed body of Santa Monica community representatives and subject matter experts tasked with advising and contributing to the development of the Shared Mobility Pilot Program.

Contractor Model: A business model in which device transportation (i.e. collection, deployment) and charging are performed by contracted workers on behalf of the provider.

Drop Zone: Shared Mobility Drop Zones are designated areas in which users are encouraged to park and providers are likely to deploy e-scooters and e-bikes.

E-Bike: A seated, electric-powered bicycle that is rented by individual users through the use of a smartphone app.

E-Scooter: A standing, electric-powered scooter that is rented by individual users through the use of a smartphone app.

E-Trike: A seated, electric-powered tricycle that is equipped with a cargo receptacle and used by a provider's employees to collect and deploy e-scooters during the day.

FLM: First/Last-Mile refers to the first or last leg of a traveler's public transit trip. Specifically, it relates to the problem of how best to connect public transit users — potential or realized — from their origins or destinations to the nearest transit stop or station.

Gig Worker: In the case of this project, the device transporters and chargers contracted by providers using a contractor model.

Hex Cell: A hexagon created in ArcMap Geographic Information System (a mapping software program) representing 600 square feet of land in Santa Monica, the unit of geographic measurement for spatial analysis of e-scooter locations and trip data.

In-House Model: A business model in which device transportation (i.e. collection, deployment) and charging are performed by paid employees of the provider.

LCA: Life-cycle analysis (also known as life-cycle assessment) is a methodology for assessing environmental impacts associated with all the stages of the life-cycle of a commercial product, service, or process.

Mobility Division: Our client; a division housed within the Planning & Community Development Department of the City of Santa Monica. It oversees the City's transportation policy and programs, including regulation of e-scooters and e-bikes in Santa Monica.

PMT: Passenger-Miles Travelled on a given transportation mode (e.g. e-scooter), the unit of analysis for trip distance.

Providers: To better differentiate between device operators and device users, we opted to label the private shared mobility companies permitted to operate within Santa Monica as "Providers".

PROW: Public Rights-of-Way allow the public to walk, or sometimes ride, cycle or drive, along specific routes over land owned and maintained by a municipal government.

South Coast AQMD: South Coast Air Quality Management District, formed in 1976, is the agency responsible for regulating stationary sources of air pollution in the South Coast Air Basin, in Southern California.

SMC: Santa Monica College is the largest educational institution in Santa Monica.

SMPP: The Shared Mobility Pilot Program administered by the Mobility Division beginning in September 2018 and extended through May 2020.

SOV: Single-Occupancy Vehicle refers to private automobiles in which the only passenger is the driver.

Trip-Start: The beginning of an e-scooter ride, when it is unlocked by a user.

Trip-End: The conclusion of an e-scooter ride, when it is finished by a user.

UR: Utilization Rate is a ratio of the number of e-scooters used compared to the number available in a particular area.

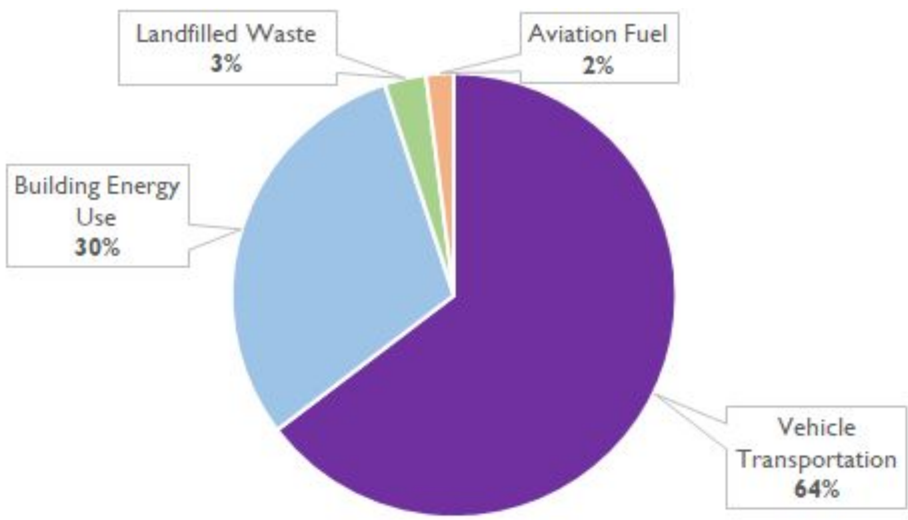
VMT: Vehicle-Miles Travelled measures the distance a vehicle travels. In the case of cars, it can be used as a rough proxy for correlated externalities associated with automobile use such as congestion, pollution, and roadway degradation.

I. INTRODUCTION

1. Transportation-Related Carbon Emissions and the Role of E-Scooters

Transportation represents the largest portion of carbon emissions by sector in the United States, accounting for more than a quarter of the nation's total greenhouse gas (GHG) emissions.[5] This trend follows at both the state and local level. According to the California Air Resources Board, air pollution generated through transportation constituted 41 percent of all GHG emissions in 2017.[6] In Santa Monica, carbon emissions generated by transportation represent 64 percent of the City's emissions.[7]

Figure 1: Carbon Emissions Sources in Santa Monica



[5] United States. Environmental Protection Agency. "Fast Facts on Transportation Greenhouse Gas Emissions." July 16, 2019. Retrieved from https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions.
[6] Mac Taylor. California. Legislative Analyst Office. "Assessing California's Climate Policies— Transportation." *Legislative Analyst Office*. December 21, 2018. Retrieved from https://lao.ca.gov/Publications/Report/3912.
[7] Garret Wong. Santa Monica. Office of Sustainability and the Environment. "City of Santa Monica Climate Action & Adaptability Plan." May 2019. Retrieved from https://www.smgov.net/uploadedFiles/Departments/OSE/Climate/CAAP_SantaMonica.PDF, 14

High levels of transportation-related carbon emissions are driven largely by private automobiles and the high percentage of single-driver trips made in them.[8] Single-occupancy vehicles (SOVs) are the primary mode of transport that cities and sustainability advocates, including the City of Santa Monica, desire to replace with trips made by foot, bicycle, public transit, and, now, e-scooters.[9] Reducing emissions in the transportation sector by shifting passengers out of cars and into such "greener" modes when applicable has become a primary goal of many government agencies. In this political environment — and particularly in the dense, urban setting of Santa Monica — e-scooters present a reasonable alternative to private vehicle trips and could be added to the menu of transportation options that agencies recommend to travelers in their jurisdictions.[10]

2. E-Scooters and the City of Santa Monica

E-scooters represent one of the new, popular transportation modes that the private market has developed and marketed as an alternative to driving alone. Their popularity can be gauged by the millions of trips that were taken by e-scooter in Santa Monica since their introduction in 2017. Yet, absent adequate oversight and regulation, e-scooter providers may neglect to address externalities of e-scooter use that impact equity, public safety, and environmental sustainability. Despite e-scooter providers' capacity to discover and meet new market demand for convenient transportation options, concerns persist as to who is able to afford and access e-scooters, how they may be impacting the safety of riders and the community, and the carbon impact of devices throughout their life-cycle.

In an attempt to better understand and regulate this burgeoning form of transportation, the City of Santa Monica developed a permitting process and pilot program in September 2018.[11] The program, which is overseen by the Mobility Division within the City's Planning and Community Development Department, permitted four private companies (i.e., Bird, Lime, Lyft, and Jump) to operate a combined total of 2,000 e-scooters and 1,000 e-bikes within the City during the approximately 16-month pilot.[12] In November 2019, the City Council of Santa Monica approved a five-month extension of the program with the intention of facilitating a second pilot-program based on lessons learned over almost two years.

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[8] Christopher G. Hoehne and Mikhail V. Chester. "First-last mile environmental life-cycle assessment of multimodal transit in Los Angeles." *Arizona State University*. July 11, 2017. Retrieved from https://pdfs.semanticscholar.org/0918/de10924ef4d594f3c91a05b171707c8f3d5d.pdf.

[9] Wong. "City of Santa Monica Climate Action & Adaptability Plan.", 15.

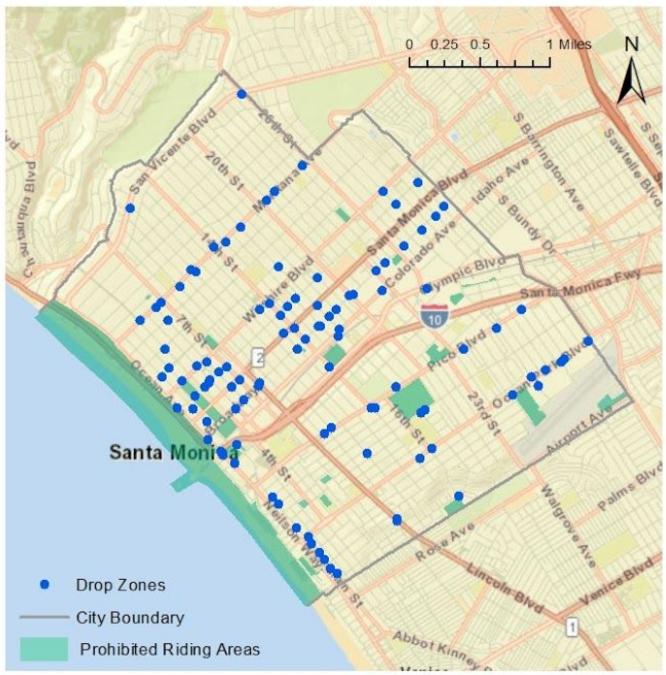
[10] Inrix. "Shared Bikes and Scooters Could Replace Nearly 50 Percent of Downtown Vehicle Trips." September 9, 2019. Retrieved from https://inrix.com/press-releases/micromobility-study-us-2019/

[11] Santa Monica. Planning & Community Development. Mobility Division. "Scooter and Bike Share Services." 2020. https://www.smgov.net/Departments/PCD/Transportation/Shared-Mobility-Services/

[12] Ibid. "City of Santa Monica Shared Mobility Device Pilot Program Administrative Regulations"

So far, Santa Monica has undertaken significant measures to regulate e-scooter providers and their fleets including developing an operating permit process, launching an evaluative pilot program, and installing infrastructure specifically designed for devices. The City created shared mobility drop zones (Drop Zones) as an attempt to better manage provider fleet deployment and to organize rider parking behavior. As of November 2019, the Mobility Division placed 107 drop zones both on-street and in sidewalk areas.[13] Additionally, the City and entities such as Santa Monica College (SMC) prohibited the use of devices in specific areas due to public safety concerns, as shown in **Figure 2** below.

Figure 2: Shared Mobility Drop Zones and Prohibited Riding Areas



3. Our Client: The City of Santa Monica's Mobility Division

Chief among its various obligations, the Mobility Division oversees transportation policy and planning for the City of Santa Monica. Its role has recently expanded to encompass the management and regulation of e-scooters and e-bikes. In this capacity, the Mobility Division administers the Shared Mobility Pilot Program (SMPP), which seeks to evaluate the ability of e-scooters and e-bikes to help the City achieve several strategic goals.

In conducting the pilot program, the Santa Monica City Council asked that the Mobility Division regulate private providers with three goals in mind: protect public safety; promote community

[13] Mobility Division. "Shared Mobility Pilot Program Summary Report.", 30.

well-being and sustainability; and equity. The Mobility Division then established specific guidelines and incentives designed to address several key considerations related to e-scooters, including fare equity, rider behavior, public safety, fleet size, and deployment location.[14]

However, similarly specific regulations concerning the environmental sustainability of e-scooters are yet to be articulated. The City has included e-scooters among their intended means of shifting passengers from SOVs and achieving carbon neutrality by 2050.[15] Within this context, it is the goal of this project to provide actionable recommendations to the Mobility Division to maximize e-scooters' potential as an environmentally sustainable transportation mode.

4. Policy Question

In consideration of the City of Santa Monica's environmental and transportation-related goals, as well as its position as the public body best-suited to regulate the local e-scooter industry, we seek to answer the following policy question:

How can the City of Santa Monica utilize e-scooters to reduce carbon emissions attributable to the transportation sector?

[14] Santa Monica. "City of Santa Monica Shared Mobility Device Pilot Program Administrative Regulations."
[15] Wong, "City of Santa Monica Climate Action & Adaptability Plan.", 15.

II. BACKGROUND

E-scooters first appeared in the U.S. when Bird Rides, Inc. (Bird) launched in Santa Monica, California in September 2017.[16] Since then, several private companies followed suit by deploying and operating fleets of e-scooters and e-bikes that are able to be rented by users through smartphone technology. These devices and the companies that provide them can now be found in many major urban centers throughout North America and Europe.

The most common e-scooter models are approximately 3.5 feet long, 4 feet tall, and weigh about 27 pounds, providing a transportation option that is relatively compact and lightweight.[17] As of July 2019, e-scooters and e-bikes are typically unlocked by users for a $1.00 fee with their smartphone. Then, users pay anywhere from $0.23 to $0.26 depending on the brand of device they choose to rent and ride.[18] E-scooter providers employ various practices to maintain and operate their rentable fleets, but all collect, charge, and deploy at least a portion of their respective devices throughout the day.

While some regard this new technology as a relatively economical solution for urban congestion and transportation-related emissions, others view the devices as a nuisance. Initial issues with Bird's unregulated and unannounced launch prompted public criticism, which resulted in the City of Santa Monica filing suit against the company.[19] Prevailing concerns regarding e-scooters include their obstruction of public rights-of-way, pedestrian and rider safety, equity, access, and life-cycle carbon emissions associated with the devices.

Despite their alleged shortcomings, e-scooters represent a particularly attractive potential solution to several transportation problems that plague both the region and the City. Traffic congestion in the Los Angeles metropolitan area is consistently rated among the nation's worst,[20] and this phenomenon is pronounced in the Westside area including the City of Santa Monica.[21] The significant number of relatively short-distance car trips that contribute to congestion could

[16] Mobility Division. "Shared Mobility Pilot Program Summary Report." November 2019, 4.
[17] Mi Global Home. "MI Electric Scooter." Accessed on March 17, 2020. Retrieved from https://www.mi.com/global/mi-electric-scooter/specs
[18] Madeline Pauker. "Prices spike for e-scooter rentals." *Santa Monica Daily Press.* July 5, 2019. https://www.smdp.com/prices-spike-for-e-scooter-rentals/177117
[19] Joseph Vandernorth. Santa Monica. "City Attorney Files Criminal Complaint Against Illegal Business Operations by Bird Rides, Inc." December 7, 2017. Retrieved from https://www.santamonica.gov/press/2017/12/07/city-attorney-files-criminal-complaint-against-illegal-business-operations-by-bird-rides-inc.
[20] City News Service. "L.A.'s traffic congestion is world's worst for sixth straight year, study says." *LA Times*. February 6, 2018. Retrieved from https://www.latimes.com/local/lanow/la-me-la-worst-traffic-20180206-story.html
[21] Southern California Association of Governments. "Mobility Go Zone & Pricing Feasibility Study." March 2019. Retrieved from http://scag.ca.gov/Documents/MobilityGoZone_Report_FINAL.pdf.

provide ample opportunity for e-scooters to serve as a viable alternative.[22] Additionally, planning agencies are beginning to actively utilize e-scooters as an answer to the First/Last-Mile (FLM) problem after the devices had been marketed as a potential solution by shared mobility companies.[23] Proponents contend that potential transit riders would be more likely to use public transportation if users could reliably connect the first and last leg of a transit trip between their home or destination and the station or stop via e-scooter or e-bike.

E-scooters and e-bikes have widely been recognized for their potential to reduce emissions associated with the transportation sector, particularly in urban environments. Transportation-related emissions reductions are as important as ever due to worsening air quality for the first time in decades for the region.[24] Yet, to leverage e-scooters effectively as a tool for reducing carbon emissions associated with the transportation sector, it is desirable to maximize the displacement of SOV trips and minimize the displacement of trips made by foot, bicycle, or public transit. To further reduce emissions, e-scooters may help substitute SOV trips by complementing sustainable travel modes. For instance, e-scooters offer a means of connecting to relatively distant transit and bikeshare hubs for travelers who may have otherwise driven the entirety of their trip. Furthermore, considerations must be made regarding externalities associated with the devices as well as the private market's ability to effectively and equitably provide this new mobility choice. Although a wide range of valid concerns exist regarding the private market provision of this new mobility option, it is through an environmental sustainability lens that we frame our analysis and develop policy recommendations. At the request of our client, the Mobility Division of the City of Santa Monica, our team demonstrates how e-scooters might be utilized to reduce carbon emissions attributable to the transportation sector.

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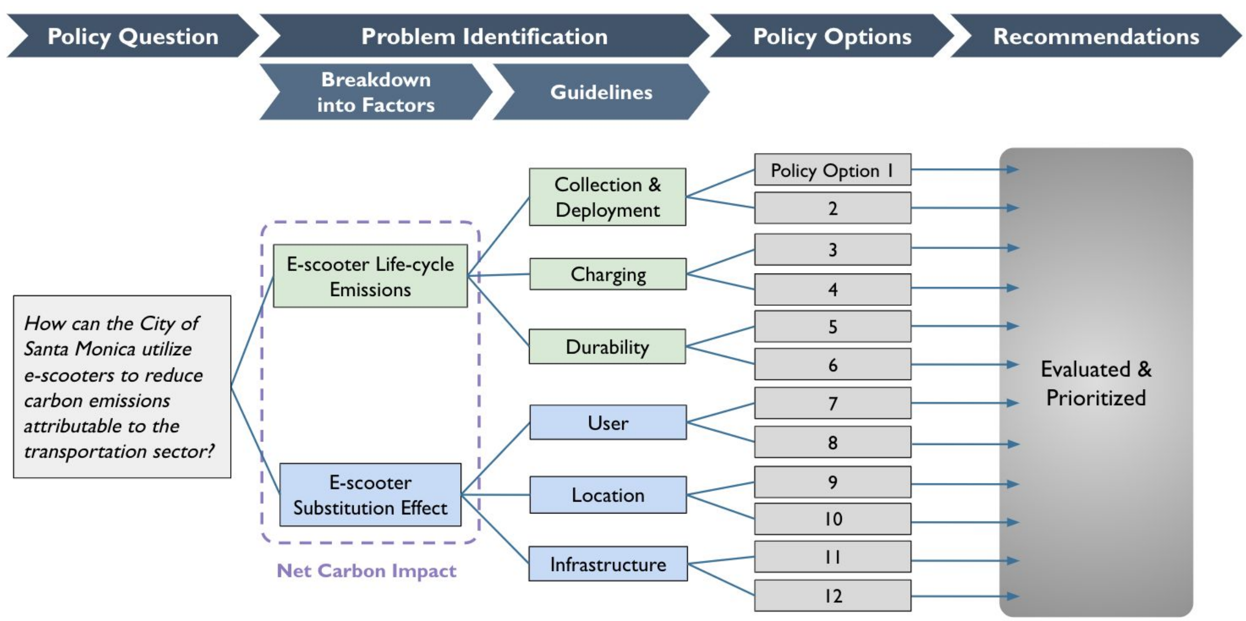
[22] Cailin Crowe. "Micromobility could replace 48% of car trips in 10 US cities." *Smart Cities Dive.* September 9, 2019. Retrieved from https://www.smartcitiesdive.com/news/micromobility-could-replace-48-of-car-trips-in-10-us-cities/562489/.
[23] American Public Transportation Association. "Sacramento RT and Micromobility Integration." August 20, 2019. Retrieved from https://www.apta.com/sacramento-rt-and-micromobility-integration/.
[24] Tony Barboza and Rahul Mukherjee. "The war on Southern California smog is slipping. Fixing it is a $14-billion problem." *LA Times*. July 1, 2019. Retrieved from https://www.latimes.com/local/lanow/la-me-smog-southern-california-20190701-story.html.

