Safe *Walk*ways

For the right of people to walk in safety

The Impact of

The Motorized Scooter Rental Industry

On the Carbon Footprint of San Diego

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FEBUARY 12th. 2019

ABOUT THE AUTHORS

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Dewey Szemenyei has a Bachelor of Science degree from Harvey Mudd College and began his career with Union Oil as a Research Chemist developing industrial lubricants. He has extensive experience in the fuels, lubricants, and related chemical additives business.

He retired from Afton Chemical where he held the position of Asia Pacific Region Technical Director, prior to which at Afton he served as North American Technical Services Manager for Engine Oils and as North American Marketing Manager for Engine Oils.

Prior to Afton Chemical Dewey served as Technical Director, Lubricants Research for Cognis Corporation where he managed product development in the area of synthetic and biodegradable lubricants for commercial and industrial lubrication. He also held roles at Pennzoil -Quaker State ranging from Product Manager to Research Director and worked with virtually every fuel, lubricant, and petroleum product.

Dewey was very active in the Society of Automotive Engineers. He chaired the Engine Lubrication committee for more than five years where he coordinated efforts among oil companies, automobile, truck, and railroad engine manufacturers, petroleum additive companies, and consultants to promulgate new engine oil standards designed to enable new engine technologies, provide longer oil change intervals, improve fuel economy, and reduce emissions.

Dewey has numerous patents.

He lives in San Diego, California has two daughters.

JONATHAN FREEMAN

Born and raised in the UK, Jonathan Freeman graduated with an honors degree in Economics from Manchester University. He intended to move to the USA and pursue graduate studies, when his father died unexpectedly and his life took a different direction. Instead, he ran the family's business and became involved in local politics.

He returned to academia to obtain Masters and Doctoral degrees, and, as a Professor of Marketing, taught graduate courses at Warwick Business School, where his academic interests included firm survival in new industries and the emergence of dominant designs.

He has received awards from the Wharton School, University of Pennsylvania, the Economic and Social Research Council in the UK, as well as an Outstanding MBA Teacher Award from the University of Warwick.

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Both authors are members of Safe *Walk*ways, a group of residents of San Diego who seek to protect and promote the right of people to walk in safety.

Our thanks to Prof. Yuche Chen, Assistant Professor, Department of Civil and Environmental Engineering, University of South Carolina, for comments on an earlier version of this paper.

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ABSTRACT

Motorized scooter rental companies claim that their vehicles reduce carbon dioxide emissions thereby helping the City of San Diego achieve its Climate Action plan goals, which are to significantly reduce the carbon emissions of the city as a whole. However these claims depend on the assumption that “the same trips (had) been made by the average car”, thus that one mile traveled by scooter is equivalent to one mile travelled by car, and the scooter rental industry does not emit significantly.

The goal of the authors is to assess the impact of the motorized scooter rental industry on San Diego’s carbon footprint and to thus determine whether the scooter industry is reducing carbon emissions in the city and if so by how much. We use secondary data, some recently published by the Portland Bureau of Transportation, regarding scooter usage and transportation replacement, other from federal sources, conservatively applied to a robust methodology.

Our estimates indicate that there is no basis to support a claim that the motorized scooter rental industry reduces CO_2e in San Diego. Instead, the results indicate that San Diego’s dockless motorized scooter rental industry increases emissions and thus is increasing pollution in the city, not reducing it.

The factors creating this effect are:

- USAGE: A low proportion of scooters are used to replace passenger vehicles.
- ZERO-EMISSIONS REPLACEMENT: Much scooter use replaces zero emissions alternatives like walking rather than carbon emitting automobiles.
  These two factors alone mean that, in terms of emissions, one mile travelled by a rented scooter replaces only <u>one sixth of a mile</u> travelled by car.
- FRAGILITY: The short lifespan of scooters leads to frequent replacement resulting in a large number needing to be manufactured.
- CARBON-EMITTING SUPPORT SERVICING: The current system to service e-scooters, including recharging them, relies on CO_2 emitting vehicles.

Our analysis examines these factors to consider possible policy directions that could improve the CO_2e emissions of the industry and indicates that the following would help reduce the pollution created by the scooter rental industry:

- Increase the replacement of Last-Mile automobile usage.
- Increase the lifespan of scooters.
- Replace the current collection/distribution system of charging with solar powered stations.

The analysis explained in this paper involved the development of a flexible analytical framework, the adoption of a conservative approach and the inclusion of qualitative and quantitative data, some only recently published.

BACKGROUND

Motorized rental scooters were introduced to the San Diego market in February, 2018 and their number has grown since. The rental companies have promoted their vehicles as a convenient form of transportation for short trips in San Diego's Downtown and Beach communities. Some have claimed that their vehicles reduce carbon dioxide emissions because they are electric and use relatively little energy to transport a rider. For example, in September 2018, Bird stated to the City of San Diego's Public Safety and Livable Neighborhoods committee that in their first 230 days of operation, users had travelled a total of 2,488,613 miles resulting a reduction in carbon dioxide emissions of 2,216,528 pounds, "had the same trips been made by the average car", and, on their website, they state "Powered by electricity, Bird scooters help reduce pollution and improve air quality".[1] Are such claims true?

Some studies have simply assumed that one mile travelled on a motorized rental vehicle replaces one mile driven by car. Most likely, this is not a correct assumption. But how much vehicle driving does a mile of e-scooter driving really replace?

For example, the analysis done by Bird to derive the claims made above appears to have been based on the following assumptions:

1. The motorized rental vehicle is perfectly green, emitting zero carbon dioxide.
2. 1 mile of scooter travel leads to the elimination of 1 mile of automobile driving.
3. The automobile contains no passengers other than the driver.
4. Automobiles consume fuel at a rate of 22 miles/gallon, the US national average as stated by The Bureau of Transportation Statistics
5. Carbon footprint analyses are extremely complex and challenging for an innovative, new corporation to carry out.