III. METHODOLOGY OF DATA COLLECTION AND ANALYSIS

1. Overview of Analysis

To explore and answer our policy question, we develop our own method to conduct a multi-stage analysis as shown in **Figure 3**. First, we deconstruct the cause of e-scooters' net carbon impact into two central factors: e-scooter life-cycle emissions relative to other modes and the substitution effect from trips made by other modes to e-scooters. Through the lens of these two factors, we identify problems and implications. We summarize our findings under policy guidelines from the perspective of six levers — collection and deployment, charging, durability, user, location, and infrastructure — which our client could address to achieve greater effectiveness (i.e. emissions reductions). Then, we generate several specific policy options that follow the categorized policy guidelines. Lastly, for the purpose of making actionable recommendations, we evaluate and prioritize our policy options based on criteria informed by our client's capabilities and goals.

Figure 3: Overview of the structure of analysis in this project



2. Data Sources and Methodology

In order to identify the factors influencing carbon impact and the opportunities for reducing carbon emissions through e-scooter use, as well as to generate and evaluate policy options, we critically reviewed relevant data collected through statistical analysis, spatial analysis, and interviews. We also conducted a broad review of relevant literature on the subject (e.g. government documents, academic publications, press articles, etc.) to better inform our research and methodology. **Table 1** outlines the method of analysis, data analyzed, and rationale for analyzing. We subsequently describe our data sources and methodology in more detail below.

Table 1: Summary of Data Sources and Methodology

Method	Data Source	Description	Rationale for Analysis
Statistical Analysis	Anonymized Raw Survey Responses	● Winter Shared Mobility User Survey 1,901 total responses ● Summer Shared Mobility User Survey 4,760 total responses ● Santa Monica Community Survey 1,261 total responses	To understand travel behavior in Santa Monica over time
	Anonymized Trip Data	● Approximately 3.2 million total trips, aggregated by distance traveled and organized by count per quarter-mile	
Spatial Analysis	Anonymized Trip Data	● Approximately 3.2 million total trips, aggregated by spatial hex cell and organized by trip-start and trip-end	To understand e-scooter utilization, deployment, and availability by location
		● Approximately 100,000 total trips, aggregated by spatial hex cell and organized by trips starting and trips ending near Expo Line station	To understand first/last-mile usage by location
Interviews	Key Stakeholders & Subject Matter Experts	● 4 City of Santa Monica Staff ● 3 Community Advisory Committee (CAC) members ● 2 Shared Mobility Providers ● 1 Active Transportation Advocate ● 1 Journalist ● 1 Santa Monica College Staff ● 3 Transportation Policy & Research Experts	To understand local shared mobility affairs as well as stakeholder roles and views To understand transportation and environmental sustainability research methodology To inform evaluative criteria

2.1 Statistical Analysis

To assess the change in travel behavior since the adoption of e-scooters, we collected and analyzed raw data from three surveys: a general community survey conducted by the City; and two surveys administered by the City during its Shared Mobility Pilot Program (SMPP) and distributed by shared mobility providers to their users.

The community survey was conducted from July 16 to August 2, 2019, with the primary purposes of better understanding perceptions of the pilot program, community awareness of shared mobility rules, and community sentiment toward issues specific to shared mobility. In total, 1,261 community members responded to this survey.

As part of the SMPP, the City worked with the four permitted companies to conduct surveys of their users in order to better understand rider behavior and the impact of devices in Santa Monica. These two user surveys were available to riders in 2019 from January 15 to February 15 and from May 28 to June 9, respectively. The City gathered a total of 6,661 responses. We provide summary statistics on the transportation modes replaced by the devices, trip purposes of the devices for frequent users, and perceived barriers to device usage.

Additionally, we use aggregated e-scooter trip distance data to calculate the miles of travel on other modes that were displaced by e-scooters during the pilot. The dataset contains 3.2 million e-scooter trips recorded from October 25, 2018 through December 1, 2019. The trips were sorted by distance and generously provided by our client.

2.2 Spatial Analysis

The City of Santa Monica provided aggregated location-based data for all e-scooter trips — roughly 3.2 million trips — in Santa Monica over a 402-day period from October 25, 2018 through December 1, 2019. This dataset contains anonymized trip starts, ends, and deployments located within Santa Monica, and constitutes all rides made on devices provided by the four permitted providers over this period. The City aggregated and sorted the location-based trip data into 312 hexagonally-shaped parcels ("hex cells"), each measuring about 600 square feet and spanning the entirety of Santa Monica. We rely on aggregated trip-start and trip-end location data rather than analyzing entire trip routes to help protect rider privacy. However, the hex cells still allow us to analyze e-scooter trips with considerable precision as the area of the cells is much more focused than those of census tracts or other geographic area units commonly used for spatial analysis.

To understand how intensively e-scooters are used in a particular location, we calculate the Utilization Rate ("UR") in each hex cell by dividing the e-scooter trip-starts by device availability. Simply put, UR is a ratio of the number of e-scooters used compared to the number available in a particular area. We calculate device availability by combining the number of e-scooter deployments and the number of e-scooter trip-ends in a given hex cell. High UR reflects areas where e-scooter trips are generated efficiently compared to device availability. However, UR does not reflect absolute deployment volume, which is the total number of devices supplied by providers. To gain a more comprehensive understanding of how deployment volume affects UR, we construct a measure of the relative allocative inefficiency of e-scooters in a hex cell (Allocative Inefficiency Index, or "AI Index"). To calculate AI Index scores, we divide the volume of deployment by UR in a hex cell. A higher AI Index score reflects areas where providers may be deploying too many e-scooters relative to their usage.

For a deeper analysis of how e-scooters complement public transit usage, our client also provided data on trips that start or stop at one of Santa Monica's three Metro Expo Line stations. Aggregated trip-start and trip-end combinations at these locations allow us to assess the degree to which e-scooters are used to connect with transit, with counts of trips that started within 200 feet of an Expo Line Station and ended within a given hex cell, and vice versa. We refer to these trips as a "First/Last-Mile (FLM)" trip, which describes the beginning or end of an individual trip made primarily by public transportation. These FLM trip data account for more than 100,000 total trips during the analysis period. To assess the level of demand for FLM trips, we created an FLM demand index by calculating the number of FLM trips divided by all e-scooter trips starting in each hex cell. This index allows us to identify the areas that have a potential for e-scooters to encourage more sustainable travel by facilitating transit use.

We focus on connections between e-scooters and rail stations, rather than e-scooters and bus stops, primarily because of the high volume and density of bus stops within Santa Monica. Due to the aggregated nature of our trip-start and trip-end location data, it would be nearly impossible to correlate e-scooter trips with bus ridership. There may be several bus stops and multiple potential other destinations within a given hex cell where e-scooter trips begin or conclude.

2.3 Interviews

The SMPP involved three very different stakeholders: private shared mobility companies that spawned a new mode of transportation; the Santa Monica citizenry; and the City government. We interviewed all three parties to coherently and wholly understand the pilot, stakeholders' perceived experiences and roles, and to investigate qualitative questions about environmental impact relevant to their respective role.

We also conducted interviews with transportation and sustainability experts for the purpose of validating our estimation of net carbon impact of e-scooters, which directly informs our policy question. Additionally, the interviews helped build the basis for the criteria used to evaluate our specific policy options. Stakeholder input contributed to our understanding of the relative feasibility of our options as well as relevant societal impacts separate from carbon emissions. The details of our interview process as well as a list of interviewees are described in **Appendix A**.

City of Santa Monica's Mobility Division

The Mobility Division, our client, served as the point of contact between staff at the City of Santa Monica, the Community Advisory Committee (CAC), and shared mobility providers. The Mobility Division also granted our team access to the aforementioned quantitative data sources critical to our analysis. Both of these sources were gathered through the course of the pilot and enabled us to conduct a thorough analysis of e-scooters' substitution effect.

Community Advisory Committee (CAC)

Members of the Santa Monica community were asked by the Mobility Division to serve on an advisory committee based on their personal commitment to community affairs or their expertise on relevant matters such as climate change policy and active transportation. We were able to interview three of these eight members. We viewed the findings from our interviews with the CAC members as an appropriate and approximate reflection of community sentiment on the pilot as well as on shared mobility in Santa Monica overall.

Shared Mobility Providers

Private shared mobility providers have acted differently from one another depending on local conditions and the policies of local governments. As an example, one provider expressly left the City of San Diego because a city ordinance banned devices from certain areas.[25] We were able to speak to two of the four permitted providers in Santa Monica that we subsequently refer to as "Provider A" and "Provider B." We deemed it necessary to understand their view of operating in a city unique in both its structure and municipal response to e-scooters.

Advocates

The City launched the SMPP primarily to regulate the behavior of dockless shared mobility users and its impact on the public-right-of-way (PROW). The pilot also sought to assess other critical elements including income equity considerations. Interviewing advocates of communities impacted by these issues served as a means for our team to assess the pilot's scope and effectiveness.

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[25] Brittany Meiling, "Dockless scooter giant, Lime, is leaving San Diego. Here's why." *San Diego Union-Tribune*." January 9, 2020.
https://www.sandiegouniontribune.com/business/technology/story/2020-01-09/lime-is-leaving-san-diego-and-11-other-cities-citing-too-much-red-tap-declining-ridership.

Transportation Policy and Research Experts

Interviews with subject matter experts at UCLA and its Institute of Transportation Studies aided our analysis. Such experts helped us to assess the pilot and shared mobility, generally, through the lens of net emissions impact, in an appropriate and informed manner.

Journalists

The novelty of e-scooters and e-bikes meant media coverage held a strong weight in our particular regard for research. To our knowledge, the *LA Times* has conducted the only quantitative assessment of lifetime duration of shared mobility devices in Santa Monica and adjacent areas.

IV. KEY FINDINGS

In this chapter, we identify the problems underpinning the current carbon impact of e-scooters in Santa Monica that warrant policy intervention. First, we outline and explore factors that affect the net carbon emissions of e-scooters. Second, we develop a model that estimates their carbon impact. Lastly, we summarize implications from our findings as policy guidelines.

1. Factors Influencing Net Carbon Emission Impact of E-scooters

To understand the factors that influence the carbon impact of e-scooters in Santa Monica, we first break down total transportation emissions into emissions generated by each mode. We do so in order to understand the emissions that e-scooters may add or displace through their substitution effect on other modes. Then, we reduce emissions from each mode to their respective average life-cycle emissions (gram CO_2 per passenger-mile traveled, or PMT) and multiply this by the total miles traveled on each mode (passenger-mile), as shown in **Figure 4** below. We focus on two elements that particularly relate to e-scooters:

A) **E-scooter Life-cycle Emissions**: Average carbon emissions attributable to an e-scooter from manufacturing to decommissioning

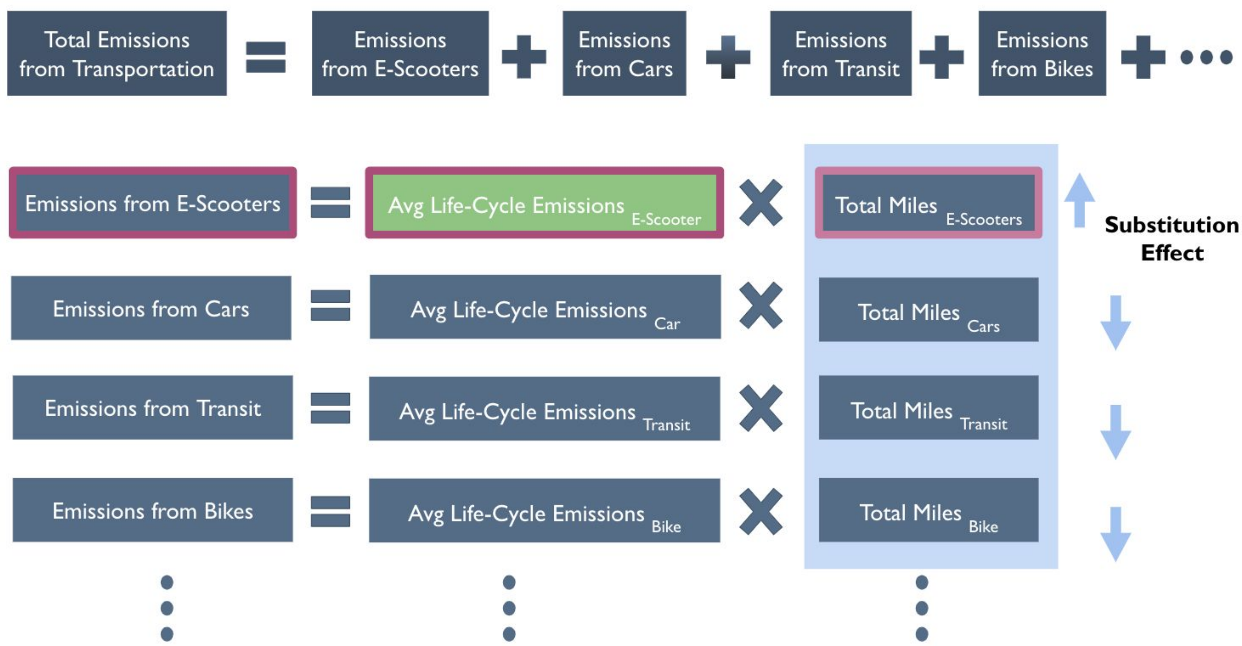
B**) Substitution Effect**: The extent to which e-scooters substitute for travel by other modes of transportation

Average e-scooter life-cycle emissions refer to the grams of CO_2 emitted by one e-scooter per PMT on that device in its life-time. Although e-scooters do not generate any "tail-pipe" emissions, their average life-cycle emissions can be attributed to provider practices including the means employed to transport, charge, and maintain the devices.

We define the substitution effect in this case as the displacement of other travel modes by e-scooters and analyze some of the primary external characteristics that influence users' mode choice. These two factors collectively result in our estimate of e-scooters' net carbon impact, assuming all other factors (e.g., average life-cycle of other transportation modes) are held equal.

In the following two subsections, we identify what factors affect A) e-scooter life-cycle emissions and B) substitution effect. The findings will inform our key policy implications.

Figure 4: Simplified Equation Representing Total Emissions from Transportation



A) E-scooter Life-Cycle Emissions

Finding: Device collection, deployment, and lifetime length contribute significantly to average e-scooter life-cycle emissions

Materials and manufacturing, shipping, collection and deployment, and charging are the factors producing carbon emissions during the e-scooter life-cycle.[26] The average carbon impact of e-scooters is driven by emissions generated from energy, electricity, heat, and transportation fuels used in each process.[27] In a study of e-scooters' environmental sustainability,

[26] Mikhail V. Chester, Arpad Horvarth, Samer Madanat. 2010 Comparison of life-cycle energy and emissions footprints of passenger transportation in metropolitan regions Atmos. Environ. 44 1071–9

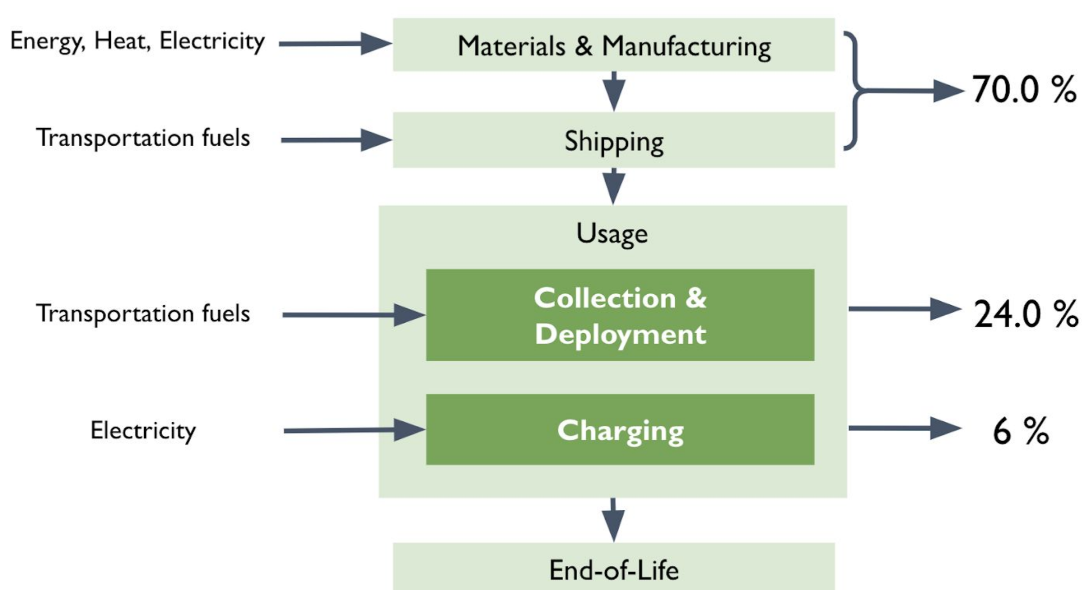
[27] Hollingsworth, J., B. Copeland, J.X. Johnson, 2019, Are e-scooters polluters? The environmental impacts of shared dockless electric scooters, Environ. Res. Lett., 14 (8) (2019), Article 084031

Chester M. "It's a Bird...It's a Lime…It's Dockless Scooters! But Can These Electric-Powered Mobility Options Be Considered Sustainable Using Life-Cycle Analysis?" 2019. Retrieved from https://chesterenergyandpolicy.com/2019/01/28/its-a-bird-its-a-lime-its-dockless-scooters-but-can-these-electric-powered-mobility-options-be-considered-sustainable-using- life-cycle-analysis/

Hollingsworth et al found that materials and manufacturing contribute 50 percent of the average CO_2 impact, followed by collection and deployment constituting 43 percent of the total. The impact of shipping and charging proves to be relatively trivial (2.3 percent and 4.7 percent respectively).[28] Yet, these estimates are adjusted when we calibrate e-scooter life-cycle emissions according to travel behavior in Santa Monica: materials, manufacturing, and shipping account for 70 percent of emissions; collection and deployment, 24 percent; and charging, 6 percent.

Research conducted by Hollingsworth et al on devices in Raleigh, North Carolina served as the basis for our baseline understanding of e-scooters' average life-cycle CO_2 emissions. Although this scholarship is generally representative for most U.S. cities in which e-scooters operated, we deemed it necessary to re-calibrate emissions estimates for specific characteristics of the City of Santa Monica. To do so, we primarily account for differences between Raleigh and Santa Monica in the nature of vehicle trips made for device transportation (i.e., collection and redeployment). Based on our calibration, we found the average life-cycle CO_2 emission is 151 gram per PMT in Santa Monica (compared to 202 gram per PMT in Raleigh). Collection and deployment processes constitute nearly a quarter of these emissions (24 percent), while the charging process constitutes 6 percent (**Figure 5**). The detailed calibration method is shown in **Appendix B**.

Figure 5: Estimates of E-scooter Life-Cycle Emissions for Santa Monica



28 Hollingsworth et al.

Additionally, the average carbon emission impact is sensitive to e-scooter lifetimes. Thus, we would expect to see lower average e-scooter CO_2 emissions over a device's lifetime as the length of time increases. For example, ensuring a two-year lifetime would decrease the average life-cycle emissions by 30.2 percent.[29] Reporters at the LA Times, based on their data review, found that the average lifetime for a Bird e-scooter was 126 days, which stands in contrast to earlier analysis that puts the lifespan at the time at 28.8 days.[30] In interviewing one of the LA Times reporters, we found that the lifetimes of e-scooters for the other three providers are comparable to Bird, given the use of similar hardware among providers.[31] Interviews with Santa Monica Code Enforcement and City staff that supervised the SMPP suggest that over the course of the pilot there was a reduction in the sort of vandalism and theft that may shorten e-scooter lifetimes.[32]

Although a large portion of a device's average life-cycle CO_2 emissions are caused by the manufacturing process and materials chosen for use, it is beyond the scope of this project and the technical expertise of this team to specifically assess each providers' individual engineering choices. Additionally, providers continue to release new iterations of devices on an almost yearly basis, meaning that assessments related to manufacturing and materials emissions might prove to be inapplicable in a short time. Considering the capacity of our client to intervene, as well as the significant impact that other processes have on life-time emissions, our policy analysis and recommendations focus on three elements, 1) collection and deployment, 2) charging, and 3) e-scooter lifetimes.

Finding: Collection and deployment practices may contribute to increased congestion and emissions

Collection procedures differ substantially by provider: Provider A uses an "in-house" model where all collectors are employed staff who utilize an electric-powered cargo e-trike for collection during the day and light cargo commercial vans at night;[33] Provider B utilizes a

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[29] Hollingsworth et al.
[30] Sam Dean and Jon Schleuss, "Can Bird build a better scooter before it runs out of cash?". *LA Times*. May 5, 2019. https://www.latimes.com/business/technology/la-fi-tn-bird-scooters-money-profit-strategy-20190505-story.html.
Allison Griswold. "Shared scooters don't last long". March 1, 2019. *Quartz.* Retrieved from "https://qz.com/1561654/how-long-does-a-scooter-last-less-than-a-month-louisville-data-suggests/
[31] Sam Dean, phone interview with authors, March 3, 2020.
[32] Code Enforcement Manager, phone interview with authors, February 25, 2020.
Code Enforcement Officer, phone interview with authors, February 18, 2020.
[33] Provider A, phone interview with authors, December 5, 2019.

contractor model and doesn't track the mode of transportation nor the vehicle used by their contracted collectors.[34] Consequently, in this contractor model, there are currently no rules as to the type of vehicle used, who may collect or deploy, or the scope and frequency of trips made for collection and deployment.

The Deputy Director at the UCLA Institute of Transportation Studies was critical of the "hunter-gatherer" nature of the contractor model due to its perverse incentives and further emissions it generates through competition-induced inefficiencies during collection.[35] Simply put, competition among contracted collectors may lead to more vehicle-miles traveled (VMT) as multiple contractors seek to be the first to arrive at and collect a device. Conversely, the in-house model, with its centralized collection facility, as well as its use of light cargo commercial vans and zero-emission e-trikes, make the process of collection and deployment more efficient than the contractor model in terms of carbon emissions.

Finding: Charging devices in Santa Monica uses completely renewable energy

Santa Monica recently transitioned to providing businesses and residents with entirely renewably-sourced energy through the City's grid.[36] A Community Advisory Committee (CAC) member and transportation specialist for the National Resource Defense Council (NRDC) noted during our interview that it would be ideal that shared mobility devices are charged within Santa Monica as the power supply is sourced from 100 percent renewable energy.[37] This is notable as one of the providers already centralizes its charging at a warehouse in Santa Monica.[38] Compared to the grid in neighboring Los Angeles, which relies on renewable energy sources for just 30 percent of its electricity,[39] charging devices in Santa Monica is more sustainable.

[34] Provider B, phone interview with authors, December 11, 2019.
Taylor Lorenz, "Electric Scooter Charger Culture Is Out of Control." *The Atlantic*. May 20, 2018. Retrieved from https://www.theatlantic.com/technology/archive/2018/05/charging-electric-scooters-is-a-cutthroat-business/560747/
[35] Juan Matute, in-person interview with authors, February 27, 2020.
[36] Santa Monica. "Santa Monica Businesses Transition to Green Power Starting in May." April 4, 2019. https://www.santamonica.gov/press/2019/04/04/santa-monica-businesses-transition-to-green-power-starting-in-may
[37] CAC Member C, phone interview with authors, January 6, 2020.
[38] Provider A interview.
[39] Los Angeles. Department of Water and Power. "Facts & Figures." 2018. Retreived from https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-power/a-p-factandfigures?_adf.ctrl-state=imc6t3b5t_4&_afrLoop=296101670793807&_afrWindowMode=0&_afrWindowId=null#@?_afrWindowId=null&_afrLoop=296101670793807&_afrWindowMode=0&_adf.ctrl-state=15qtj404vb_4

Finding: Average life-cycle emissions of e-scooters are much less than cars, but higher than buses and bikes

The net carbon impact of e-scooters is influenced by the average life-cycle emissions of other transportation modes replaced. Hollingsworth et al reported that the average life-cycle CO_2 emissions of e-scooters (202 gram/PMT) is 51.2 percent lower than that of an automobile (414 gram/PMT), 146 percent greater than that of a bus with high ridership (82 gram/PMT), and 25 times that of a bicycle (8 gram/PMT).[40] When we use the value of e-scooter life-cycle CO_2 emissions calibrated for the city of Santa Monica (151 gram/PMT), the net carbon impact of e-scooters would be further reduced. Usage contributes more than three quarters of the average CO_2 impact of a conventional gasoline vehicle (80 percent),[41] which implies that replacing car trips with e-scooter trips can largely decrease net carbon emissions even if car ownership rates remain unchanged. These findings show that the transportation mode replaced by e-scooters determines the net emissions reduction to a large extent.

Replacing singular car trips, which produce more average life-cycle CO_2 emissions than trips made via other modes, with e-scooters is a net positive. Yet, there might be currently unquantifiable long-term benefits when we consider the potential for e-scooters to serve as a permanent substitute for private vehicles. In the long-run, our client as well as a CAC Member are of the belief that e-scooters might lead to greater mode shift away from and decreased ownership levels of cars over time.[42]

B) Substitution Effect

Finding: E-scooter and e-bike trips substitute car trips more than any other mode. And among car trips, e-scooters and e-bikes most likely replace dining and work-related trips

By analyzing survey data, we find nearly half of e-scooter and e-bike trips would have otherwise been made by car (49 percent). On the other hand, 39 percent of trips made by e-scooters and e-bikes replaced walking, while 7 percent replaced personal non-electric bike and scooter trips, and 4 percent replaced public transit trips (**Figure 6**). Unfortunately, limitations in the survey data prevent us from evaluating e-scooters' potentially complementary relationship to the same

[40] Hollingsworth et al.
[41] The International Council on Clean Transportation. "Briefing, Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions". 2018. Retrieved from https://theicct.org/sites/default/files/publications/EV-life-cycle-GHG_ICCT-Briefing_09022018_vF.pdf
[42] CAC Member C interview.

extent that we quantitatively analyze their substitution effect.

We further analyzed the composition of e-scooter/e-bike trip purposes when those trips substituted ones made by car (**Figure 7**). Notably, 62 percent of dining-related and 51 percent of work-related trips made by e-scooter and e-bike are found to replace car trips. A crucial characteristic of the survey question that revealed this trend was the specificity of asking about users' *most recent trip*; the immediacy of the question limits the uncertainty of an answer a respondent may otherwise provide to a question that lacks such specificity. As a contrast, asking that same question for the previous month of trips would elicit a less insightful answer because it increases the likelihood of misremembering.[43]

Figure 6: Modes Replaced by E-scooter/E-bike Trips

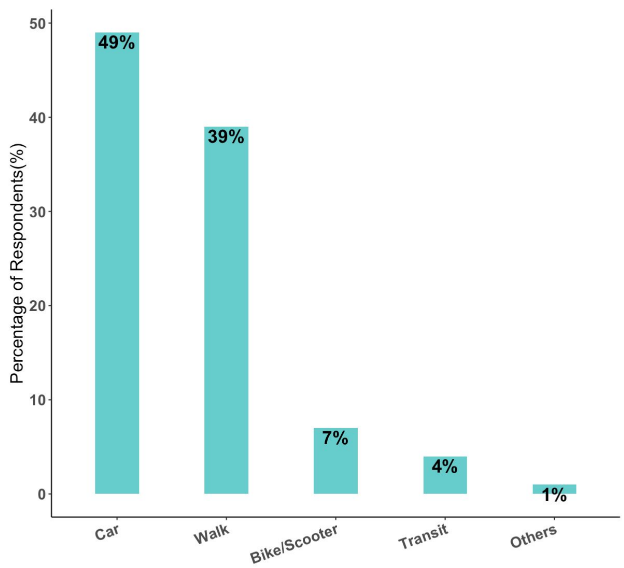
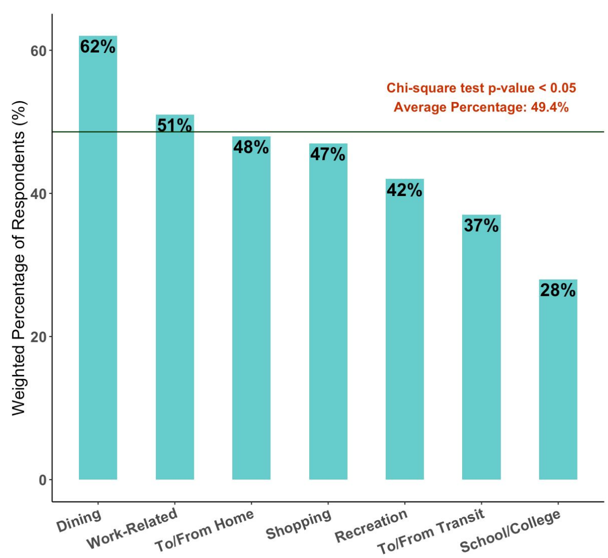


Figure 7: Car Displacement by Trip Purposes



Finding: E-scooters and e-bikes are used most frequently for school and work-related trips

In **Figure 8** below, we see the distribution of e-scooter and e-bike usage frequency. A quarter of the survey respondents are frequent users who reported using a device at least three times per week. **Figure 9** shows that nearly half of these frequent users reported using devices for work-related trips (47 percent) and almost a third for school/college trips (30 percent). Policy options targeting students and workers would likely increase e-scooter usage. Cars are very likely to be replaced by e-scooters and e-bikes particularly for work-related trips, and frequent

[43] Gilens, in-person interview with authors.

users tend to use the devices for work-related purposes. Removing barriers for these kinds of trips are an excellent area to target with policy options because they are likely to replace car trips consistently among frequent users. Therefore, there is potential for a relatively high volume of car trips to be replaced and carbon emissions to be reduced.

Figure 8: Distribution of E-scooter and E-bikes Usage Frequency

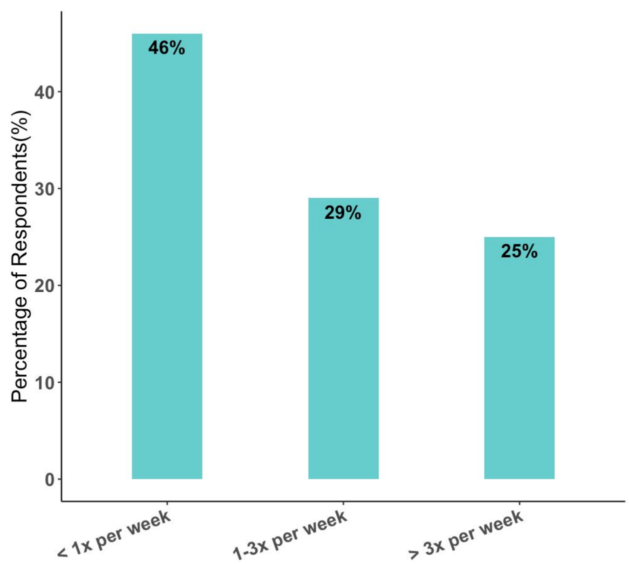
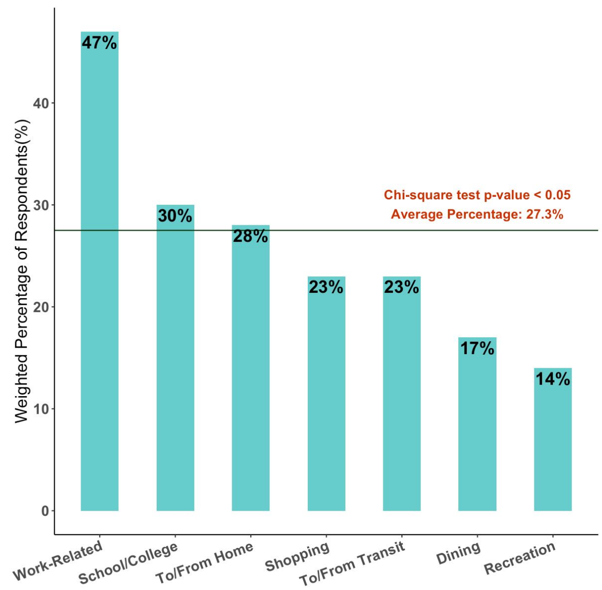


Figure 9: Trip Purposes of Frequent Users



Finding: A lack of bike lanes and the difficulty of locating devices are the two barriers most frequently reported among all users

"No bike lanes" and "difficult to locate" are the two most frequently reported barriers preventing travelers from using e-scooters and e-bikes (**Figure 10**). Although the City added approximately 19 miles of bike lanes to its approximately 130-mile network in 2019, 39 percent of e-scooter riders viewed a lack of bike lanes as the most significant barrier.[44] Our analysis shows that work-related and school/college related trips, in particular, are likely to face these two barriers (**Figure 11** & **Figure 12**). Frequent users are also more likely to report these two factors than other groups (**Figure 13** & **Figure 14**). These findings cumulatively imply that improving bicycle and e-scooter-friendly infrastructure, such as bike lanes or signage, would facilitate more

[44] Ryan Fonseca. "How Santa Monica Established Order From Scooter Chaos (And What It Can Teach LA)." LAist. November 22, 2019. Retrieved from https://laist.com/2019/11/22/santa_monica_scooter_program_mobility_future.php

use of e-scooters.

Figure 10: Reported Barriers among All Users

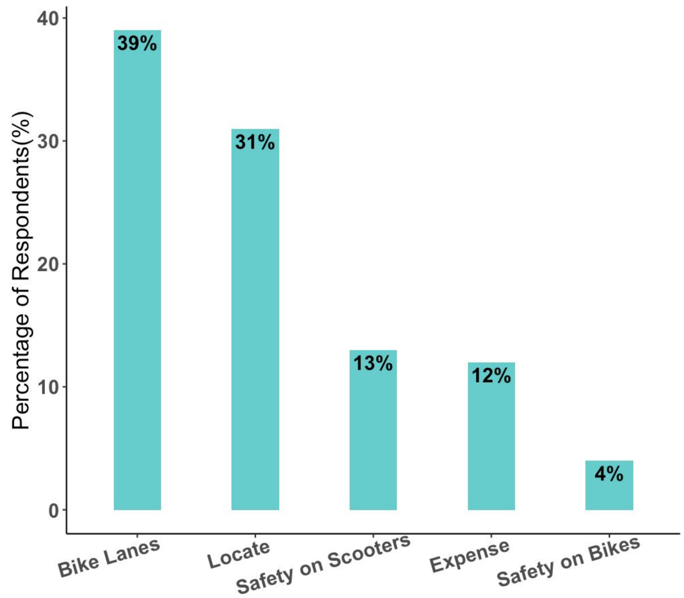


Figure 11: Reporting "No Bike Lanes" by Trip Purposes

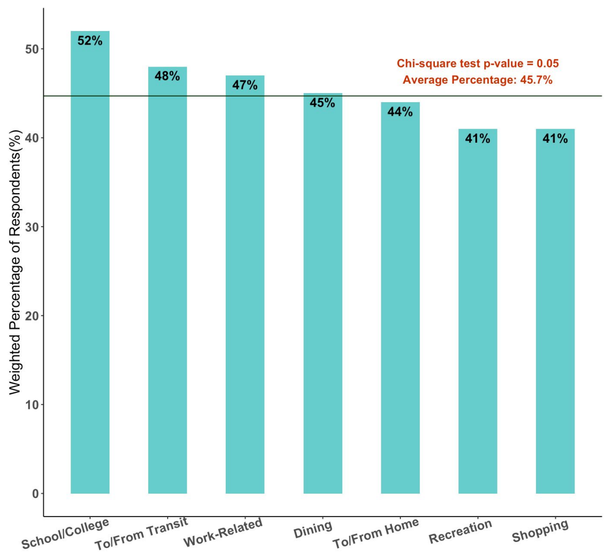


Figure 12: Reporting "Hard to Locate" by Trip Purposes

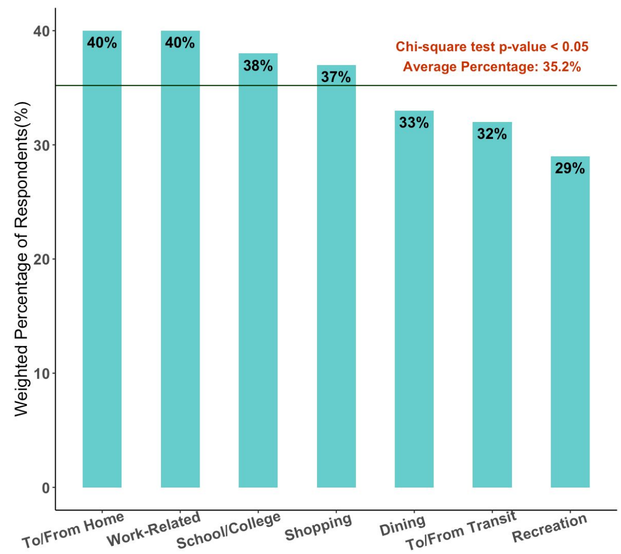


Figure 13: Reporting "No Bike Lanes" by Device Use Frequency

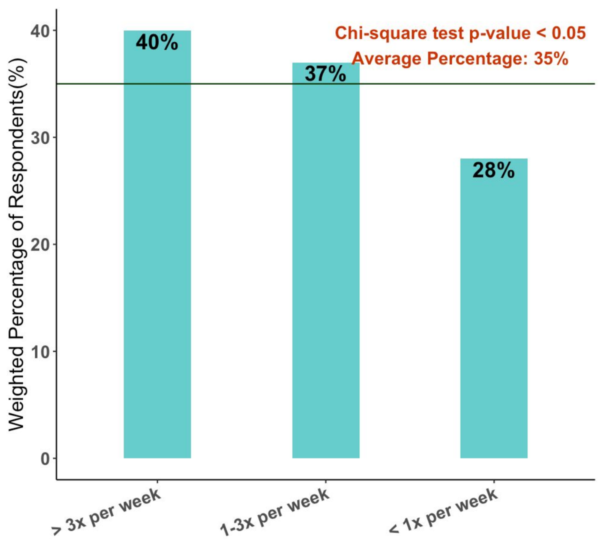
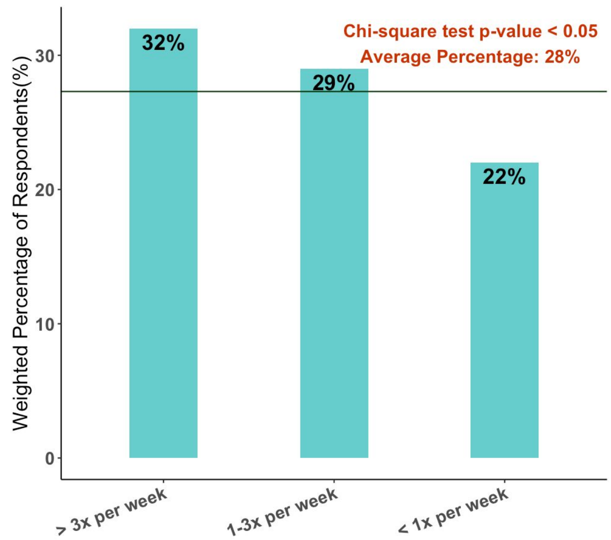


Figure 14: Reporting "Hard to Locate" by Device Use Frequency



Finding: Despite reduced fare programs, high costs were a barrier to ride among lower income groups

Individuals with an income under $50,000 are more likely to report devices being "too expensive" as a barrier to usage than individuals at higher income levels (See **Figure 15**). Notably, three of the four providers increased their fares during the pilot program.[45] As shown in **Figure 16**, the percentage of users reporting "too expensive" as a barrier increased in all lower income groups from the first user survey to the second. This trend may reflect users' responses to fare increases. The results have implications on providing policy options that help ensure equal access to, and broader adoption of, e-scooters among different income groups.

[45] Pauker.