As we shall show, the first three of those assumptions are incorrect. Other investigators have found the analysis required to be complex because:

- The market is in a strong growth phase that can result in highly variable results over time.
- The sources of the energy used to produce electricity used to recharge the rental vehicles must be determined.
- The method by which scooters are collected, recharged and repositioned is highly variable, making it difficult to generate the data needed to calculate the carbon emissions associated with this process.

While there is complexity and uncertainty to be dealt with in calculating any carbon footprint[2], ignoring both and adopting a simplistic approach instead can be misleading.

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[1] https://www.bird.co/impact/; viewed January 21st., 2019

[2] https://www.theguardian.com/environment/blog/2010/jun/04/carbon-footprint-definition

METHODOLOGY

This report examines the impact of the motorized scooter rental industry currently operating in San Diego, (for brevity we henceforth call this just “the industry”), on the carbon dioxide emissions of the city of San Diego. It is a work in progress designed to initiate an effort to better understand the impact of the industry on carbon dioxide emissions. In doing so it helps policy-makers identify data that should be collected and compiled to improve the validity of any future analysis. It consolidates the information currently available to make the most accurate assessment of how much the industry has changed the carbon footprint of San Diego.

The comprehensive analysis that accompanies this report enables the reader to both understand how different aspects of the industry contribute to its carbon emissions as well as provides flexibility to quickly calculate the impact of updates to the data used, or changes to assumptions made.

In the following analysis, given the small number of motorized rental bikes available over the past year, our analysis focuses on motorized scooters. However the approach taken can be easily applied to examine the motorized rental bike industry, something we shall examine in a further report.

We selected the Xiaomi M365 scooter as typical, as, based on information derived from maintenance operatives, a local scooter removal company and secondary research over the past year, that model and equivalent designs, (e.g. the E2), have been the primary type of scooters in use in San Diego in terms of weight and durability, variables of significance to our analysis.

Our analysis uses the following process.

1. Estimate the fraction of e-scooter rides that replace existing trips taken by alternative transportation modes, e.g. cars, public transit, ride-share vehicles, walking etc. To do so we first estimate the proportion of scooter usage that provides transportation utility as against usage that provides amusement, entertainment and other non-transportation utility. After allowing for non-transportation utility, we then examine the alternative transportation modes that scooter use replaces and estimate the equivalencies of those modes used for transportation with the use of an average carbon-emitting automobile to calculate the overall equivalency of one mile travelled by scooter as against the alternatives that replaces.

2. Calculate the carbon footprint/mile for e-scooters and the various modes of transportation which scooters replace over the extent of that mode’s lifespan including:

    - Manufacture
    - Operating
    - Servicing

We do this by summing the carbon emissions in each of those stages of manufacture of an automobile and make a similar calculation for scooters.

3. Calculate the net carbon footprint impact. The net carbon dioxide impact of e-scooters is determined by calculating the difference between the carbon dioxide created by scooters and the carbon dioxide their use eliminates and subtracting the emissions per mile equivalent of scooters from the estimate of the emissions per mile from the alternatives that scooter users would have used if scooters were not available. From that we derive the impact of the industry on the carbon footprint of San Diego.

4. Using that data we then estimate the annual impact of the industry on the City of San Diego's Climate Action Plan goals.

5. Finally, we examine how various changes that might occur in the industry could improve the industry's impact on the city's carbon footprint.

DATA

Because dockless motorized scooters are new, usage data is not widely available. However, in 2018 the Bureau of Transportation of the City of Portland, Oregon, conducted a study of dockless motorized scooters as part of a pilot program which included a survey of shared e-scooter users in cooperation with three scooter companies, Bird, Lime, and Skip, the first two of which also operate in San Deigo. Both the survey[3] and the findings of the study[4] are available publicly online. The scope of the program included:

- Duration 120 days: July 23 to November 15, 2018
- 2,043 scooters
- 700,369 trips
- 801,888 rides

Users were surveyed for qualitative and quantitative information regarding their scooter use habits and we use this secondary data to estimate how many miles of scooter riding might replace a mile of transportation by other modes.

The PBOT study attempted to address whether scooters make a contribution to the City of Portland's emissions goals and although it described e-scooters as "efficient, active, low-emission vehicles", (p.11), it also noted some significant limitations faced by the researchers:

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[3] https://www.portlandoregon.gov/transportation/article/700916?utm_medium=email&utm_source=govdelivery

[4] https://www.portlandoregon.gov/transportation/article/709719

"…it is important to note three key limitations to this analysis. First, whether survey respondents would behave in accordance with what they stated in the survey is unknown. Second, without occupancy data on the number of shared Uber and Lyft rides (i.e., two or more riders), we assumed that 10 percent of those rides would have been shared and 90 percent would have been single rides. **Third, we simply do not have the data necessary to account for the emissions associated with e-scooter companies' business models. This includes data about emissions associated with e-scooter companies' supply chains, manufacturing processes, charging and deployment operations, frequency of scooter replacement, their waste stream, or more.** Without these data**, it seems reasonable to assume that if those emissions were accounted for, then they could potentially reduce or eliminate the greenhouse gas benefits modeled above.** Understanding more about e-scooter-related emissions would also help evaluate the climate impact of e-scooter trips replacing walking and personal bicycling trips (42%) as reported in the user survey. Clearly, more data are needed to determine whether or how e-scooters contribute to Portland's adopted policy goals of reducing air pollution, including climate pollution."[5] (Emphasis added)

In essence then, the PBOT study lacked sufficient data to come to a conclusion about the carbon emissions impact of the scooter industry on the carbon footprint of Portland. However, our analysis considers elements missing from the Portland Study, except that associated with waste/disposal and draws on other secondary data from established federal and industry sources.

IS IT REASONABLE TO APPLY DATA FROM A STUDY CONDUCTED IN PORTLAND TO SAN DIEGO?

We believe that the Cities of Portland, OR, and San Diego, CA, are sufficiently similar that the data gathered about scooter use in one may reasonably be applied in the other. Examining some pertinent statistics suggests in fact that doing so adds yet a further element of conservatism to our analysis.

TABLE 1. COMPARISON OF PORTLAND AND SAN DIEGO		
ELEMENT	PORTLAND	SAN DIEGO
Population	0.6m	1.4m
Ave. length of rides	1.15mi	1.3 mi
Overnight tourist trips per million population	14.33	25
Areas Scooters Used	Downtown	Downtown & Beach Communities

[5] https://www.portlandoregon.gov/transportation/article/709719. (P28).

Pilot Scheme?	Yes	No
Numbers capped at?	2,043	No cap

The average length of rides in both cities are similar and, in both, scooters are used in Downtown areas. In San Diego, the other location where scooters are heavily used are the beach communities, (e.g. Pacific Beach), which are popular with tourists. San Diego has a significantly larger per capita tourist industry. Given this, applying the usage statistics from the Portland study to San Diego introduces a significant element of conservatism into our estimation of the industry's impact on the carbon footprint of San Diego, both because tourists use scooters for amusement to a greater extent and replace carbon emitting alternatives to a lesser extent, than local commuters.

As we examine next, the usage patterns of scooters in any city affect the calculation of the industry's carbon footprint impact on that city.

ESTIMATE THE FRACTION OF E-SCOOTER RIDES THAT REPLACE EXISTING TRIPS TAKEN BY ALTERNATIVE TRANSPORTATION MODES

HOW E-SCOOTERS ARE USED

Our interest is to determine the NET carbon impact of the scooter industry in San Diego. To understand this we must understand to what extent scooters are used for purposes that replace other modes of transport, and to what extent scooters are used for purposes that have no effect on replacing the use of other forms of transport. This is implicit in the claims made by scooter companies such as Bird, where the simplistic assumption is made that one mile of scooter travel replaces one mile of travel by car. This implies that traveling by a scooter always replaces traveling by car and is not, for instance, undertaken for fun, amusement, or entertainment.

The PBOT survey provides data that shows that 55.3% of scooter rides were taken for the purpose of transportation and 44.7% for fun and recreation. In the table below we present that data slightly re-arranged to indicate usages classified as having a transportation utility (TU), versus a Non-Transportation utility, (NTU), the third column

Table 2. What are the top three trip types for which you use shared e-scooters?

To or from work	TU	18.35	19.31
To or from a Bus/MAX/Streetcar	TU	5.69	5.99
To or from school	TU	2.09	2.20
To or from a restraurant	TU	11.09	11.67
Shopping or errands	TU	9.61	10.11
To or from work-related meeting/appointment	TU	5.72	6.02
Social/entertainment	NTU	13.85	14.58
Get exercise	NTU	0.46	0.48
For fun/recreation	NTU	28.16	29.64
Transportation Utility Total		52.55	55.30
Non-Transportation Utility Total		42.47	44.70

Only the primary selection was used in the calculation
Original survey results do not sum to 100% since respondents could select multiple answers
TU = Transportation Utility, NTU = Not Transportation Utility

showing the original percentage data, which does not sum to 100% and the fourth showing the data normalized to sum to 100%. This shows that, in contrast to the claims made by Bird, rather than 100% of scooter rides replacing transportation and zero being for non-transportation uses, in fact, 55.3% of scooter rides replace transportation and 44.7% are new rides that people take because the presence of scooters entices people to ride them.

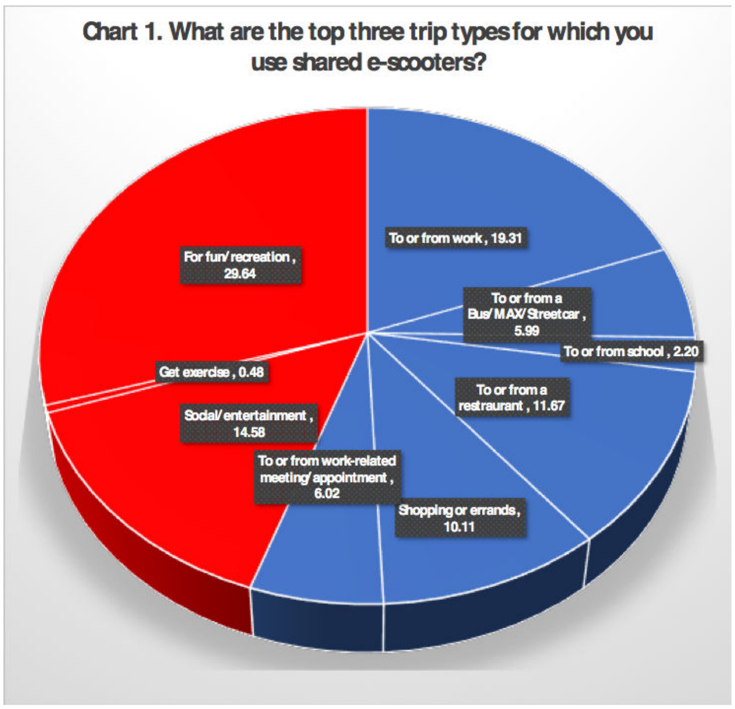

Figure 1.

From the Portland survey we can see that a mile of scooter riding replaces a little more than half a mile of transportation that would have been taken by other means and that a little less than half a mile of scooter riding had no impact on the carbon emissions of other transportation modes.

In section 1.f. we apply this 55.3% value and refer to the factor it represents as T, the proportion of scooter trips made for transportation rather than fun.

THE TYPES OF TRANSPORTATION E-SCOOTERS REPLACE

Having determined that roughly half the trips taken by scooter are for transportation purposes, we now examine what modes of transportation they replace, what emissions are associated with them and the distribution of those modes. This is relevant because not all modes of transport have significant carbon emissions, e.g. walking, and if, to give another extreme example, all the scooter rides that were for transportation only replaced walking, the net impact of the industry on San Diego's carbon footprint would be to increase it rather than decrease it.

The PBOT study contains survey data that gives us some valuable insight. Table 3 contains data taken from it.