Figure 15: Reporting "Too Expensive" Barrier by Income Groups

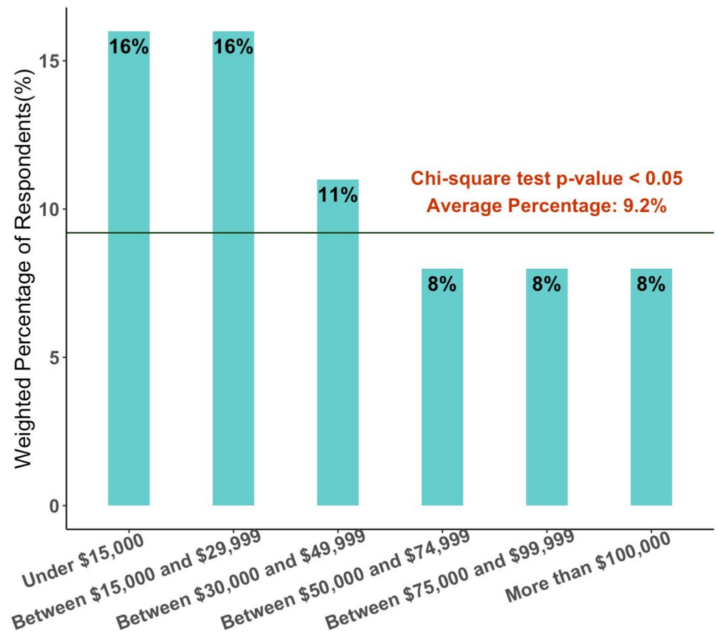
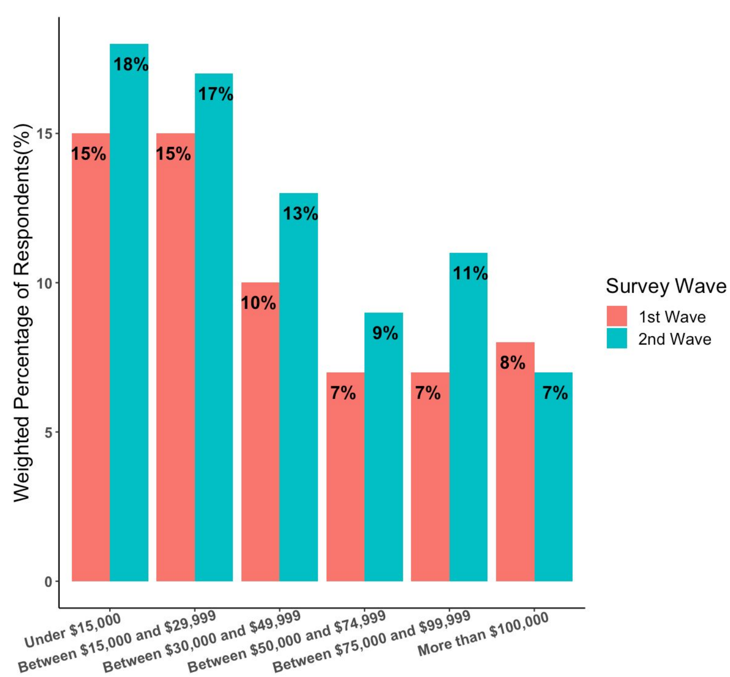


Figure 16: Reporting "Too Expensive" Barrier Change by Income Groups



Access is not facilitated evenly across diverse income groups; almost half of riders reported earning an annual income over $75,000. The City sought to address this disparity during the SMPP by requiring that providers administer low-fare programs for qualifying riders.[46] These programs reduced fares and allowed for cash payments to better accommodate low-income populations, those without access to a smartphone, and those without credit cards. However, relatively low participation levels (253 enrollments across all provider programs) reflect the need to improve the programs through more effective outreach and marketing.[47] An interview with a City official involved with the project revealed that the City was disappointed with this level of participation.[48] Though it is anecdotal, one CAC member specifically cited cost as a barrier to his own usage of the device, stating he has used them far less often since "fares had doubled".[49]

Finding: In some areas, e-scooters may be misallocated relative to their utilization

First, **Figure 17** maps the distribution of device usage by calculating each hex cell's Utilization Rate (UR) − a ratio of the number of e-scooters used compared to the number available − in the city of Santa Monica. The darker purple hex cells represent areas with higher UR, while the lighter purple cells depict areas with lower UR. Some areas with more than 90 percent UR appear to be located around commercial and office land uses. On the other hand, some areas with less than 25 percent UR tend to be located around residential areas.

Second, in **Figure 18,** we map the average deployment volume per day in each hex cell. The darker red cells have more e-scooters deployed than do the lighter color cells. In some areas, especially around downtown, there are more than one hundred e-scooters deployed on average per day. Moreover, redeployments are implemented throughout the day by providers intending to increase ridership as much as possible.[50] On the other hand, deployment levels tend to be relatively less in hex cells with more residential land use and areas east of Santa Monica College (SMC) and Bergamot Expo Stations; such areas see fewer than one device deployment on average per day.

Also, it appears hex cells with drop zones (depicted as blue dots in **Figure 18**) tend to have relatively higher levels of deployment. In addition to providers deploying in these areas, users are financially incentivized to end their trips and park devices in drop zones. The City requires

[46] Mobility Division. "Shared Mobility Pilot Program Summary Report." November 2019, 7.
[47] Ibid. 7.
[48] Anuj Gupta, phone interview with authors, February 26, 2020.
[49] CAC Member C interview.
[50] Provider A interview.
Provider B interview.

that providers inform, direct, and incentive riders to "return equipment to… drop zones."[51] These designated areas serve as a mechanism by which to not only regulate device parking, but also to more efficiently guide e-scooter and e-bike availability. The smallest zones measure 36 square feet and cost between $200 and $800 per zone, making them a low-cost investment both financially and spatially.[52] Cumulatively, this implies that more sustainable device transportation practices as well as increased e-scooter usage might be facilitated by the optimization of drop zone functionality.

Figure 17: Utilization Rate

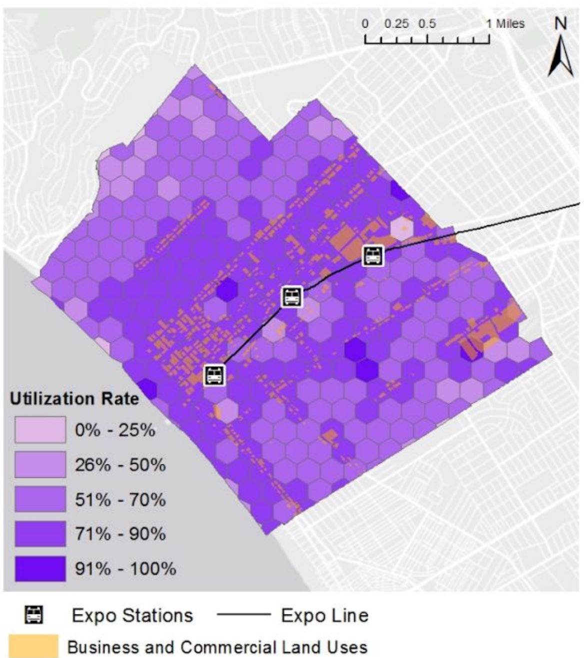
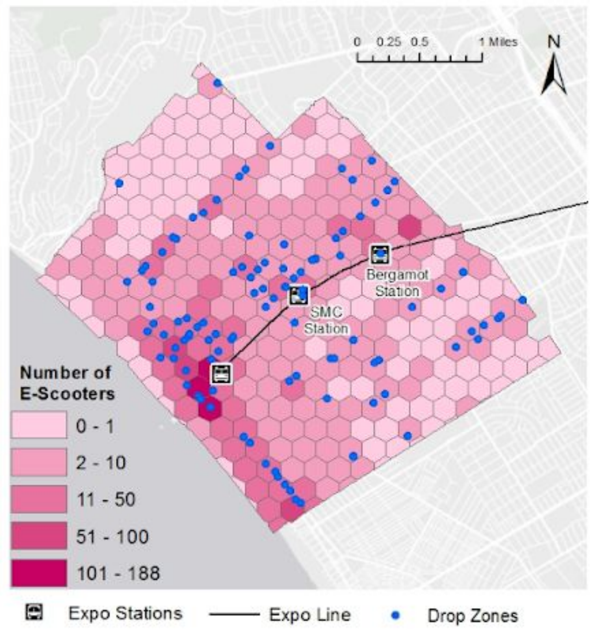


Figure 18: Deployment Volume

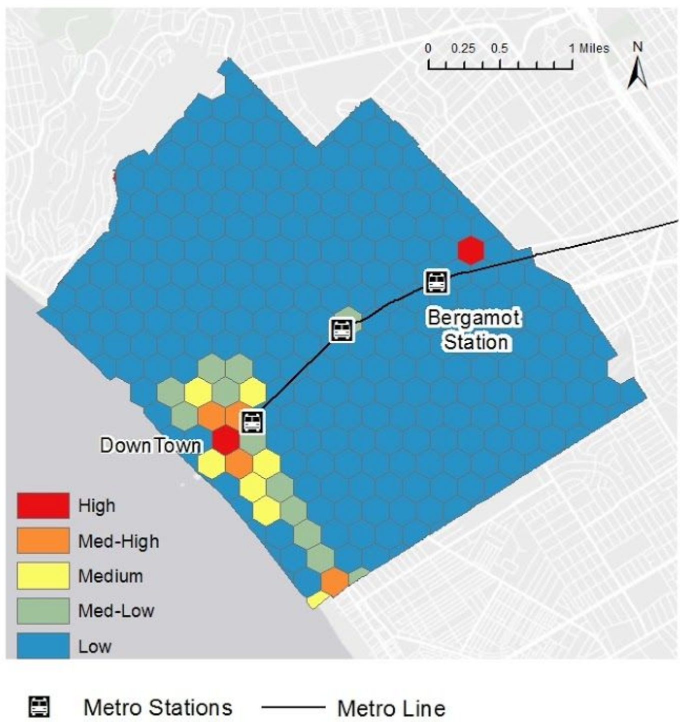


Apparently, high deployment volume seems to follow the areas of high UR when we compare **Figure 17** and **Figure 18**. However, when we map an Allocative Inefficiency Index (AI Index) − a measure of allocation compared to utilization of e-scooters in a particular area − as shown in **Figure 19**, we can identify the areas where e-scooters might be reallocated e-scooters to encourage more efficient use, even in areas with high UR. The red and orange hex cells have relatively more supply compared to the utilization in these areas than do the blue cells. Areas scoring highly on our AI Index are primarily located around downtown and Bergamot Station. However, high AI Index areas observed near Bergamot Station may be caused by misleading

[51] Santa Monica. "City of Santa Monica Shared Mobility Device Pilot Program Administrative Regulations"
[52] Linton, Joe. "Santa Monica Installs In-Street E-Scooter Parking Corrals." *Streetsblog LA.* November 8, 2018. Retrieved from https://la.streetsblog.org/2018/11/08/santa-monica-installs-in-street-e-scooter-parking-corrals/

data representing the storage of scooters after they are collected and charged at a provider's central facility.[53] That almost entirely limits the allocatively inefficient areas to just around downtown, even though the City of Santa Monica has already instituted a cap on the number of e-scooters around the downtown area.[54] So, one option for mitigating allocatively inefficient areas would be to relocate e-scooters from the downtown area where they are now deployed disproportionately more than they are utilized.

Figure 19: Allocative Inefficiency Index (AI Index)



Finding: Several areas, especially around SMC, have high First/Last-Mile usage but relatively low deployment volume

To at least partially assess the complement effect e-scooters may have on other sustainable travel modes, we analyze e-scooter trips likely to connect with public transit. Assuming that potential transit riders would be more likely to use public transportation if they could reliably connect to rail service with more e-scooters around stations, we explore apparent First/Last-Mile trips and the e-scooter deployment. In **Figure 20**, we show the distribution of demand for First/Last-Mile

[53] Provider A interview.
[54] Santa Monica. "City of Santa Monica Shared Mobility Device Pilot Program Administrative Regulations"

(FLM) trips to and from the three Expo Line Stations in Santa Monica. The darker green cells represent high FLM usage while lighter green depicts low FLM usage. In particular, the center map showing trips made to and from SMC Station indicates some areas with relatively high demand for FLM trips. Two cells to the southeast of the station show a relatively higher percentage (20.1 to 40 percent) of all e-scooter trips made were FLM trips. This index implies that the areas around Expo Line Stations facilitate higher rates of FLM trips. Simply put, the closer to a transit station, the more likely an e-scooter is used to connect with transit. On the other hand, **Figure 18** (Deployment Volume) shows that providers deploy devices at relatively lower volumes around Expo Line Stations. Therefore, to encourage more sustainable use of e-scooters as complements to public transit, Expo Line Station areas could be potential locations to which e-scooters from high AI Index areas are reallocated.

Figure 20: Demand for FLM Trips at Santa Monica's Three Expo Line Stations

For a more precise understanding, we focused on the areas around SMC that have high demand for FLM usage in **Figure 21**. Several factors related to transportation at SMC merit further attention including their high likelihood of school-related trips and their existing transportation policies. SMC prohibits the use of e-scooters on its campus primarily due to perceived safety concerns relating to the use of motorized transportation in pedestrian areas.[55]

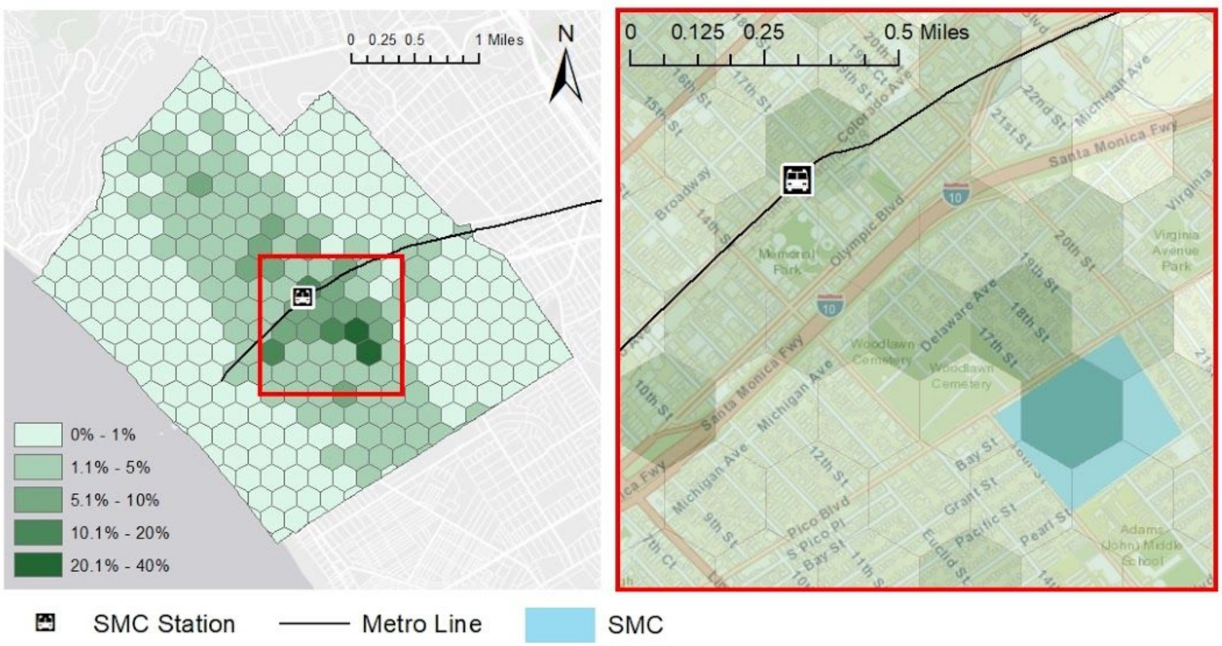
With regard to safety to and from campus, SMC's Office of Institutional Research conducted a survey of student transportation trends at SMC this past fall. It revealed half of all students felt unsafe trying to commute to campus when cycling.[56] Similar to our finding regarding e-scooter

[55] Santa Monica College. "Electric Scooter Policy." Accessed on March 17, 2020. http://www.smc.edu/StudentServices/transportation/Pages/Electric-Scooter-Policy.aspx

[56] Office of Institutional Research. "Santa Monica College 2019 Student Transportation Trends." Santa Monica

barriers, relevant SMC staff informed us that the source of students' perceived lack of safety is likely due to an absence of bike lanes on busy thoroughfares adjacent to the campus. However, a new bike lane with bollards will be implemented in the near future that would connect SMC to SMC station.[57] This would likely improve perceived safety and serve e-scooter riders as well. Thus, if e-scooters are encouraged to be used on or around the SMC campus in the future, there may be an increase in the potential demand for e-scooters as complements to transit use.

Figure 21: Demand for FLM Usage around the SMC Station



2. Estimation of Net Carbon Emission Impact of E-scooters

In this subchapter, we test whether additional e-scooter use would decrease total transportation-related carbon emissions and thus justify their increased marginal use. To do so, we develop a model that enables us to estimate the net carbon impact of an additional e-scooter use. The model incorporates the two factors that we explored in the previous sub-section: e-scooter life-cycle emissions and substitution effect. Therefore, the model also allows us to estimate how much a policy intervention affecting those two factors would influence total carbon

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College. Fall 2019. Online survey was administered to all enrolled students (not on the "do not contact" list) 10/28/2019 to 11/18/2019. Retrieved from http://www.smc.edu/ACG/InstitutionalResearch/SiteAssets/Pages/Report-Respository/Fall%202019%20Transportation%20Survey%20Results.pdf

57 SMC Transportation Staff, phone interviews with authors, March 16, 2020.

emissions caused by transportation. We further rely on this model to evaluate policy options in a later chapter.

Finding: E-scooter trips reduce CO_2 emissions *on average* even when considering substituted trips that otherwise would have been made by walking, biking, or transit

First, as we articulated in the previous section, the net carbon impact of e-scooters is influenced by A) e-scooter life-cycle emissions and B) substitution effect, and it is expressed as the difference in total emissions from transportation. With this in mind, we can make a general model to estimate the net carbon impact caused by a policy implementation (**Equation 1**). Then we reorganize the expression above to consider the case of the introduction of e-scooters in Santa Monica (**Equation 2**).

$$\begin{aligned} Net\ Carbon\ Impact &= \frac{\delta}{\delta Policy} Total\ Emissions\, from\ All\ Transportation \\ &= \frac{\delta}{\delta Policy} \sum_i Emissions_i \\ &= \frac{\delta}{\delta Policy} \sum_i (Avg\ Life\ Cycle\ Emissions_i \times Total\ Miles_i) \end{aligned} \quad \textbf{(1)}$$

**i* = transportation mode*

$$\begin{aligned} Net\ Carbon\ Impact_{Introduction} &= \frac{\delta}{\delta Policy_{Introduction}} \sum_i (Avg\ Life\ Cycle\ Emissions_i \times Total\ Miles_i) \\ &= \sum_k ((Avg\ Life\ Cycle\ Emissions_{e-scooter} - Avg\ Life\ Cycle\ Emissions_k) \\ &\qquad \times Trip\ Numbers\ Displaced_k \times Avg\ Miles\ Displaced_k) \end{aligned} \quad \textbf{(2)}$$

**k* = transportation modes other than e-scooter*

For the average life-cycle emissions of e-scooters, we use the value calibrated for the case in Santa Monica (151 gram/PMT). For the average life-cycle emissions of other transportation modes (i.e., automobiles, buses with high ridership, and bicycles), we rely on the values reported by Hollingsworth et al. As for public transit in Santa Monica, we treat its average emissions equivalent to the value of buses with high ridership. Using this value would result in a more conservative estimate because Metro Rail and Big Blue Bus service in Santa Monica have higher ridership and are relatively more efficient than assumptions used by Hollingsworth et al.[58] We

[58] Hollingsworth et al.

determined the values for the average life-cycle emissions of cars and bicycles may not need recalibration for the City of Santa Monica because the assumptions made by Hollingsworth et al are representative for general automobile and bicycle use nationwide.