Table 3. If an e-scooter had not been available for your last trip, how would you have made that trip?		
Mode	Crbn FP Eq	%
Driven	Automobile	18.8
Taken a taxi, Uber, or Lyft	1/2 Automobile	15.4
Ridden in a vehicle, dropped off	Automobile	1.35
Other	unknown	1.19
Ridden a personal e-scooter	Scooter	0.19
Ridden BIKETOWN	nil	3.69
Taken a bus/ MAX/ Streetcar	nil	10.2
Ridden a personal bike	nil	5.13
Walked	0	36.5
Would not have made this trip	0	7.55

To simplify the analysis we related the carbon dioxide emissions of various modes of transportation to an automobile, an approach adopted by the authors of the PBOT study.

Automobile Travel

We regard the first three modes ("Driven", "Taken a taxi, Uber, or Lyft", and "Ridden in a vehicle, dropped off"), as types of automobile travel, but differing in the degree to which their replacement by a scooter trip affects carbon emissions.

The first, "Driven" refers to the private use of a car to make a trip. We assign a value of 1.0 to such a trip, meaning that a if a scooter is used to replace such a trip it replaces one trip by a car, and thus saves the carbon emission associated with that journey. The carbon emissions associated with journey types is calculated in Section 2.

For-hire travel is not so simple. We first determine the market share of ride-share vehicles and taxis and then examine the differences in their associated carbon emissions.

A 2015 report stated that ride-share companies in Portland had a 60% share of the market, leaving taxis with 40%[6]. However, by 2018 the ride-sharing companies were described as responsible for “the bulk” of for-hire trips in Portland suggesting that this 60% market share had grown. This distinction matters because ride-share trips and taxis have different emissions.

In San Diego, a 2017 report indicated that similar effects had been seen in the for-hire market:

> “For the most part, permit holders have been surrendering their permits due to lack of business, a shortage of licensed drivers and overall adverse market conditions,” an MTS spokesman said.
>
> Meanwhile, the number of local cab drivers has plummeted from about 3,500 to an estimated 1,700, with many former cab drivers now working for Uber and Lyft. And dispatch centers for taxis, which handle the calls the cabs respond to, are also struggling with decreased demand.”[7]

Comparing private and for-hire trips, an article published in the summer of 2018[8] stated:

> “…a lot of private drivers spend time circling around trying to find parking, and Uber and Lyft drivers, and taxis, don't need to do that.
>
> But common sense suggests a typical Uber or Lyft trip requires more miles driven than a private vehicle. Someone driving their own car goes straight from their house, while Uber and Lyft must drive to pick them up and then take them to their destination.”

This “common-sense” assertion is undermined by the greater efficiency associated with the ride-share services, which are reported to collect customers faster, and in a matter of only a few minutes, than taxis.

> “Riders on average spent less time waiting for Uber or Lyft than for taxis. Only 25 percent of Uber or Lyft users had to wait more than six minutes for a ride, while 42 percent of cab riders had to wait more than six minutes.”[9]

Thus although ride-share vehicles drive to the customer, the distances driven are relatively short and the added carbon emissions associated with them are off-set by the greater emissions of a private vehicle circling to find parking.

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[6] https://www.oregonlive.com/commuting/index.ssf/2015/10/uber_lyft_now_dominate_portlan.html

[7] https://www.sandiegouniontribune.com/news/politics/sd-me-taxi-deregulate-20170915-story.html

[8] https://pamplinmedia.com/pt/9-news/399043-293259-more-ride-services-more-congestion

[9] https://www.oregonlive.com/commuting/index.ssf/2015/10/uber_lyft_now_dominate_portlan.html

However, there is a significant difference between ride-share services and taxis, that results in a difference in their associated carbon emissions, and is referred to as “deadheading”:

> “Another factor is "deadheading," the time for-hire vehicles spend driving around without a passenger inside. Studies show that Uber and Lyft drivers spend a greater share of their work time driving around with no passengers than taxi drivers, who are more prone to park at designated spots waiting to be dispatched. Studies have shown 20 percent to 50 percent of the miles driven by Uber, Lyft and other ride service drivers are spent deadheading.”[10]

Distinctions such as these matter because if a scooter trip replaces an Uber journey, for example, but the Uber vehicle is driving around regardless of whether it is hired, the substitution of a scooter trip for an Uber trip has had no impact in reducing carbon emissions, unless the impact of scooters was so widespread that it reduced the overall demand for Uber ride-shares to such an extent that Uber drivers turned to some other form of employment. Given that, in California, scooters are restricted to 25mph roads or 35mph roads with Class 2 or 4 bike lanes and their average trips in San Diego are only 1.3 miles, we regard this as unlikely to happen.

As a result, we conservatively assigned a value of 0.5 of an automobile to “Taxi, Uber or Lyft”. Although a taxi trip contributes nearly the same amount of carbon dioxide per mile as an automobile, Uber and Lyft drivers constantly drive, changing their locations to be available, as, unlike taxis, they are not routed via a dispatcher. Thus, they generate essentially the same amount of carbon dioxide whether or not they are transporting a passenger. Again conservatively, for this analysis we have given taxis a 50% market share, but our modeling approach easily allows for this and other variables to be changed.

We treat “Ridden, being dropped off” in a vehicle as an automobile trip.

So, for a first approximation we can classify the first three items in the table as “Automobile Travel”, albeit with differences in their carbon emissions.

Zero-Emissions Modes

The bottom two items, “Walked” and “Would not have made this trip” have a zero carbon footprint.

Other Modes

Modes 5-8, “Ridden a personal e-scooter”, “Ridden BIKETOWN”, “Taken a bus / MAX / streetcar”, “Ridden a personal bike” all have low carbon footprints.

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[10] https://pamplinmedia.com/pt/9-news/399043-293259-more-ride-services-more-congestion

BIKETOWN is a shared bicycle program similar to the DISCOVER bicycles in San Diego. The only carbon footprint would be that of manufacturing and maintaining the bicycles, which we regard as insignificant, compared to an automobile.

Mass transit runs along a specified route whether or not there are passengers. Replacing a mass-transit passenger with a scooter trip would not impact this analysis.