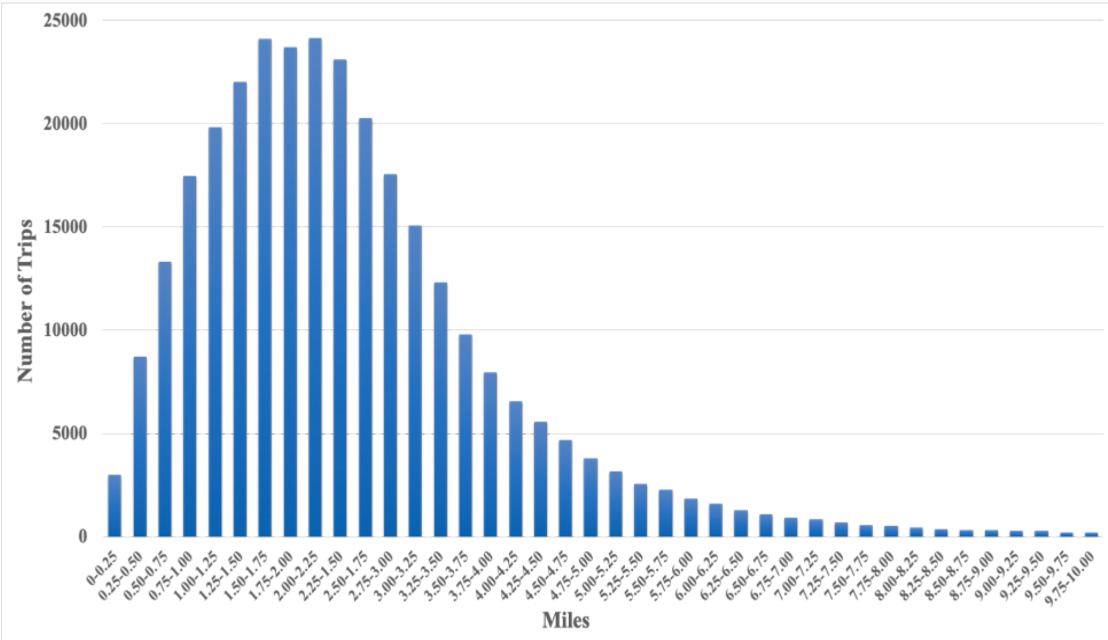
For the trip numbers of each transportation mode that are displaced by e-scooters, we use the survey data that reveals the percentages of modes replaced by shared mobility devices during the SMPP (**Figure 6** in the previous chapter). For the mode category listed by the City as "Other," we conservatively assume that there are no carbon emissions generated by "other" transportation modes (which may include skateboards, unicycles, etc.). This means there would be an increase of carbon emissions from e-scooters (151 gram/PMT) as a substitution effect for these modes that likely do not generate CO_2. Additionally, mode displacement, as described by the survey results, includes modes that are replaced by both e-scooters and e-bikes. Our calculation for average life-cycle emission focuses solely on e-scooters because the life-cycle emission of e-bikes (37 gram/PMT)[59] is lower than e-scooters. By assuming only e-scooters replace alternative modes, our calculation for net carbon impact is more conservative than if we included both e-scooters and e-bikes.

As for the average passenger-miles displaced by e-scooters per mode, we first construct a histogram displaying the distribution of e-scooter trip distances in Santa Monica by quarter-mile, based on trips recorded over a period of about 400 days (from October 25th in 2018 through December 1st in 2019) as shown below.

[59] European Cyclists' Federation, "Cycle More Often 2 Cool Down the Planet! Quantifying CO2 Savings of Cycling." January 16, 2016. Retrieved from https://ecf.com/sites/ecf.com/files/ECF_CO2_WEB.pdf.

Transportation Research and Education Center, "The E-Bike Potential: Estimating the Effect of E-Bikes on Person Miles Travelled and and Greenhouse Gas Emissions". May 2019. Retrieved from https://wsd-pfb-sparkinfluence.s3.amazonaws.com/uploads/2019/05/E-bike-Potential-Paper-05_15_19-Final.pdf

Figure 22: Distribution of E-Scooter Trip Distances in Santa Monica (based on trips recorded from 10/25/18 through 12/1/19)



Then, using the percentage of displaced trips per mode, we envision three scenarios — moderate, more conservative, and less conservative — for the average passenger-miles displaced by e-scooters per mode (**Figure 23**, **Figure 24**, and **Figure 25**, respectively). For each scenario, we allocate e-scooter trip distances proportionally to the percentage of reported displaced trips by mode. The moderate scenario assumes that the average walking trip displaced by e-scooters is the shortest distance among all transportation modes, the average biking trip is the second shortest, and the average length of car and transit trips are the same and the longest. The more conservative scenario assumes that the average distances of walking and biking trips displaced by e-scooters are the same and the shortest, while the average length of car and transit trips are the same and the longest). Lastly, the less conservative scenario assumes that the average trip distances increase proportionally from walking, bike, transit, then cars.

Figure 23: Moderate Scenarios of Trip Distances Displaced by E-scooters

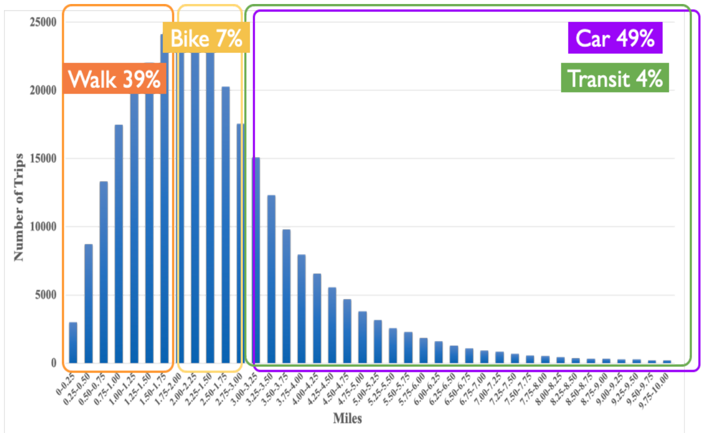


Figure 24: More Conservative Scenarios of Trip Distances Displaced by E-scooters

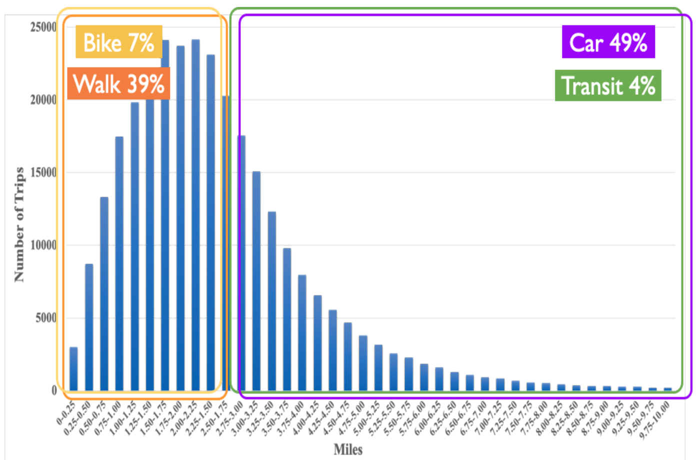
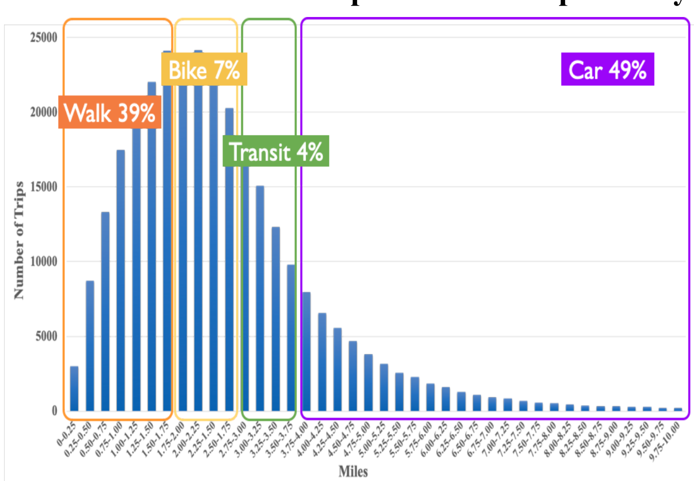


Figure 25: Less Conservative of Trip Distances Displaced by E-scooters



Based on these scenarios, we estimate, across all modes displaced, one additional e-scooter trip leads to an average decrease of about 347−367 grams of CO_2 emissions. Put simply, **marginal increases in e-scooters trips lower CO_2 emissions across even the most conservative assumptions about mode displacement**. The estimation result for each scenario is shown in **Table 2**. The results here indicate that an e-scooter is an environmentally-friendly transportation mode in Santa Monica and reduces overall emissions from transportation. In other words, facilitating the increased use of e-scooters would be justified in terms of their positive climate impact. Furthermore, taking into account the problems we identified in the previous section, we find that e-scooters' net carbon impact could be further improved through public-sector intervention that will improve e-scooter life-cycle emissions or further facilitate the substitution effect of e-scooters.

Table 2: Estimated Average Decrease of Carbon Emissions per Additional E-scooter Trip

Scenario	More Conservative	Moderate	Less Conservative
Average decrease of carbon emissions per one additional e-scooter trip (gram per passenger)	**347**	**348**	**367**

As a note about the limitation of this analysis, we are unable to determine whether e-scooters generated additional trips rather than simply replacing trips that would have been made by another travel mode because of the form of questions asked in the City's user surveys. We rely on responses to the question which asked "What mode would you have used for your last trip if not for shared e-scooter/e-bike?" to help inform our estimation of e-scooter's substitution effect. However, this question assumes and projects the rationale that all e-scooter trips *replace* other modes. E-scooters might reasonably produce a marginal increase in the total number of trips across all modes because a likely small number of trips may have been made by riders who otherwise would not have traveled at all (i.e. to try an e-scooter for the first time or for recreational travel unto itself). We are unable to gauge the validity of this concern due to qualitative data limitations. Furthermore, the same data limitation makes it difficult to evaluate the extent to which e-scooters may complement sustainable modes like bicycling and walking, and so we assume that e-scooter trips always substitute trips via other modes. In other words, we assume in our analysis that there is only a substitution effect; e-scooter trips always displace other transportation modes and there is no additional total increase in the number of trips.

3. Policy Guidelines

Lastly, we summarize the implications gathered in this section as the policy guidelines (**Table 3**). Here, we subcategorize the policy implications based on the particular levers our client would target to improve the net carbon impact. Implications related to the improvement of e-scooter life-cycle emissions are subcategorized based on whether they address 1) Collection and Deployment, 2) Charging, and 3) Device Durability. Implications related to the substitution effect are subcategorized as 4) User, 5) Device Location, and 6) Infrastructure. The guidelines within this subcategorization enable us to consider policy options based on the levers our client can use to intervene.

Table 3: Policy Guidelines

A) E-scooter Life-cycle Emissions	B) Substitution Effect
1. Collection and Deployment ● Increased miles of travel, particularly by less fuel-efficient vehicles, should be reduced	**4. User** ● Increased use by frequent user groups like students and workers should be facilitated ● More affordable service should be provided for low income groups
2. Charging ● E-scooters should be charged with cleaner energy	**5. Device Location** ● Deployment should be better aligned with areas with high First/Last-mile (FLM) usage
3. Device Durability ● E-Scooter's lifetime should be extended	**6. Infrastructure** ● Bike lanes should be added ● Locating e-scooters should be made easier

V. POLICY OPTIONS

Based on our findings, we developed twelve policy options. Our policy options are categorized based on the preceding policy guidelines (**Table 4**). First, we identify options that target processes related to device collection and deployment. Second, we identify options that address device charging practices. Third, we identify options dealing with device durability and lifetime. Fourth, we identify options that may improve per-device usage rates based on frequent user groups. Fifth, we identify options designed to optimize the distribution and location of devices throughout Santa Monica. Lastly, we identify options that involve infrastructure improvements. In this chapter, we outline and define our specific policy options. In the subsequent chapters, we will evaluate policy options according to our criteria.

Table 4: Policy Options Corresponding to Policy Guidelines

	Target	Policy Guidelines	Specific Options
E-Scooter Life-Cycle Emissions	**1. Collection & Deployment**	• Increased miles of travel, particularly by less fuel-efficient vehicles, should be reduced	1A) Use fuel-efficient or zero-emission vehicles for device transport 1B) Limit number of trips made for sole purpose of device charging 1C) Install outdoor device charging stations near high utilization areas
	2. Charging	• E-scooters should be charged with cleaner energy	2A) Ensure devices are charged within Santa Monica city limits
	3. Device Durability	• Scooter's lifetime should be extended	3A) Require the submittal of lifecycle analysis for device models 3B) Establish average device lifetime minimums
Substitution Effect	**4. User**	• Increased use by frequent user groups like students and workers should be facilitated	4A) Encourage higher education centers to promote device usage 4B) Encourage employers to promote device usage
		• More affordable service should be provided for low income groups	4C) Develop subsidies for low-income riders
	5. Device Location	• Deployment should be better aligned with areas with high first/last mile usage	5A) Incentivize redeployment of devices to areas with high utilization and high first/last-mile usage
	6. Infrastructure	• Bike lanes should be added	6A) Construct more bicycle and non-automobile infrastructure
		• Locating e-scooters should be made easier	6B) Optimize shared mobility drop zones

1. Collection and Deployment

1A: Use fuel-efficient or zero-emission vehicles for device transport

To curb emissions related to vehicles used for device collection, deployment, and rebalancing, operators would employ vehicles that generate little to no carbon emissions. Possibilities for such vehicles could include hybrid vehicles (on the higher-emitting end) or cargo bicycles/tricycles (on the lesser-emitting end). This option would address a stage in the e-scooter life-cycle that contributes to nearly half of its attributable carbon emissions.

1B: Limit number of trips made for sole purpose of device charging

Putting a cap on the number of trips that operators are allowed to make for the exclusive purpose of charging would reduce VMT for collection. This option could encourage operators to conceive of more efficient means of device collection, such as setting low battery thresholds for devices to be collected or employing only Santa Monica-based collectors.

1C: Install outdoor device charging stations near high utilization areas

The installation of permanent, outdoor device charging stations would reduce the need for operators to collect devices for the sole purpose of re-charging. The apparatus, as well as the installation process, would be similar to those used for the on-street charging of electric automotive vehicles. Stations would ideally be placed in areas of high utilization, locations where shared mobility drop zones already exist, or both. Alternatively, Santa Monica could lower costs and increase flexibility by setting up temporary charging stations. The City would supply, rent, or contract for the use of electrical generators which would then be outfitted for the charging of devices. In either case, this option would likely necessitate an incentive for users to charge the devices themselves upon completing a ride near a charging station.

2. Charging

2A: Ensure devices are charged within Santa Monica city limits

Following device collection, operators would charge e-scooters at sites within Santa Monica city limits as opposed to sites in neighboring cities. This policy would reduce emissions primarily in two ways: by increasing the likelihood that the electricity used to charge devices is 100 percent renewably sourced; and by increasing the likelihood that vehicles used to transport devices travel shorter distances to do so.

3. Device Durability

3A: Require the submittal of lifecycle analysis for device models

To better evaluate the lifetime, performance, and impact of devices provided by operators, the City would conditionally require operators to submit life-cycle analysis for devices prior to their use. This option would allow City staff to review expected outcomes and evaluate performance factors relative to device specifications.

3B: Establish average device lifetime minimums

Setting a minimum amount of time that the average device per fleet must be in use would incentivize operators to develop more durable, longer-lasting devices and prioritize more comprehensive maintenance practices. Doing so would extend device lifetimes and increase per-device environmental efficiency, as life-cycle emissions would be dispersed over a longer period of time.

4. User

4A: Encourage higher education centers to promote device usage

Local educational facilities such as SMC and the Art Institute would promote device usage through student subsidy programs and designated riding and parking areas on campuses. The City would provide funding and marketing support to education centers that implement this option.

4B: Encourage employers to promote device usage

This option would incorporate e-scooter usage into the City's comprehensive emissions reduction program for employers. Devices would be included as one of the commute options that employers must demonstrate are being used by employees in order to comply with local and regional transportation demand management regulations.

4C: Develop subsidies for low-income riders

Rather than relying solely on operators to provide subsidies or discounts, the City would fund and administer fare subsidies for low-income users. The subsidy could also be incorporated into existing low-fare programs offered for qualified users of the City's proprietary bus (Big Blue Bus) or bikeshare (Breeze Bike Share) services, thus creating a comprehensive transportation subsidy program for low-income users across a number of sustainable modes. Alternatively, the

City could offer outreach and marketing assistance to bolster existing reduced fare programs offered by providers.

5. Device Location

5A: Incentivize redeployment of devices to areas with high First/Last-Mile usage

The City would encourage providers' to redeploy devices in zones demonstrated to have proven to have high UR and high FLM usage rates. An incentive structure could be developed that encourages providers, transporters, and/or users to either redeploy or end rides in such zones. This option emphasizes individual device usage and would improve net environmental efficiency per device.

6. Infrastructure

6A: Construct more bicycle and non-automobile infrastructure

The City would construct additional bicycle infrastructure such as bike lanes, bike signalization at intersections, and/or pedestrian-only thoroughfares. Funding for such projects could be generated by levying per-device operating fees or by pursuing state and federal grants. This option would encourage usage, enhance rider safety, and prioritize travel modes that are more sustainable than driving.

6B: Optimize shared mobility drop zones

The location and number of shared mobility drop zones would be optimized if more were placed in areas with high device utilization rates. Additionally, a stronger incentive system for allocating devices to the drop zones would enhance the environmental, safety, and access benefits gained through their use.

VI. CRITERIA AND METHOD FOR EVALUATING POLICY OPTIONS

1. Definitions of Evaluative Criteria

To evaluate our twelve specific policy options, we use the following six criteria: Effectiveness, Safety, Equity, Financial Feasibility, Administrative Feasibility, and Political Feasibility. We choose to evaluate options based on their Effectiveness, Safety, and Equity to encapsulate the primary goals of our client as it administers the Shared Mobility Pilot Program and regulates providers. The criteria involving feasibility are meant to capture the real-life determinants of policy implementation by a government. For each criterion, we rank the policy option as "High," "Medium," or "Low." Rankings are decided according to a scoring rubric and our ranking decisions are informed by our interviews, empirical data, and relevant literature on the problems and potential solutions. We describe each of our evaluative criteria in more detail below.

Effectiveness

Each option's effectiveness depends on whether it would be effective at addressing our primary focus: the reduction of CO_2 emissions generated by transportation. We evaluate the effectiveness of each option by using a model that we developed in the previous chapter to estimate the net carbon impact of a specific policy intervention. Then we compare the expected average CO_2 emission reductions relative to other options to determine whether an option falls within a certain emissions reduction range. The ranges are defined as an average 0-5 percent reduction, 5-10 percent reduction, or 10 percent reduction or greater.

	Low	Medium	High
Effectiveness	Policy has an unknown or relatively lower impact on reducing CO_2 emissions, which would be in the range of less than 5 percent.	Policy has a relatively moderate impact at reducing CO_2 emissions, which would be in the range of 5 percent to 10 percent.	Policy has a relatively high impact on reducing CO_2 emissions, which would be in the range of more than 10 percent.

Safety

In proposing a set of recommendations, we consider the potential for options to impact both rider safety and general community safety. Public safety is a paramount responsibility for governments and it is particularly so in the case of Santa Monica which hopes to capture the benefits of the recently introduced and privately developed e-scooters while mitigating any associated externalities. A recent study published in Transportation Research Interdisciplinary Perspectives suggests only 1.7 percent of scooters are improperly parked.[60] Though this figure is low compared to other evaluated transportation modes, this report considers the likelihood, absent adequate consideration for and regulation of, device use could potentially lead to increases in injury rates and healthcare spending, lawsuits and litigation, and a damaged public image for the City. Relevant interviews led us to believe that actions that contributed to a reduction in PROW complaints in particular would be a useful metric in determining overall increase in safety.[61]

	Low	**Medium**	**High**
Safety	Policy jeopardizes the safety of either users or the public at large.	Policy has a neutral effect on the safety of users and the public at large.	Policy improves the safety of either users or the public at large.

Equity

In proposing a set of recommendations, we want to ensure that a proposed policy or procedure does not diminish general transportation access for any party based on characteristics such as race, age, income level, residential neighborhood, ability, or gender. To help foster equitable access and mobility across various dimensions, we evaluate our policy options based on how they may impact equity.

[60] Anne Brown, Nicholas J. Klein, Calvin Thigpen, Nicholas Williams. "Impeding access: The frequency and characteristics of improper scooter, bike, and car parking" *Transportation Research Interdisciplinary Perspectives.* March 3, 2020, as quoted in Cailin Crowe. "2 % of scooters are improperly parked: study" *SmartCitiesDive*. March 5, 2020. Retrieved from https://www.smartcitiesdive.com/news/parking-scooters-cars-city-curbsides/573521/?fbclid=IwAR2CxGLawFf1lqNAcSQrYywL6qAC21PhuZEj--QiPpkG_KqAO-a3UtueyXk

[61] Tafarai Bayne. Phone interview with authors, February 13, 2020.
Code Enforcement Manager interview.
Code Enforcement Officer interview.

	Low	Medium	High
Equity	Policy exacerbates access and mobility disparities based on demographic, socioeconomic, or geographic characteristics.	Policy has a neutral effect on access and mobility among varying populations, whether rider or non-rider.	Policy improves access and mobility disparities based on demographic, socioeconomic, or geographic characteristics.

Financial Feasibility

We analyze the financial feasibility associated with the implementation and maintenance of each policy option, including initial costs and operational costs, to either oversee or implement the option. Policy options with no or relatively lower costs are predictably more feasible than those with relatively higher projected encumbrances. Examples of costs may include funds needed for the hiring of new staff, the creation of a new administrative procedure, or the installation of new fixed infrastructure. In these examples, conventional wisdom tells us that new infrastructure investments would require significantly more capital relative to hiring new staff and would thus be categorized as having "Low" Financial Feasibility. We incorporate costs that would be incurred to anyone other than our client into political feasibility analysis. For example, if an option is costly to entities outside of the city office, such a cost may negatively impact the option's political feasibility because external groups would be less likely to support the option.

	Low	Medium	High
Financial Feasibility	Policy would encumber relatively higher costs and require substantial funding allocated from the City budget or transferred from other existing projects.	Policy would encumber relatively moderate costs and may require additional funding through federal, state, or regional grants.	Policy would encumber relatively lower costs and requires little to no funding allocated from the City budget or transferred from other existing projects.

Administrative Feasibility

Administrative feasibility depends on whether the city has the technical and administrative capacity to implement and maintain the respective option given their jurisdictional and resource constraints. Therefore, to assess administrative feasibility, we consider whether the city is currently able to implement the proposal with their current expertise, authority, and resources.

	Low	**Medium**	**High**
Administrative Feasibility	Policy requires considerable additional staff, administrative procedures, or infrastructure to implement. Policy may be beyond current technical and logistical means for the City.	Policy requires some additional staff, administrative procedures, or infrastructure, but the requirement is not extensive. Policy is within current technical and logistical means for the City.	Policy may be implemented with limited or no additional staff, administrative procedures, or infrastructure required. Policy is within current technical and logistical means for the City.

Political Feasibility

Implementing each policy option involves various stakeholders within the City who may have conflicting perspectives. For instance, it can be expected that in some cases e-scooter providers may oppose an option that the public or the City may support, and vice-versa. Demonstrating this delicate stakeholder balance, the City expressed their preference to avoid enacting too much of an "onerous policy" on providers and their business models, which might result in reduced access, service, or ridership.[62] Also, given that our client operates within a larger (i.e. federal, state, county) bureaucracy where important decisions are often constrained by political dynamics at various levels, an option's political feasibility depends on whether the City would need support from external political groups, such as environmentalist organizations, transit advocacy groups, or the public at large. Thus, political feasibility is defined as the ability to achieve buy-in from the most impactful stakeholders – providers of shared mobility, Santa Monica City Council, and community members within the City – as well as higher levels of government. When possible, we highlight the type of support each policy option requires.

[62] Kyle Kozar, phone interview with authors, February 20, 2020.

	Low	Medium	High
Political Feasibility	Policy requires authorization from multiple government entities or agencies and would likely only gain support from one or two stakeholder groups.	Policy requires authorization from a single government entity (including City Council) and would likely only gain support from several stakeholder groups.	Policy requires authorization from only City Council or the mobility Division and would likely gain support from all or nearly all stakeholder groups.

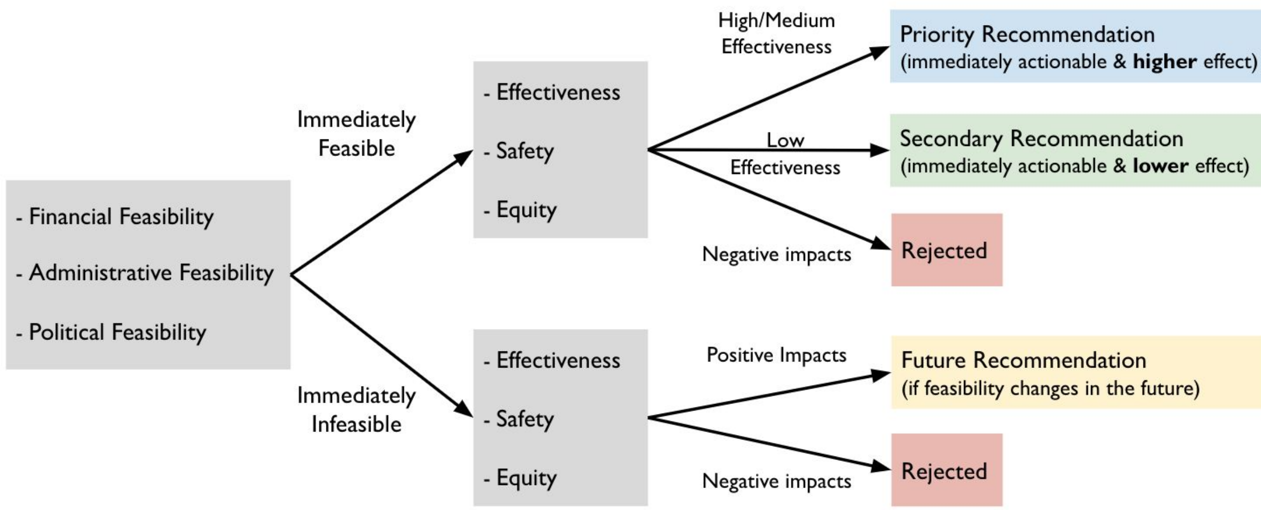
2. Methodology for Evaluating Policy Options

Our client aims to utilize e-scooters to reduce carbon emissions from the transportation sector while being considerate of the City's strategic goals to promote safety and equity, in a feasible manner. So, we take two steps to evaluate policy options, as **Figure 26** shows. First, we determine whether each policy option is immediately feasible by using three criteria: Financial Feasibility, Administrative Feasibility, and Political Feasibility. In other words, if the policy options include at least one "Low" score, we put those policy options into the "Infeasible" category where it is difficult to implement policy options immediately. Accordingly, if the policy option consists of a "High" score, we put those policy options into the "Feasible" category in which policy options would be low hanging fruit. Policy options that we evaluate as "Medium" are also deemed feasible, but they may be more difficult to implement than those consisting of a "High" score.

After that, we rank each policy option by using three criteria: Effectiveness, Equity, and Safety. In the "Feasible" category, the policy options with relatively higher Effectiveness scores are regarded as "Priority Recommendations", which means those policy options are immediately actionable, and highly effective. Also, in the "Feasible" category, the policy options with relatively lower effectiveness scores are regarded as "Secondary Recommendations". Those policy options would not necessarily be recommended with high priority because of their lower effectiveness. In mirror fashion, we reject options that may be immediately feasible if they have "Low" Safety or Equity scores because they would worsen safety and equity outcomes relative to the status quo.

As for the "Infeasible" category, if policy options score "Low" in the criterion of either Safety or Equity, we reject them for the same reasoning as above. Otherwise, policy options that may be infeasible today, but might be feasible if conditions change in the future, are regarded as "Future Recommendations."

Figure 26: Methodology for Evaluating Policy Options



VII. EVALUATION AND RECOMMENDATION OF POLICY OPTIONS

We evaluate and recommend policy options according to the aforementioned evaluative methodology. **Table 5** shows the evaluation result of every option according to three criteria: Financial Feasibility, Administrative Feasibility, and Political Feasibility. **Table 6** shows the Effectiveness, Safety, and Equity evaluation of the policy options that we regarded "Immediately Feasible," while **Table 7** shows the evaluation results of the policy options that we regarded "Immediately Infeasible".

In this section, we explore policy options that are identified as 1) Priority Recommendation (Immediately Actionable, Higher Effectiveness) and 2) Secondary Recommendation (Immediately Actionable, Lower Effectiveness). **Appendix C** shows the evaluation results and overviews of policy options that are identified as Future Recommendation (if feasibility changes in the future). **Appendix D** contains the evaluation results of "Rejected" options. **Appendix E** provides more detail about our evaluation methodology for Effectiveness.

Table 5: Evaluation Based on Feasibility Criteria

Policy Options	Feasibility Criteria			Feasible or not?
	Financial	Administrative	Political	
1A) Use fuel-efficient or zero-emission vehicles for device transport	High	High	High	**Yes**
1B) Limit number of trips made for sole purpose of device charging	High	Low	Low	**No**
1C) Install outdoor device charging stations near high utilization areas	Low	Low	High	**No**
2A) Charge devices within Santa Monica city limits	High	High	High	**Yes**
3A) Require the submittal of lifecycle analysis for device models	High	High	High	**Yes**
3B) Establish average device lifetime minimums	High	Low	Low	**No**
4A) Encourage higher education centers to promote device usage	Medium	Low	Medium	**No**
4B) Encourage employers to promote device usage	Medium	Low	High	**No**
4C) Develop subsidies for low-income riders	Low	Low	Medium	**No**
5A) Incentivize redeployment of devices to areas with high First/Last-Mile usage	High	Medium	Medium	**Yes**
6A) Construct more bicycle and non-automobile infrastructure	Low	Low	High	**No**
6B) Optimize shared mobility drop zones	High	Medium	Medium	**Yes**

Table 6: Evaluation of Policies Categorized as "Immediately Feasible"

Feasible Options	Criteria			Evaluation Results
	Effectiveness	Safety	Equity	
6B) Optimize shared mobility drop zones	High	High	High	**Priority**
1A) Use fuel-efficient or zero-emission vehicles for device transport	High	Medium	Medium	**Priority**
5A) Incentivize redeployment of devices to areas with high First/Last-Mile usage	Low	Medium	High	**Secondary**
2A) Charge devices within Santa Monica city limits	Low	Medium	Medium	**Secondary**
3A) Require the submittal of lifecycle analysis for device models	Low	Medium	Medium	**Secondary**

Table 7: Evaluation of Policies Categorized as "Immediately Infeasible"

Infeasible Options	Criteria			Evaluation Results
	Effectiveness	Safety	Equity	
6A) Construct more bicycle and non-automobile infrastructure	High	High	High	**Future**
1C) Install outdoor device charging stations near high utilization areas	High	High	Medium	**Future**
4A) Encourage higher education centers to promote device usage	Low	Medium	High	**Future**
4B) Encourage employers to promote device usage	Medium	Medium	Medium	**Future**
4C) Develop subsidies for low-income riders	Low	Medium	High	**Future**
3B) Establish average device lifetime minimums	High	Low	Medium	**Rejected**
1B) Limit number of trips made for sole purpose of device charging	Medium	Medium	Low	**Rejected**

1. Primary Recommendation (Immediately Actionable, Higher Effectiveness)

Option 6B: Optimize shared mobility drop zones

Effectiveness (High): This policy option would improve ridership among those who find e-scooters difficult to locate, as optimizing shared mobility drop zones helps mitigate this barrier. It could lead to greater improvements if these highly visible zones are placed in commercial areas where work-related trips are more likely. We estimate that it would result in a net CO_2 emissions decrease of 13.4 percent on average.

Safety (High): Drop zone optimization may help declutter the public right-of-way as well as help normalize both parking and riding behavior, thus providing safety benefits to riders and non-riders alike.

Equity (High): Optimizing drop zones to correct misallocation could improve the current geographic inequities of deployment by facilitating greater e-scooter access for areas that currently may not be adequately supplied.

Financial Feasibility (High): This option represents relatively low costs per drop zone optimized because installation is limited primarily to bollard installation, stenciling, and signage.

Administrative Feasibility (Medium): Installing new drop zones and/or further encouraging their use would not require substantial infrastructure investment or much additional staff.

Political Feasibility (Medium): This could increase equitable access and therefore gain support from the City and CAC. It would also likely generate support among users who find the difficulty of locating devices to be a barrier, but it may alienate non-users who do not wish to forfeit additional PROW space for e-scooters and e-bikes. Also, asking providers to improve their incentive structure may seem too prescriptive with regards to their business models and foment their opposition.

Overview & Implementation

Optimizing shared mobility drop zones would entail primarily three actions: increasing the total number of zones; locating new zones in areas characterized by high UR and high FLM usage; and developing a stronger incentive structure for their use by riders. Our spatial analysis demonstrates that there are areas, particularly around Expo Line Stations like SMC Station, that could benefit from higher levels of deployment. Additional areas that could be targeted include locations with a high density of commercial, retail, and educational land uses. Installing new drop zones in such locations would signal to providers that fleet deployment should be prioritized in these areas. For riders, the zones' permanent and visible presence signal device availability, which is important for helping to overcome the barrier of being "too difficult to locate."

To implement this option, the City should explore creative ways to incentivize riders' use of these zones. Providers could be asked to increase existing incentives, but we recommend instituting a penalty for riders who do not park scooters within a drop zone when they end their trip within a certain distance of that zone. Asking providers to add an improper parking fee to users' bills seems technically feasible and would more strongly discourage improper parking. To help prevent excessive levying of the fee and to ensure users have an abundance of areas to properly park, the City should increase the number of drop zones.

Another approach may be to encourage increased subsidies for users who park in the zones. Perhaps granting providers a reimbursement for a portion of in-lieu fees paid in exchange for offering greater monetary incentives to riders who park in the zones through their respective apps. Working with providers to increase rider rebates or credits might be a likely route for implementation; however, the City may also consider creating a public rewards program for users from all modes to earn credits redeemable at Santa Monica businesses, Big Blue Bus, or Breeze Bike Share.

This option may be limited by the ability to find adequate space for new zones, particularly near Downtown or in on-street locations, while still ensuring public rights-of-way and specific neighborhoods share an equitable balance of travel modes. Additional limitations include that it may further restrict the locations in which providers are allowed to deploy their fleets as well as the possibility that it may be difficult for providers to identify suitable funding sources for zone-use subsidies. Both of these limitations might discourage providers from supporting this option.

Option 1A: Use fuel-efficient or zero-emission vehicles for device transport

Effectiveness (High): This option would decrease the emission generated by vehicles used for collection and deployment. By replacing gasoline-only vehicles with plug-in hybrid or electric vehicles, we estimate that it would result in a net CO_2 emissions decrease of 22.0 percent on average.

Safety (Medium): This option would have a limited and likely negligible impact on user safety. It may increase community safety if providers opt to utilize cargo e-trikes for device transportation as this would reduce the number of private vehicles and commercial vans traveling throughout Santa Monica in search of scooters.

Equity (Medium): This option would have a limited and likely negligible impact on equity along geographic, income, and ability dimensions. Collectors working for providers that employ a gig-worker business model may be affected if they are disqualified from collecting devices because they do not own a fuel-efficient vehicle, but this impact is likely minimal.

Financial Feasibility (High): This option would not require funding for any resources, infrastructure, or administration on the part of the City. For providers, costs may increase if they choose to comply by using EV/hybrid vehicles that are more expensive than their current vehicles; however, in most cases, costs would remain the same or decrease if they use e-trikes.

Administrative Feasibility (High): This option would require minimal monitoring and enforcement on the part of the City, once fuel-efficient or zero-emission vehicles are initially demonstrated to be in operation by providers. Requiring transport fleets to be fuel-efficient could be done by incorporating it into subsequent permitting requirements.

Political Feasibility (High): This option would help align provider practices with the City's carbon-neutrality and private vehicle reduction goals, and it would likely be viewed favorably by the City Council as well as constituents, environmentalists, and safe streets advocates. Providers, however, may react adversely to enforced changes to their respective business plans.

Overview & Implementation

Using fuel-efficient or zero-emission vehicles targets a reduction in the 24 percent of emissions generated by vehicles used for device collection and deployment in Santa Monica. Some providers already employ vehicles, such as electric-assist cargo tricycles, that are recommended by this option; however, multiple providers rely on contract workers and their private vehicles to transport devices. In some cases, these private vehicles are large-capacity, emissions-intensive cars, vans, and pickup trucks. Whenever appropriate, providers would be required to rely on zero-emission transport made by e-trikes or electric vehicles which ideally are charged in Santa Monica.

To implement this option, the City could permit providers on the condition that a portion of their transport fleets consist of fuel-efficient vehicles. Furthermore, the City could offer incentives like a limited relaxation in fleet caps for providers that demonstrate their collection vehicles emit less carbon. The City could also assess the feasibility of operating its own fleet of e-trikes, which it might rent to providers to be used exclusively for device transportation. This might mitigate concerns on the part of hesitant providers as well as ensure more sustainable practices are employed, while simultaneously providing a revenue stream for the

City.

Monitoring and enforcement requirements would likely be minimal because providers would have to prove they purchased and use fuel-efficient vehicles before receiving an operating permit. Once providers prove they have made the initial transition, there is little incentive for them to “game the system” and revert to vehicles that pollute more for several reasons: marginal costs for fuel would be lower; public relations and marketing regarding sustainability would be improved; and the threat of having a permit revoked would be too great. Admittedly, this option would disproportionately impact providers who currently contract outside labor to collect and charge devices.

2. Secondary Recommendation (Immediately Actionable, Lower Effect)

Option 5A: Incentivize redeployment of devices to areas with high First/Last-Mile (FLM) usage

Effectiveness (Low): This policy option would likely encourage SMC students and employees to use e-scooters more, because they could facilitate their school or work-related trips by accessing the Expo Line more easily than before. We estimate that it would result in a net CO_2 emissions decrease of 1.0 percent on average.

Safety (Medium): Incentivizing redeployment to high FLM usage areas likely has a neutral impact on the safety of both users and the general public.

Equity (High): This option calibrates deployment where demand and supply are mismatched, increasing the accessibility of devices where they are desired. This is further a benefit to equitable policy as it would directly prioritize accessibility to public transit, which is available to populations who may be unable to afford a private vehicle.

Financial Feasibility (High): This option would likely not require any additional financial costs or staff effort beyond what the City already performs to ensure fleets are deployed in certain locations.

Administrative Feasibility (Medium): This option could be administered entirely by the Mobility Division and added as an additional requirement under the existing administrative regulations for device providers. Compliance monitoring would be performed using existing protocols regarding MDS data reporting and device location tracking, but this process would need to be ongoing.

Political Feasibility (Medium): This option would likely generate support among riders, environmentalists, and transit advocates. Providers may also be supportive if they estimate higher ridership after redeployment; however, they may react adversely to an additional fleet allocation requirement.

Overview & Implementation

Incentivizing deployment to areas with high FLM usage rates seeks to capitalize on the positive and complementary relationship between e-scooters and public transit. We observed relatively low deployment levels in areas that seem to facilitate connections between devices and nearby Expo Line Stations. Santa Monica can help administer greater transit ridership and lower average life-cycle e-scooter emissions if it promotes trips which connect these two modes.

To implement this option, the City could request or require that a portion of providers' fleets are dedicated to areas around Expo Line stations that have demonstrably high FLM usage rates. For further effectiveness and more provider flexibility, time windows could be established for these deployments to align with regular peak-hour transit use on weekdays. This would loosen restrictions on providers so that they may reallocate unused devices at other times without fear of running afoul of any requests or requirements. Similar to Policy Option 6B, the City could also position more, larger drop zones in these areas, thereby encouraging deployment and user parking in locations where FLM connections are more likely.