Nevertheless, in order to adopt a conservative approach, we give some credit for the carbon dioxide that e-scooters would replace with these modes and treat a mile of transport for items 5-8 as being responsible for the same amount of carbon as a car driven for 0.1 mile.

To keep the analysis simple and as conservative as possible, we treat the carbon dioxide contribution from the “Other” category the same as that from an automobile.

The simplified distribution is shown in the pie chart in Figure 2, where the weighted average carbon dioxide/mile of the transportation modes that are replaced by scooters is 30.9% of that produced by an automobile.

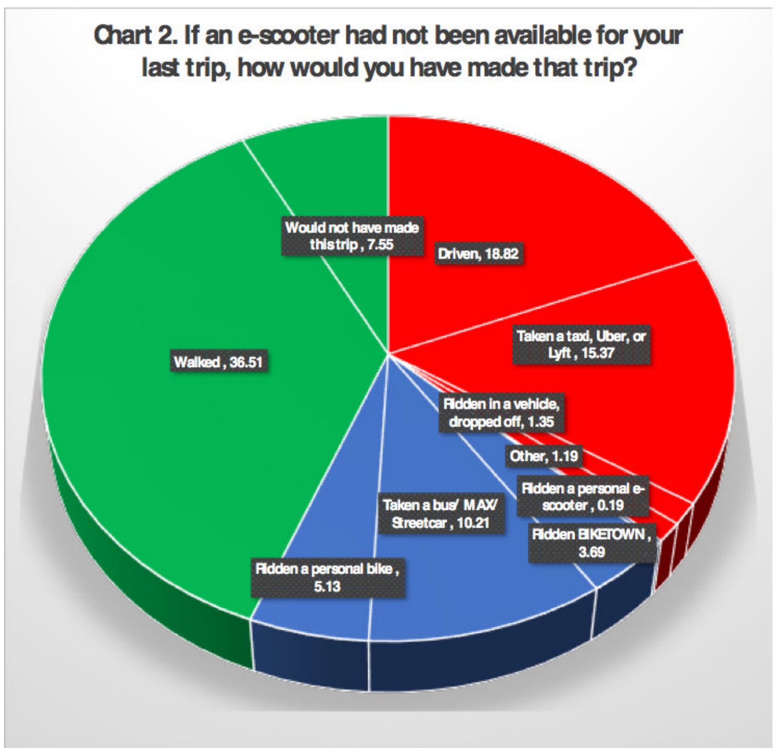


Figure 2

Below, we apply this value of 30.9% and refer to it as R, the weighted average CO_2 contribution of the transportation modes replaced by scooter use.

By this point, it should be obvious that the simplistic assumption that every mile travelled by an e-scooter replaces a mile travelled by a car is false because, as shown by the PBOT study, although e-scooters replace some car journeys, they also replace other forms of travel.

This usage pattern, which we believe is applicable to San Diego, combined with allowances for the marginal effect of replacement on the carbon emissions of other modes has led us to the conclusion so far, as stated, that, in terms of carbon emissions replacement, a mile travelled by scooter is effectively less than one third of a mile travelled by a car.

However, further factors need to be considered. For instance, the vehicles used by the industry are all single passenger vehicles, while the vehicle journeys they replace are taken in vehicles that allow for multiple occupancy.

Automobile Occupancy Rate

Scooters are single passenger vehicles while automobiles can carry multiple passengers. This is relevant to our calculation of the net impact on carbon emissions by the industry because if a scooter trip replaced a car journey but that car contained a driver and three passengers, four scooter trips would have been required to effect the same journey, not one.

The Federal Highway Administration (FHWA) performs extensive surveys to ascertain the driving characteristics of our population. Included in that survey are occupancy rates for various types of passenger vehicles. The 2017 FHWA survey results[11], shown in the chart below, indicate average passenger vehicle occupancy is 1.67.
The authors have reviewed the vehicle occupancy rate and elected to use a value of 1 instead of 1.67. It is our view that the 1.67 value is not representative of San Diego occupancy that would be replaced by a scooter. It is our estimation that the FHWA average is impacted by family trips with a full car and it is unlikely that scooters would replace such trips.

Thus, we have elected to use an automobile occupancy rate, referred to below as O, of 1 person/vehicle for this study.

CALCULATING EMISSIONS EQUIVALENCIES

Given the foregoing, we can calculate how many automobile equivalent miles will produce the same amount of CO_2 as a one-mile scooter ride, (E). Note that the implication of the simplistic claims by scooter companies, that one mile of scooter riding is equivalent to one mile of self-driving of an automobile, is that the value of E is 1.0

To calculate E we combine the three factors calculated so far, the proportion of scooter trips made for transportation usage rather than non-transportation usage, T, the weighted average carbon emissions of the transportation modes that scooters replace,

[11] https://www.energy.gov/eere/vehicles/articles/fotw-1040-july-30-2018-average-vehicle-occupancy-remains-unchanged-2009-2017.

relative to a passenger car vehicle in terms of percent, (R), and the average occupancy of a vehicle, (O), using the following formula:

$$E = (T \times R) / O$$

Thus

$$E = (55.3\% \times 30.9\%) / 1.00$$

E = **0.171**

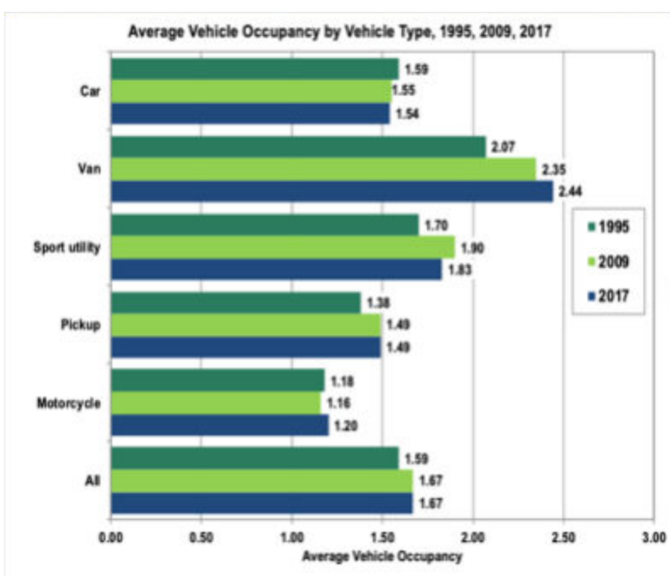
The value of E will have a significant impact on our later calculations. Given that the larger the value of E, the smaller the carbon footprint of the industry, it is worth considering how the value of E might be increased, something we address in the Appendix. For the moment, simply note that, assuming the lowest possible value of O is 1.0, (something that may need to be revised if autonomous automobiles become popular), the maximum possible value of E is 1.0, and that **E is increased if more scooter trips are made for the purpose of transportation and if they replace more carbon emitting alternatives.**

CALCULATING THE NET IMPACT OF THE INDUSTRY ON THE CARBON FOOTPRINT OF SAN DIEGO

To measure the net impact of the industry on CO_2 emissions, N, we apply the following formula:

$$N = [S_c - (E \times A_c)] \times S_m$$

Where,



E = The automobile equivalent miles that will produce the same amount of CO_2 as a one-mile scooter ride, (calculated above).

A_c = Total CO_2/mile created by an automobile.
S_c = Total CO_2/mile created by a scooter.
S_m = Total scooter miles ridden.

The value of $[S_c - (E \times A_c)]$ is the net effect per mile traveled on a scooter. When multiplied by the number of miles travelled by scooter per annum in San Diego we have the total net carbon emissions in grams of CO_2.

Conceptually, we are estimating the emissions effect on the city by calculating the difference in emissions between automobiles and scooters, per mile of travel, adjusting this for the proportion of such emissions associated with the various modes that are replaced by scooters and multiplying this by the number of miles travelled by scooters in the city.

In this case, a negative number represents a net decrease in the amount of CO_2 emitted and a positive number indicates that net CO_2 emissions increased.

Note that, although the widespread perception is that by using a scooter to travel one mile does not emit any CO_2 and thus that scooters have a zero carbon footprint, this belief fails to take account of the many carbon emissions producing activities associated with the industry. These include the emissions associated with the manufacture, shipping, charging, maintenance, service and repair of scooters, as was indicated in the caveats quoted above in the Portland Pilot study.

We next determine the CO_2/mile produced by scooters and by automobiles due to their manufacture, operation, and servicing, Sc and Ac in the formula above.

CALCULATE THE CARBON FOOTPRINT/MILE FOR THE VARIOUS MODES OF TRANSPORTATION THAT SCOOTERS REPLACE.

Manufacture

The manufacturing carbon footprint of automobiles and scooters is largely a function of the materials of which they are made and the energy consumed from first extracting raw materials from nature and converting them into refined commodities suitable for use in vehicle production.

For example iron ore must be mined and transported to a mill where it is converted to steel ingots, an energy intensive process. Later the ingots are heated to red hot and then rolled in a hot strip mill, another energy intensive process, in which it is reformed into rolls of sheet steel. Vehicle factories bring in rolls of steel and stamp, press, and form them into different shapes, coat them, and finally assemble them, processes far less energy intensive than employed in the production of the rolled steel. Aluminum production is a similar energy intensive process, but uses electricity to convert bauxite to aluminum metal via electrolytic reduction. According to the Aluminum Association[12] 5% of US electrical production is consumed by aluminum manufacture.

The Union of Concerned Scientists has a method for estimating the carbon dioxide produced in passenger car manufacture based on the weighted average of the carbon dioxide used to produce the materials of which they are made[13]. Our report defines the material composition of a passenger car shown in Table 4. below[14] from which the CO_2 emitted by production of these materials can be found.

Table 4. Carbon Emissions Values of Materials Used in Automobile Manufacture

Material	Automobile	Material	Automobile
	% Makeup	kg CO_2/kg	G CO_2/g
Steel	62	2	1.240
Cast Iron	11	1.5	0.165
Aluminum	7	12	0.840
Copper/Brass	2	3.7	0.074
Plastic (HDPE)	11	3.6	0.396
Rubber (Butyl)	3	6.6	0.198
Other	4	5.9	0.236
Sub-Total	100		3.149
Manufacturing			0.500
Total			**3.649**

We have also added a value of 0.5 g CO_2/g for additional CO_2 generated in the finishing processes to convert these materials into a vehicle. This is an estimate based on a review of data in the above reference.

[12] https://www.aluminum.org/industries/production/primary-production

[13] https://www.ucsusa.org/sites/default/files/attach/2015/11/Cleaner-Cars-from-Cradle-to-Grave-full-report.pdf

[14] http://www.dartmouth.edu/~cushman/books/Numbers/Chap1-Materials.pdf

The EPA reported the average vehicle weight for model year 2016 was 4,035 pounds[15]. As can be seen from the EPA's chart, Figure 3 below, average vehicle weight has remained relatively stable since the early 2000's so this 4,035 pounds, (1.83MT), can be used as a reasonable estimation of the average weight of the existing fleet of automobiles. This yields a CO_2 footprint of 6.68 MT for manufacture of a typical automobile.