Option 2A: Charge devices within Santa Monica city limits

Effectiveness (Low): This option would increase the share of Santa Monica residents as collectors. We estimate that it would result in a net CO_2 emissions decrease of 4.5 percent on average. To be more conservative on our evaluation, we assess this policy as low effectiveness although a 4.5 percent decrease is the threshold value for low and medium effectiveness categorization.

Safety (Medium): As stated elsewhere, we believe safety as it relates to collectors is mostly limited to the inherent risk of travel. Limiting collection activity to within the City boundaries would both limit travel distance and limit collectors to those familiar with the transit landscape of Santa Monica. This would have a positive but negligible effect on safety.

Equity (Medium): This option would not affect rider accessibility, and, at worst, would increase trip distance collection for gig workers who live outside of Santa Monica and are more likely to connect to non-Santa Monica based charging facilities.

Financial Feasibility (High): This option would likely require hiring limited additional personnel or asking existing staff to monitor or audit MDS data to ensure provider compliance.

Administrative Feasibility (High): This option would require minimal monitoring and enforcement on the part of the City, once sites are demonstrated as being established and used by providers. Requiring devices to be charged within Santa Monica could be accomplished by incorporating it into subsequent permitting requirements.

Political Feasibility (High): This option would help align provider practices with the City's carbon-neutrality and private vehicle goals and would likely be viewed favorably by the City Council as well as constituents and environmentalists. Some providers and employed non-resident collectors may oppose this change to their business model and job security.

Overview & Implementation

Charging e-scooters and e-bikes within Santa Monica would reduce average life-cycle emissions because the City's grid is supplied by renewable, non-carbon fuel sources. Limiting charging to only sites within city limits significantly decreases the likelihood that devices are powered by electricity generated by coal, fossil fuels, or other environmentally hazardous means. Most Santa Monica businesses and residents are provided with 100 percent carbon-free energy, which means this option would be effective whether devices are charged by providers' local contract workers or paid employees. Additionally, this option naturally limits the maximum distance that can be traveled by device transporters which may result in lower total VMT associated with e-scooters and e-bikes. Despite relatively modest projected emissions reductions, we believe this option would be feasible in the short-term and align with the sustainability goals of both the City and providers.

To implement this option, the City would need to monitor or audit providers' device charging practices relatively infrequently. Monitoring can be performed using real-time and historical MDS data that displays battery percentage levels and locations of devices. Providers could be encouraged to charge devices at their respective Santa Monica properties or prioritize contract workers who provide local zip codes when registering. As incentives for provider compliance, the City might consider offering fleet cap relaxations or partial reimbursement for per-device operating fees for each device demonstrated to be consistently charged within Santa Monica.

Once charging sites are established and verified, providers have little incentive to shift the charging process outside of Santa Monica. Under this option, providers would promote their long-term environmental goals, need to purchase fewer carbon offsets, and travel shorter distances to transport devices. This option may, however, be difficult to administer considering the cross-jurisdictional nature of e-scooters and e-bikes. Also, if implemented, providers may choose to prioritize Santa Monica as a charging destination for low-battery devices in neighboring cities, leading to potentially more localized VMT.

Option 3A: Require the submittal of lifecycle analysis for device models

Effectiveness (Low): This option would provide a baseline for the City to monitor and evaluate operators in terms of device performance. Its direct impact on carbon emission is unknown so we evaluate this policy option as low effectiveness.

Safety (Medium): This option does not have a foreseeable effect on safety.

Equity (Medium): This option may impose a cost that could be passed on to the rider but we do not believe that cost to be substantial overall or for per trip cost increase.

Financial Feasibility (High): This option would likely require hiring limited additional personnel or asking existing staff to enforce and review submissions from providers. It would also require the Mobility Division to spend resources developing a submission, review, and compliance schedule for providers.

Administrative Feasibility (High): Although it would require the development of a submission and review process, this option could be administered as a requisite for operators seeking to obtain or renew a permit. The entire process would be housed within the Mobility Division, easing the administrative burden as coordination would not be required.

Political Feasibility (High): This option would likely generate support among City Council, environmentalists, and providers. One provider expressed that this would be beneficial for them as it would enhance the visibility of sustainability practices and enhance their public image.

Overview & Implementation

Although it may not directly lead to emissions reductions, both providers and the City would benefit from requiring the submission of life-cycle analyses for devices in operation. One provider that we interviewed expressed it would view such a requirement as an opportunity to effectively market the sustainability of their devices. Providers can leverage published sustainability plans to stand out among competitors and the City can more meaningfully evaluate provider and device performance. Having a benchmark for the carbon emissions that should be expected for the average device per fleet would allow Santa Monica to assess providers on the basis of whether or not their devices meet environmental and durability expectations.

To implement this option, the City could withhold operating permits for providers that do not provide Life-Cycle Analysis (LCA) alongside their application submission. Alternatively, the City could offer incentives to providers who submit LCAs and whose fleets prove to perform as documented. This approach may also encourage providers to market their devices to Santa Monica staff and the public more realistically. As providers upgrade and deploy new fleets, they should submit an accompanying LCA to the Mobility Division.

VIII. CONCLUSION

The City of Santa Monica aims to achieve carbon neutrality by 2050 through various means, including the promotion of e-scooter usage. Despite their stated goal to displace private automobile trips with e-scooter trips, shared mobility devices themselves are not inherently environmentally sustainable. Their environmental impact is based primarily on factors relating to their average life-cycle emissions and their substitution effect relative to other travel modes. This report provides guidance to the Mobility Division of the Planning and Community Development Department of the City of Santa Monica on methods for creating policies that will mitigate environmental concerns related to e-scooters and will help reduce carbon emissions attributable to the City's transportation sector.

Based on the findings from our literature review and interviews with over a dozen stakeholders and experts, we established a qualitative framework for evaluating and recommending policy options. Furthermore, the quantitative analysis we conducted demonstrated the statistical and spatial rationale behind our recommendations for improving e-scooter sustainability in Santa Monica. We developed specific policy options seeking to optimize devices' environmental impact while being considerate of the City's strategic goals to promote safety and equity. It is our hope that the additional organization of policy options into six distinct categories will help the Mobility Division target areas of inefficiency and unsustainability as it finds appropriate.

We crafted and evaluated a set of specific policy options so that we may provide actionable recommendations to our client in both the short and long term. Although the Mobility Division has full discretion to rely on or to deviate from our specific recommendations, the options constitute careful considerations for the methods in which our client might achieve its environmental and transportation-related goals through the promotion of e-scooter usage in Santa Monica. For these reasons, we recommend a set of policy options that we believe could be immediately actionable and highly effective, a set that could be immediately actionable but relatively less effective, and a set that could be actionable and effective if feasibility were to change in the future.

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APPENDICES

Appendix A: Interview Guides

Name	Associated Entity & Role	Mode	Date
CAC Member A	CAC Member	Phone	Dec. 2, 2019
CAC Member B	CAC Member	In-Person	Dec. 3, 2019
Provider A	-	Phone	Dec. 5, 2019
Provider B	-	Phone	Dec. 11, 2019
CAC Member C	CAC Member	Phone	Jan. 6, 2019
Martin Gilens, Ph.D	Department Chair of Public Policy at UCLA Luskin, research focus, among other topics, on public opinion, representation and public policy	In-Person	Feb. 6, 2020
Code Enforcement Officer	Santa Monica Code Enforcement Officer	Phone	Feb. 13, 2020
Tafarai Bayne	CicLAvia Chief Strategist. Los Angeles Transportation Commission member	Phone	Feb. 13, 2020
Kyle Kozar	Santa Monica's Bike Coordinator at the Mobility Division of Santa Monica's Planning and Community Development.	Phone & In-Person	Feb. 18, 2020
Mikhail Chester, Ph.D	Arizona State University Associate Professor of Civil, Environmental, & Sustainable Engineering, and School of Sustainable Engineering & the Built Environment	In-Person	Feb. 24, 2020
Code Enforcement Manager	Santa Monica's Code Enforcement Manager	Phone	Feb. 25, 2020
Anuj Gupta	Santa Monica's Deputy City Manager and Policy Director	Phone	Feb. 26, 2020
Juan Matute	UCLA Institute of Transportation Studies Deputy Director	In-Person	Feb. 27, 2020

Sam Dean	Technology Reporter at the LA Times	Phone	Mar. 3, 2020
SMC Staffer	Santa Monica College Transportation	Phone	March 16, 2020

Interview Guide for Client & Public Agency Staff interviews

Purpose: Most interviews of individuals who worked for, or were directly associated with, the City of Santa Monica had three goals: to further inform the context of the pilot program, to help formulate an evaluative criteria definition, and to provide direct input on policy options with regard to their relevant criteria.

Pre-Interview: Contact for interview through email. We described ourselves, the focus of our project, our project status, and the purpose of speaking with them. Interviewees in this category were directed to us by our client, and we therefore referenced who referred us to the interviewee. If our client introduced us to the interviewee via email instead, this introduction was given in the interview.

Interview: If the interview was over the phone, notes were taken in real-time. If not, notes were taken typically immediately after to transcribe contemporaneous mental notes and hand-written notes. After introduction, the interview had the following goals:

1. If we felt we were missing context necessary to address our policy question that was not captured through literature review or quantitative analysis, we began there.
2. If that not be the case, we moved directly to evaluative criteria
    - 2.1. How would they define their evaluative criteria?
    - 2.2. Response to our articulation of assessing evaluative criteria.
3. End interview with request to review policy options, and note any they particularly agreed or disagreed with, and an open question to speak to any area the interview questions may have missed.

Post-Interview: Typed contemporaneous notes on the interview, typically the same day. Send policy option draft to interviewee.

Interview Guide for Provider interviews

Purpose: Gain overview, to the possible extent shared, of the business model of these providers, and ascertain the goals of providers in the area.

Pre-Interview: Contact for interview through email. Like other interview guides, we described ourselves, the focus of our project, our project status, and the purpose of speaking with them.

Interviewees in this category were directed to us by our client, and we therefore referenced who referred us to the interviewee. If our client introduced us to the interviewee via email instead, this introduction was given in the interview.

Interview: For both interviews, we were able to transcribe notes as they occurred in real-time, not immediately afterwards. After introduction, the interview had the following goal:

1. For both providers, we inquired about, model durability, collection & deployment procedure, and usage behavior.

Post-Interview: Typed contemporaneous notes on the interview, typically the same day.

Interview Guide for Community Advisory Committee members

Purpose: Interviews with the Community Advisory Committee were conducted earlier on, as we were interested in community input as it related to the political motivation to reign in these e-scooters. These interviews focused on user and Provider behavior, and the role of e-scooters in the Santa Monica transit environment.

Pre-Interview: Contact for interview made through email. Like other interview guides, we described ourselves, the focus of our project, our project status, and the purpose of speaking with them. Interviewees in this category were directed to us by our client, and we therefore referenced who referred us to the interviewee. If our client introduced us to the interviewee via email instead, this introduction was given in the interview.

Interview: For all of these interviews, we were able to transcribe notes as they occurred in real-time, not immediately afterwards. After an introduction, the interview had the following goals:

1. How they entered the CAC
2. Inciting issues for the program to review
3. CAC member relationship to e-scooters and e-bikes
4. Role of e-scooters and e-bikes in the Santa Monica transportation space
5. Numeric ranking questions on e-scooters and e-bikes and the pilot
6. Outlook on the role of e-scooters and e-bikes in the Santa Monica transportation space.

Post-Interview: Typed contemporaneous notes on the interview, typically the same day.

Interview Guide for Topic-Specific Interviews

Purpose: These interviews sought to qualitatively address a specific focus of our report, or the interviewee was uniquely qualified to speak to many areas at once. In either event, the interview in this case sought to inform the reports of problem identification, findings or evaluation in a qualitative sense.

Pre-Interview: These interviews were sourced on our own research, and interview requests were made via a “cold” email request. A brief introduction of who we were, our project purpose, stage in report and why we were contacting them was made. Attached were appointment calendar links that interviewees were able to select from.

Interview: The interview goals sought to gain further context in this field with regard to their expertise, inform our evaluative criteria definition, and how we articulated our evaluative approach along the respective criteria. Questions were specified to reflect their individual expertise and project needs at the time relative to those goals.

Post-Interview: Typed contemporaneous notes on the interview, typically the same day.

Appendix B: Calculation to Obtain Average Life-cycle Emissions of E-Scooter in Santa Monica

The research by Hollingsworth et al. served as the basis for our baseline understanding of e-scooters' average life-cycle CO_2 emissions (see **Equation A** and **Table A**). It was conducted in the city of Raleigh, North Carolina.[63] Although this scholarship was taken to be generally representative for most U.S. cities in which e-scooters operated, we deemed it necessary to re-calibrate emissions estimates for the City of Santa Monica. To do so, we attempted to account for differences in the nature of vehicle trips made for device transportation (i.e., collection and redeployment). Our calibration accounted for the differences in area, density and congestion between Raleigh and Santa Monica by using population density and congested roadway travel speed multipliers in our emissions estimation as shown in **Equation B**. Through this calibration, we found that the average life-cycle CO_2 emission is 151 gram/PMT.

$$I = \frac{M + T + \sum_{0}^{d} MPS_d \times EF_{auto} + \sum_{0}^{d}\sum_{0}^{i} E_{grid,\,i,\,d} \times EF_{grid,\,i,\,d}}{\sum_{0}^{d} D_d} \qquad \textbf{(A)}^{64}$$

Table A: Description of Parameters

Parameter	Description
I	average life-cycle CO_2 emission of e-scooters (gram/PMT)
M	emissions related to materials and manufacturing (kq-eq/scooter)
T	emissions related to transporting devices from manufacturing countries overseas (kq-eq/scooter)
MPS_d	auto-miles travelled per day per scooter for collection and distribution (auto-miles/scooter-day)
EF_{auto}	emission factor of vehicles used for collection (kq-eq/auto-mile)
$E_{grid,i,d}$	electricity used for charging (MWh/scooter)
$EF_{grid,i,d}$	emission factor of energy used for charging scooters (kq-eq/MWh)
D_d	distance travelled by scooter per day (miles/scooter-day)[65]
d	scooter lifetime (day)

[63] Ibid.
[64] Formula retrieved from Hollingsworth et al., 2019.
[65] Ibid.

$$I = \frac{M + T + Population\ Density\ Ratio \times Travel\ Speed\ Ratio \times \sum_{0}^{d} MPS_d \times EF_{auto} + \sum_{0}^{d}\sum_{0}^{i} E_{grid,i,d} \times EF_{grid,i,d}}{\sum_{0}^{d} D_d} \quad \textbf{(B)}$$

We assume that areas with higher population density would have lower vehicle miles travelled for collection and deployment of e-scooters. Raleigh (roughly 145 mi^2) is a relatively sparse city with a population density of 3,211 persons per square mile while Santa Monica (roughly 8.5 mi^2) has a population density of 10,996 persons per square mile.[66] We thus use **Equation C** to calculate the population density ratio as a weight to adjust MPS_d.

$$Population\ Density\ Ratio = \frac{Population\ Density_{Raleigh}}{Population\ Density_{Santa\ Monica}} \quad \textbf{(C)}$$

Also, we assume that more traffic congestion would lead to more carbon emissions from vehicles collecting and deploying e-scooters. According to a study on the relationship of traffic congestion and greenhouse gases, we would expect to see more CO_2 emissions per mile with lower average speed of vehicles under the stop-and-go pattern of traffic. [67] We use the Inner City Last Mile Speed (MPH)[68] of Los Angeles to approximate that of Santa Monica, and compare it to the Inner City Last Mile Speed of Raleigh. We thus use **Equation D** to calculate the travel speed ratio as a weight to adjust EF_{auto}.

$$Travel\ Speed\ Ratio = \frac{Inner\ City\ Last\ Mile\ Speed_{Raleigh}}{Inner\ City\ Last\ Mile\ Speed_{Los\ Angeles}} \quad \textbf{(D)}$$

[66] Governing, "Population Density for U.S. Cities Statistics," Retrieved from https://www.governing.com/gov-data/population-density-land-area-cities-map.html

[67] Matthew Barth and Boriboonsomsin Kanok. "Traffic Congestion and Greenhouse Gases." *ACCESS Magazine*. Fall 2009. Retrieved from http://www.accessmagazine.org/fall-2009/traffic-congestion-greenhouse-gases/

[68] Inner City Last-Mile Speed refers to the speed at which a driver can expect to travel one mile into the central business district during peak hours.

Inrix. "Inrix 2019 Global Traffic Scorecard." Accessed on March 17, 2020. Retrieved from https://inrix.com/scorecard/

Appendix C: Future Recommendation (If feasibility changes in the future)

Option 6A: Construct more bicycle and non-automobile infrastructure

Effectiveness (High): This policy option would benefit users who see an absence of bike lanes as a barrier to riding. Constructing additional bike lanes and complementary infrastructure would mitigate this barrier. We estimate that it would result in a net CO_2 emissions decrease of 13.4 percent on average.

Safety (High): Implementing such infrastructure represents a direct benefit with regard to safety, and that benefit is shared among both e-scooter users and non-users.

Equity (High): Easing access to transportation modes that are less cost-intensive than private or ride-hail automotive use represents a considerable net benefit with regard to equity.

Financial Feasibility (Low): Although a portion of funding for such infrastructure may be obtained through grants and revenue generated by public right-of-way fees on permitted operators, the costs for the City will still be relatively high. Costs would include contracting labor, conducting impact studies, and constructing the physical infrastructure. Financial feasibility could be more favorable in the future if specific grants and suitable funding sources are identified and captured.

Administrative Feasibility (Low): Despite the City's demonstrated success of recently implementing significant non-automobile infrastructure projects, this option would require significant coordination with multiple City departments.

Political Feasibility (High): This option would likely generate support among providers, cyclists, pedestrians, and environmentalists. Some motorists may oppose repurposing of traffic or parking lanes for non-automobile modes, but potential opposition would likely be limited and depend on the location and extent of bicycle infrastructure installed. Depending on the efficacy of the recently installed bike lanes, City Council may also be increasingly supportive of more complete street infrastructure.

Overview & Implementation

Constructing more infrastructure that favors non-automobile modes, such as bike lanes, helps alleviate carbon emissions by removing a significant barrier for riders. We infer that users and non-users may find e-scooters more approachable if streetspaces were made safer for non-auto travel modes. Not all improvements need to be as capital-intensive or wide-ranging as the installation of bike lanes. Bicycle signalization at intersections and wayfinding efforts, such as directional signage for non-automobile travelers, may prove to be more cost-effective solutions at particular locations. Much like pedestrian signals at crosswalks, bicycle signalization enhances safety for cyclists by designating times for them to cross intersections and by visually informing drivers to expect cyclist traffic. The benefits of bicycle signalization readily extend beyond just cyclists to device users, skateboarders, and others traveling by more efficient means than private automobiles. This option would improve device ridership and has the potential to shift travel to more sustainable modes like walking and biking.

To implement this option, the City would need to identify funding sources for street improvements as well as coordinate among various departments for evaluation and construction. Although it may be relatively infeasible in the short term due to potentially high administrative and financial costs, the process could be eased by the City's extensive experience in constructing bicycle infrastructure as well as enhanced stakeholder involvement. Santa Monica recently finished installing nearly twenty miles of bike lanes, demonstrating its commitment and ability to re-orient streets in favor of cyclists, pedestrians, and scooter uses. Existing device fees are already earmarked for sidewalk and street improvements, but persuading providers that they stand to benefit from improved ridership as a result of scooter-friendly infrastructure improvements may lead to increased willingness to contribute financially towards that end.

Option 1C: Install outdoor device charging stations near high utilization areas

Effectiveness (High): This option would increase the share of users who charge on their own by e-scooters, decrease the share of collections conducted by vehicles, and encourage using 100 percent renewable energy in Santa Monica. We estimate that it would result in a net CO_2 emissions decrease of 15.0 percent on average.

Safety (High): Concentrating trip completions at a predetermined location would reduce the number of trip completions that could potentially violate PROW, as well as reduce the volume of erroneous PROW-related Government Outreach Requests ("GO Requests"), allowing for more time to be dedicated to genuine GO Requests.

Equity (Medium): The equitable dimension of this option rests on the spatial relationship of installed stations to areas that are both residential and high FLM usage. As an example, if these charging stations are concentrated in the Downtown area and commercial corridors, this option would correspondingly be scored with a “Low” grade.

Financial Feasibility (Low): Costs will vary depending on whether stations would be installed permanently or temporarily. However, in both cases a relatively significant amount of resources and infrastructure investments would need to be made to install charging stations.

Administrative Feasibility (Low): If installed permanently, this option would require significant coordination among, and approval from, various City departments, utility companies, and device providers. If installed temporarily using portable generators, these bureaucratic procedures would be eased. However, a user incentive structure would need to be developed.

Political Feasibility (High): This option would align well with the City’s goals per its Climate Action Adaption Program (CAAP). If positioned at drop zones, this option may also reduce sidewalk clutter and encourage efficient use of sidewalk space. It would also be favorable to providers as their costs would be reduced and they would employ less labor for device collection and charging.

Overview & Implementation

We found that the electricity used to charge e-scooters and e-bikes can contribute to life-cycle carbon emissions to a marginal, but avoidable, degree; 6.0 percent of emissions are related to energy production. Furthermore, our interviews and literature review revealed that Santa Monica offers its businesses and residents completely carbon-free energy through its grid.

Installing and relying on strategically positioned charging stations would reduce overall CO_2 emissions by helping eliminate device transportation trips and by shifting a portion of devices charged to Santa Monica’s renewable energy grid. Incentivizing riders to charge devices themselves at these stations could also help consolidate e-scooters and e-bikes at high-utilization areas in a manner that declutters sidewalks. Similar to the previously recommended policy option, installing standalone device charging stations might represent relatively high financial and administrative costs.

To implement this option, the City could either invest in physical hardware and infrastructure or seek more low-cost means of providing charging stations. In addition to being infeasible due to high costs in the near future, constructing a permanent physical apparatus also reduces flexibility for the City should geographic demand patterns change. For these reasons, we recommend renting, contracting, or purchasing temporary charging equipment that could be set up on City land in areas with high-utilization.

Option 4A: Encourage higher education centers to promote device usage

Effectiveness (Low): This policy option would allow SMC students to use e-scooters more, because they can access the school by using e-scooters within the campus. We estimate that it would result in a net CO_2 emissions decrease of 0.5 percent on average.

Safety (Medium): This would primarily affect Santa Monica College (SMC), which has bike infrastructure and two-lane streets.

Equity (High): Presenting a more affordable option for those currently driving alone or using ride-hailing to commute to SMC may present a substantive benefit with regard to equity.

Financial Feasibility (Medium): Costs for this option vary depending on which body incentivizes scooter use: the City, schools, or the providers. The City could encourage providers and schools to collaborate on student subsidy and awareness programs, perhaps by offering providers fleet cap easements and providing user safety expertise and materials to schools.

Administrative Feasibility (Low): This policy would require staff time and procedures to be developed for either subsidies, marketing, or both.

Political Feasibility (Medium): This option would require coordination among the Mobility Division and the various higher education facilities in Santa Monica. Further coordination would be required if student subsidies were to be offered and administered by providers. Students and young riders may support this, but SMC may be opposed on safety grounds.

Overview & Implementation

School-related trips constitute 30 percent of the trips that are made by frequent users, defined as those who ride e-scooters and e-bikes more than three times a week. Encouraging higher education centers like SMC to capitalize on this relationship would help improve transportation options among students. Although this option may not be immediately feasible and is only marginally effective, it would help to solidify the positive FLM trends we observe between SMC and its corresponding Expo Line Station. Maintaining high FLM usage in this area presumably bolsters transit ridership and eases transit connections for students attending this higher education center.

To implement this option, the City could partner with education centers to ask that providers offer student discount rates when users register with their school-issued email address. An existing program already provides SMC students with discounts on the City's Breeze Bike Share network. Private sector providers might be encouraged to participate by negotiating greater levels of deployment near higher education centers, where they are more likely to attract frequent riders. Alternatively, Santa Monica or schools might directly provide subsidies for students who opt to ride devices instead of driving alone. At a higher level, advocating that the South Coast Air Quality Management District (AQMD) include e-scooters and e-bikes among its menu of favorable commute options might prove a heavier political lift, but would pay dividends for students and employees throughout the City and region.

Option 4B: Encourage employers to promote device usage

Effectiveness (Medium): This policy option would likely allow employees in Santa Monica to use more, because they can access the workplace easier than before. We estimate that it would result in a net CO_2 emissions decrease of 5.1 percent on average.

Safety (Medium): Per interview, increased ridership would translate to increased safety risk, whether that be by PROW violation or ridership behavior, but would be offset by appropriate adjustments to compliance and enforcement, as well as exposure to user educational outreach efforts by providers.

Equity (Medium): Theoretically, this would ease transportation-cost burdens by easing accessibility to an alternative to ride-hailing or easing the first-last mile barrier to public transit for those commuting.

Financial Feasibility (Medium): This option would likely require hiring additional personnel or asking current staff to perform additional duties relating to studying the impact of devices on private vehicle commutes.

Administrative Feasibility (Low): This option would likely require coordination among various City departments as well as the South Coast AQMD. This is especially true if devices were to be included among the menu of options for businesses to comply with employee commute reduction plans, in which case revised compliance procedures would need to be written.

Political Feasibility (High): This option would likely generate support among City Council, employers, and providers. Employers would benefit from having another means for their workers and customers to access their business and nearby amenities.

Overview & Implementation

This recommendation is based on similar logic as the preceding option and faces similar difficulties with regard to its immediate feasibility, but it augurs a greater reduction in carbon emissions. More than half of work-related e-scooter and e-bike trips replaced auto trips and frequent users ride for work-related purposes 46.9 percent of the time. Policies targeting workers who ride in Santa Monica would help sustain and promote this trend, resulting in lower overall carbon emissions.

To implement this option, the City would advocate that the South Coast AQMD include e-scooters and e-bikes among its menu of travel options for employers seeking to comply with local and regional commute regulations. Again, this task may be less politically feasible, however, if achieved, it may promote e-scooter use further, help reduce SOV commute trips, and reduce carbon emissions locally and regionally. If the South Coast AQMD were to include e-scooters and e-bikes as an alternative commute option for employers, the City should incorporate devices into its employee commute options as well.

Perhaps a simpler, but less effective, method for implementation may be for the City to solicit local businesses that may desire greater device deployment near their worksites. Employers who view devices favorably and are located in areas of high utilization may help facilitate the positive relationships upon which this option seeks to capitalize. Placing drop zones in these locations or connecting these employers with providers would help improve transportation options for local employees.

Option 4C: Develop subsidies for low-income riders

Effectiveness (Low): This policy option would assist lower-income people whose greatest barrier to e-scooter use is cost. We estimate that the corresponding increase in trips would result in a net CO_2 emissions decrease of 3.0 percent on average.

Safety (Medium): Per interview, increased ridership would translate to increased safety risk, whether that be by PROW violation or Ridership behavior, but would be offset by appropriate adjustments to compliance and enforcement, as well as exposure to user educational outreach efforts by providers.

Equity (High): This option would facilitate greater access to devices for lower-income populations. This could have a more positive impact on low-income riders who do not own or cannot afford private vehicles or other modes of transportation.

Financial Feasibility (Low): This option would entail relatively high costs as the City would need to find or allocate funding as well as effectively market the program. The costs could be mitigated by developing a comprehensive Santa Monica transportation subsidy which accommodates and generates ridership on Big Blue Bus and Breeze Bike Share.

Administrative Feasibility (Low): This option would require either budgetary approval and allocation from City Council or grant funding from a state or federal source. It would also necessitate additional staff to administer and oversee the subsidy program.

Political Feasibility (Medium): This option would likely generate support from low-income users, advocacy organizations, and providers; however, the City Council may be reluctant to provide funding before proving the efficacy of providers' existing low-fare subsidy programs.

Overview & Implementation

Unsurprisingly, we found that lower-income groups were more likely than relatively higher income-earners to view costs as a barrier to riding. Increasing fares over the course of the SMPP seems to have compounded this trend as the percentage of those earning less than $30,000 reporting cost as a barrier increased from just below 15 percent to 17.5 percent between the two survey periods. Developing stronger subsidies for lower-income riders would help remove this barrier, thereby increasing ridership and reducing CO_2 emissions. Importantly, this option represents a significant step towards the City's strategic goal of providing equitable transportation access for its residents.

To implement this option, the City could develop and fund a program that directly subsidizes lower-income riders. This strategy might prove expensive and cumbersome to administer; hence this option's low financial and administrative feasibility. An alternative might be to leverage existing low-income fare programs offered by providers. The City might help providers identify and successfully reach this segment of the rider population by providing marketing, demographic, and programmatic support. Similar to their "Take the Friendly Road" e-scooter safety campaign, the City might opt to launch a marketing campaign designed to increase enrollment in provider subsidy programs.

Appendix D: Evaluation Result of Rejected Policy Options

Option 1B: Limit number of trips made for sole purpose of device charging

Effectiveness (Medium): This option would decrease the total carbon emissions by 11 percent for incentivizing operators to set the battery threshold for charging to 50 percent. By encouraging operators to hire more Santa Monica-based collectors, this option would further decrease a net CO_2 emissions by 4.5 percent on average.

Safety (Medium): We are not aware of safety related issues related to the act of collection itself. We assume that less trips would probably have some reduction in collisions inherent to the act of travel itself, though this is probabilistic and would have a negligible measurable outcome.

Equity (Low): Capping the number of trips would act as a constraint on provider fleet maximizing potential, and incentivize the concentration of device deployment. While this would have a neutral or at least indirect effect as it relates to accessibility by income, it would affect accessibility in a spatial sense, impacting residents of areas where high utilization is occurring.

Financial Feasibility (High): A cap would not generate revenue, but there is no cost to the city, and therefore no concern of cost-recovery.

Administrative Feasibility (Low): MDS is currently not precise enough to infer collection by given collector, hindering ensuring compliance.

Political Feasibility (Low): CAC is likely to be indifferent given rider-centric motivations. This would additionally impose a specific ordering of the business model on providers, which has received pushback.

Option 3B: Establish average device lifetime minimums

Effectiveness (High): This option would have a direct impact on device lifetimes with setting a 1.5 years to 2 years threshold, we would expect to see an average 20.5 percent decrease in net CO_2 emissions impact.

Safety (Low): The primary changes to device construction this team is aware of relates to increased device weight, and we are not aware of a substantial change in safety related to it.

Equity (Medium): This option may impose a cost that could be passed onto the rider but we do not believe that cost to be substantial overall or for per trip cost increase.

Financial Feasibility (High): This option would likely require hiring limited additional personnel or asking existing staff to monitor or audit MDS data to ensure provider compliance.

Administrative Feasibility (Low): Although this option would be technically feasible, Mobility Division staff expressed that it would be fairly difficult to track devices that travel in and out of its jurisdiction. This could be eased by establishing agreements and administrative procedures with neighboring cities to track devices and ensure device lifetime minimums are met.

Political Feasibility (Low): This option could generate both support and opposition based on how providers choose to meet the minimum requirements. Users and providers may ultimately be supportive if device durability is improved to meet this requirement; however, if devices are still allowed to operate despite “wear and tear” it may cause safety concerns.

Appendix E: Detail of Evaluation for Criterion of Effectiveness

We evaluate the effectiveness of each option by using a model developed in chapter IV to estimate the net carbon impact of a specific policy intervention (see **Equation 1**, reproduced below as **Equation E)**. In this appendix, we explore the evaluation method for 1) the policy options that improve average life-cycle emissions of e-scooters (i.e., Option 1A through Option 3B), which affect "Avg Life Cycle Emission$_{e\text{-}scooter}$" in the model and 2) the policy options that encourage substitution from other transportation modes to e-scooters (i.e., Option 4A through Option 6B), which affect "Total Miles$_i$" in the model).

$$\begin{aligned} Net\ Carbon\ Impact &= \frac{\delta}{\delta Policy} Total\ Emissions\ from\ All\ Transportation \\ &= \frac{\delta}{\delta Policy} \sum_i Emissions_i \\ &= \frac{\delta}{\delta Policy} \sum_i (Avg\ Life\ Cycle\ Emissions_i \times Total\ Miles_i) \end{aligned} \qquad \textbf{(E)}$$

**i = transportation mode*

1) Effectiveness of policy options that affect e-scooter life-cycle emissions

To estimate the net impact of each policy option on the average life-cycle CO_2 emission of e-scooters, we used the formula of the average life-cycle CO_2 emissions calibrated for the city of Santa Monica (see **Equation B** and **Table A** in **Appendix B**). As each policy option would affect one or some of the parameter(s) in the formula, estimating changes in the parameter(s) allows us to approximate the average life-cycle CO_2 emissions of e-scooters after policy implementation. Then, by applying the estimated value of e-scooter average life-cycle CO_2 emissions to the model in **Equation E**, we can calculate the net impact of each policy on total carbon emissions. Note that we used the data obtained during SMPP for the trip numbers of each transportation mode displaced by e-scooters, and the moderate scenario developed in chapter IV for the average miles displaced by e-scooters per mode. Evaluation results for each option affecting average life-cycle emissions are as follows.

<u>Option 1A: Use fuel-efficient or zero-emission vehicles for device transport</u>

Parameters affected: $\boldsymbol{EF_{auto}}$

Assumptions: (1) gasoline-only (381 gram/mile) vehicles are used for all collection and deployment before policy intervention; (2) plug-in hybrid electric (177 gram/mile) and battery electric (95 gram/mile) are used with the implementation of this policy option.[69]

Results: We expect to see a 20 percent to 22 percent decrease in average life-cycle CO_2 emission and a 21 percent to 23 percent decrease in net carbon emissions impact.

Option 1B: Limit number of trips made for sole purpose of device charging

Parameters affected: $\boldsymbol{MPS_d}$ and $\boldsymbol{EF_{grid,i,d}}$

Assumptions: (1) Setting the battery level for charging to 50 percent would decrease the average life-cycle CO_2 emissions by 19 percent (Hollingsworth et al., 2019). (2) Encouraging operators to employ more Santa Monica-based collectors would lead to less distance travelled to collect devices and more collectors charging devices with 100 percent renewable energy in Santa Monica. (3) The ratio of Santa Monica-based collectors is from 40 percent to 100 percent, and the difference in distance travelled to collect devices between, within, and outside of Santa Monica is 3 percent.

Results: We expect to see a 2 percent to 6 percent decrease in average life-cycle CO_2 emission and a 2 percent to 11 percent decrease in net carbon emissions impact.

Option 1C: Install outdoor device charging stations near high utilization areas

Parameters affected: $\boldsymbol{MPS_d}$, $\boldsymbol{EF_{auto}}$, and $\boldsymbol{EF_{grid,i,d}}$

Assumptions: (1) this policy option would encourage users to charge devices on their own but a certain number of collectors would still be seen in the short term. (2) the ratio of charging by users is from 40 percent to 100 percent.

Results: We expect to see a 8 percent to 21 percent decrease in average life-cycle CO_2 emission and a 9 percent to 22 percent decrease in net carbon emissions impact.

Option 2A: Ensure devices are charged within Santa Monica city limits

Parameters affected: $\boldsymbol{MPS_d}$ and $\boldsymbol{EF_{grid,i,d}}$

[69] Vehicle specific emission data are retrieved from https://evtool.ucsusa.org/.

Assumptions: (1) This policy option would encourage operators to employ Santa Monica-based collectors but a certain number of collectors from outside Santa Monica would still be seen in the short term. (2) The ratio of charging by users is from 40 percent to 100 percent.

Results: We expect to see a 2 percent to 6 percent decrease in average life-cycle CO_2 emission and a 2 percent to 7 percent decrease in net carbon emissions impact.

Option 3A: Require the submittal of lifecycle analysis for device models

Parameters affected: ***d***

Results: This option only provides a baseline for the City to monitor and evaluate operators. Therefore, we cannot estimate its specific impact on average life-cycle emissions.

Option 3B: Establish average device lifetime minimums

Parameters affected: ***d***

Assumptions: (1) By increasing device lifetimes to 2 years, we would expect to see a 30 percent decrease in average life-cycle CO_2 emissions.[70] (2) There is a linear relationship between device lifetimes and average life-cycle CO_2 emission. (3) Lifetime minimum is set to 1.5 through 2 years.

Results: We expect to see a 8 percent to 30 percent decrease in average life-cycle CO_2 emission and a 9 percent to 32 percent decrease in net carbon emissions impact.

2) Effectiveness of policy options that affect substitution effect

To estimate the net impact of each policy option on the substitution effect from other transportation modes to e-scooters, we assumed the scope of potential users that each option would affect, based on their characteristics (travel behavior, socioeconomic status, etc). Furthermore, as a means of conducting sensitivity analysis, we apply the range of 5 percent to 30 percent to the identified scope of potential users to estimate those who are actually affected by each option. Also, we assumed that the percentage of displaced trips per mode and the average miles displaced by e-scooters per mode are both unaffected by each policy option (in other words, only the trip numbers displaced by e-scooters per mode are affected by each policy

[70] Hollingsworth et al.

option). Evaluation results for each option affecting the substitution effect e-scooters exert on other transportation modes are as follows.

Option 4A: Encourage higher education centers to promote device usage

This policy option would facilitate more e-scooter use among SMC students. By using the survey data, which shows that students accounted for 3.0 percent of all e-scooter use during the SMPP, we estimate that e-scooter trips that displace other modes would increase by 0.2 percent to 0.9 percent. As a result, we expect to see a 0.2 percent to 0.9 percent decrease in net carbon emissions impact.

Option 4B: Encourage employers to promote device usage

This policy option would facilitate more e-scooter use among employees in Santa Monica. By using the survey data, which shows that those employees accounted for 29.0 percent of all e-scooter use during the SMPP, we estimate that e-scooter trips that displace other modes would increase by 1.5 percent to 8.7 percent. As a result, we expect to see a 1.5 percent to 8.7 percent decrease in net carbon emissions impact.

Option 4C: Develop subsidies for low-income riders

This policy option would assist lower-income people whose primary barrier to e-scooter use is high cost. By using the survey data, which shows that those lower-income people accounted for 17.0 percent of all e-scooter use during the SMPP, we estimate that e-scooter trips that displace other modes would increase by 0.9 percent to 5.1 percent. As a result, we expect to see a 0.9 percent to 5.1percent decrease in net carbon emissions impact.

Option 5A: Incentivize redeployment of devices to areas with high First/Last-Mile (FLM) usage

This policy option would likely encourage more SMC students and more employees to use e-scooters. By using the survey data, which shows that SMC students and employees accounted for 5.9 percent of all e-scooter use during the SMPP, we estimate that the e-scooter trips that displace other modes would increase by 0.3 percent to 1.8 percent. As a result, we expect to see a 0.3 percent to 1.8 percent decrease in net carbon emissions impact.

Option 6A: Construct more bicycle and non-automobile infrastructure

This policy option would benefit users who see an absence of bike lanes as a barrier to riding. The substitution effect would be greater if bike lanes are installed in business and commercial district areas, where dining, shopping, recreation, and work-related trips are likely to occur. By using the survey data, which shows that users reporting these trip purposes accounted for 76.6 percent of all e-scooter usage during the SMPP, we estimate that e-scooter trips that displace other modes would increase by 3.8 percent to 23.0 percent. As a result, we expect to see a 3.8 percent to 23.0 percent decrease in net carbon emissions impact.

Option 6B: Optimize shared mobility drop zones

This policy option would improve ridership among those who find e-scooters difficult to locate. The substitution effect would be greater if these drop zones were placed in business and commercial district areas, where dining, shopping, recreation, and work-related trips are likely to occur. By using the survey data, which shows that these users accounted for 76.6 percent of all e-scooter usage during the SMPP, we estimate that e-scooter trips that displace other modes would increase by 3.8 percent to 23.0 percent. As a result, we expect to see a 3.8percent to 23.0 percent decrease in net carbon emissions impact.