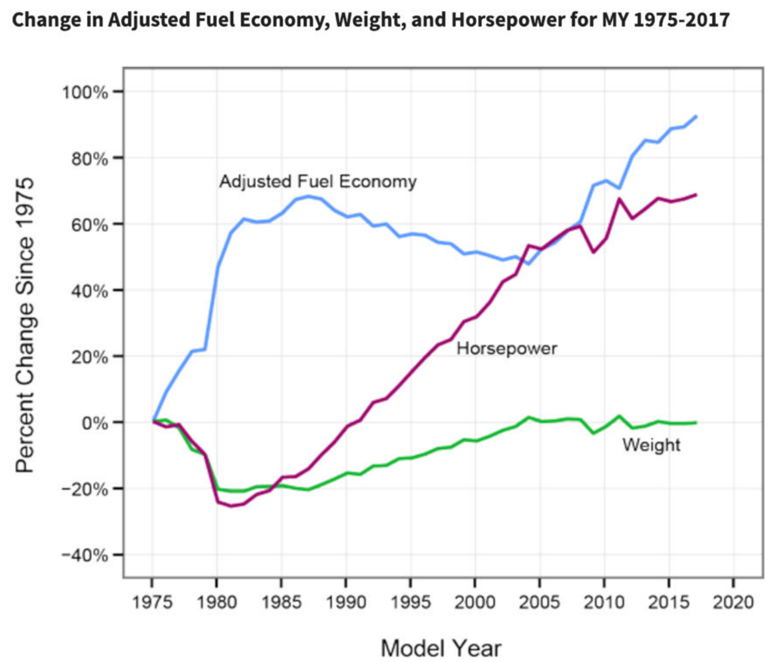


Figure 3

Our calculations must allow for differences in the productive lifespan of vehicles. We do so by dividing the emissions from the manufacture of a vehicle by the expected total miles of transportation provided by the vehicle during its expected life.

The Department of Transportation has found[16] that an average automobile will provide 152,137 miles of service over its life-time. Using this figure we determine the average CO_2/mile emissions that results from automobile manufacture, which comes to 44.0 g CO_2/mi. The unit "g CO_2/mi" becomes the common comparative measure used in our calculations.

We can do the same analysis for a scooter. We assume that the material composition is the same for a scooter as for an automobile. Precise compositional information for scooters is not readily available, but a cursory look at a scooter indicates that its composition does not seem to be very different from that of an automobile.

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[15] https://www.epa.gov/fuel-economy-trends/highlights-co2-and-fuel-economy-trends

[16] https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809952

For this report, data regarding the life span of an e- scooter was obtained from interviews with those familiar with the e-scooter business and press reports. These indicate the life of a Xiaomi M365 used by the industry is about 2.5 months. With its weight specified at 26.9 pounds (12,202 g), 2.9 trips/day from data in the PBOT report, and 1.3 average miles/trip reported for San Diego by Bird in September 2018, this yields a total CO_2/mi footprint from manufacture of 157.5 g CO_2/mi. The results of this analysis are shown in Table 5.

Note that the factors in this calculation, lifespan, weight, frequency of use and distance travelled are inter-related. For instance, increasing the weight of a scooter to make it more durable and thus last longer will increase the emissions associated with manufacture. Increasing the frequency of use or distance travelled will decrease the lifespan of the scooter and require more to be manufactured for a given size of rental fleet.

Table 5. CO_2 Emissions per Mile from Manufacture, gCO_2/mi	
Automobile	44.0
Scooter	157.5

The difference between the two numbers, which may strike the reader as surprising at first, is affected by the significant difference in the life spans, (and thus productive miles of transportation), of the two types of vehicles. If scooters had a longer lifespan the value for scooters would be reduced, all other things being equal.

Operation

Calculating the CO_2 emissions from passenger car operation is straight forward.

The US government's rule of thumb is that one gallon of fuel combustion results in the formation of 20 pounds of CO_2.[17]

In addition, we must include the carbon footprint of extraction, transportation, and refining steps required to produce gasoline. A study undertaken by Stanford and published in *Science,*[18] estimates the carbon footprint of petroleum fuel manufacturing at about 15 – 40% of their consumption footprint. Taking a mid-range value of 25% yields a simple calculation of 5 pounds for manufacturing or a total footprint of 25 pounds of CO_2 per gallon of consumed fuel.

According to the Bureau of Transportation Statistics, today's automobile fleet has an average fuel consumption of 22.0 miles per gallon, a value it seems Bird also selected

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[17] https://www.fueleconomy.gov/feg/contentIncludes/co2_inc.htm

[18] http://science.sciencemag.org/content/361/6405/851

for their analysis. Our approach is to calculate the emissions associated with traveling one mile by alternative modes, in this case by automobile. This calculation of passenger car operational CO_2 emissions per mile, (Ac), is derived by dividing the amount of CO_2 created by combustion per gallon of fuel burned by the number of miles travelled per gallon, i.e. 25 pounds / 22 miles = 1.14 lbs CO_2/ mi = **515.9 g CO_2/mi**.

Calculating the CO_2 emissions for e-scooter operation is more complex. Since scooters are electrically powered we have to understand how the electrical system generates its electricity and quantify the CO_2 emissions associated with that electricity production.

Electricity in San Diego is provided by a monopoly supplier, SDG&E, which produces most of its power from natural gas. Gas is a highly desirable fuel for electricity production as it enables the supplier to operate turbines at peak efficiency conditions.

The US Energy Information Administration provides data[19] that show that California energy production, with an energy source mix similar to SDG&E's, emits approximately 0.21 g CO_2/watt-hr. That is for existing electricity supply. Additional demand would likely require the use of gas to produce the incremental energy. This means that the incremental CO_2 emissions rate would be 0.21/(100%-43%) = 0.37 g CO_2/watt-hr.

The Xiaomi M365 scooter claims 1.1KWH/100km which yields **6.3 gCO_2/mi** of emissions for scooter operation.

Table 6. CO_2 Emissions from Operation, gCO_2/mi	
Automobile	515.9
Scooter	6.3

Note that the City of San Diego is considering switching to a system in which all electricity consumed will be from renewable sources. Our development of a model to analyze the carbon footprint of the industry allows for an assessment of the impact of such a switch – see Appendix. It also allows carbon footprint calculations to be made for other types of shared micro-mobility vehicles using similar elements in their business model.

Servicing
Both Automobiles and e-scooters need service.

Servicing Automobiles
Automobiles require tire changes, oil changes, and transmission fluid flushes.

There is little readily available data that summarizes average passenger car tire life. Cars.com, a well recognized source of passenger vehicle information, discusses this

[19] https://www.eia.gov/tools/faqs/faq.php?id=74&t=11

issue in detail[20]. Based on the information in this article we have chosen 25,000 miles for average tire life, which we believe is a conservative estimate. The Centre for Remanufacturing and Reuse states[21] that carbon footprint for a typical automobile tire is 60.5 kg. Combining these two figures yields a CO_2 footprint of manufacture for four tires of **9.6 g CO_2/mi**. We have made no allowance for the use and replacement of a spare, fifth, tire in our calculations therefore, implicitly, regarding it as never needing to be replaced.

National Oil & Lube News surveys[22] indicate the average motor oil drain interval is 4,470 miles despite the fact that auto manufacturers seldom recommend shorter than 7,500 miles. Many vehicles today include automatic notices on the dashboard when an oil change is required. But old habits die slowly and it wasn't that long ago that automakers recommended much shorter oil change intervals. The authors estimate the carbon footprint of an oil change is about 10 kg CO_2, which equates to **2.2 g CO_2/mile**.

Transmission fluid changes are more complex than motor oil changes because draining the transmission fluid leaves a substantial amount of old fluid in the torque converter. It has been increasingly popular to flush transmissions with machines particularly designed for this purpose. Transmission flushes require much more fluid than a traditional drain and refill, but do a much better job of removing the old fluid. A typical transmission flush requires about 4 gallons of fluid. The authors estimate the carbon footprint of a transmission fluid flush is about 40 Kg CO_2 footprint. Cartalk.com[23] reports typical OEM recommended transmission change intervals of 30,000 to 60,000 miles for manual transmissions and 60,000 to 100,000 miles for automatic transmissions. Some transmissions are built for the fluid to never need changing. Using a mid-range value of 60,000 mile yields **0.7 g CO_2/mile**.

This brings the total automobile carbon footprint resulting from the three types of servicing to **12.5 g CO_2/mi**.

We can now calculate the total carbon footprint of a typical passenger vehicle by summing the results from manufacture, operating, and servicing. This equals **572.4 g CO_2/mile,** as shown in Table 6.a.

Table 6.a. Automobile Emissions Per Mile g CO_2 / mi	
Manufacturing	44.0

20 https://www.cars.com/articles/2013/05/how-long-do-tires-last/

21 https://www.retreadingbusiness.com/information-support/marketing/the-centre-for-remanufacturing-and-reuse-carbon-footprint-report/

22 https://noln.net/2015/05/26/number-busts-biggest-myth-21st-century/

23 https://www.cartalk.com/content/service-your-car-14

Operation	515.9
Service	12.5
TOTAL (Ac)	**572.4**

THE EMISSIONS CREDIT FOR A SCOOTER

With that figure we can now calculate a critical value, the CO_2 emissions credit for a scooter, C, which is:

$$C = E \times Ac = \mathbf{\underline{97.9\ g\ CO_2/mi}}$$

Note that this 97.9 g CO_2/mi estimate is the critical level against which the industry's emissions are to be measured. The industry has claimed, and many others have repeated, that its net effect is to reduce carbon emissions[24]. If the industry in San Diego has a combined level of CO_2 emissions per mile for manufacture, operation and service lower than C, the net effect of the industry is to decrease carbon emissions, as the industry has claimed. However, if it is higher than that figure, its net effect is to increase carbon emissions.

From Tables 5 and 6 we can already see that the estimates of the footprint for manufacture and operations alone, 157.5 and 6.3 g CO_2/mi, (combined, 163.8 g CO_2/mi) is nearly double that critical figure. Indeed the estimate for manufacturing alone exceeds it significantly. We can thus see, even at this point, **that the net effect of the industry is not to decrease carbon emissions, but is actually to increase them**.

This is mainly because a large proportion of scooter use is not to solve the "Last Mile" problem facing local commuters, but rather for other uses as well as entertainment, (i.e. the value of E, at 0.171, is much less than 1.0), and because the scooters currently available have a relatively short lifespan.

To understand the significance of the transportation usage, (T), and replacement, (R), factors, note that if E was at its potential maximum value of 1, and thus all scooter use was for transportation and replaced automobile equivalent emissions, the value of C would be 572.4 g CO_2/mi.

However, we have yet to include the carbon emissions associated with the industry's process for servicing its vehicles.

Servicing Scooters

Calculating the scooter service contribution to its carbon footprint is more complicated than for automobiles. An e-scooter has to be collected, charged, and moved to a drop-

[24] This belief among users is natural if one only compares the operational emissions of scooters, (6.3 g CO_2/mi) with the operational emissions for automobiles, (515.9 g CO_2/mi), but it is a fallacy because it ignores the other carbon emissions associated with the industry.

off staging location that is not necessarily the same location from which it was collected. The service process varies, with some e-scooters being collected by company personnel in large batches, using commercial vans. Others are collected in personal cars using an app from the e-scooter company to locate scooters in need of charging. Sometimes independent e-scooter chargers are only able to collect a few scooters. These are charged at the collector's home using charging equipment supplied by the e-scooter provider. The carbon footprint of these charging devices has not been included in our analysis for the sake of developing a conservative estimate. The Xiaomi M365 has a battery life that provides about 18 miles of service. It becomes available for charging after about 14 miles of service.

Note that a further aspect of "service" is the re-location of scooters during the day by the industry for repositioning and returning haplessly returned scooters to more orderly positioning. In order to apply a conservative approach to our estimates we have not included the impact of this element of service in our calculations.

Because of the high variability in the way scooters are serviced and the lack of firm data about the distribution of vehicles used by the industry to service them, we built cases around two types of service vehicles: 1) a typical passenger car and 2) a hypothetical large service vehicle with a weight of 10,000 pounds, gasoline consumption of 12 miles/gallon, and a vehicle life of 250,000 miles. We also assume that the CO_2 footprint to service this truck is double that of a passenger vehicle.

Using the equations developed for the passenger vehicle we can calculate the per mile carbon footprint for the large service vehicle which = **1,037 g CO_2/mi.**

For each vehicle, we created driving round-trip scenarios of 2, 5, 10 and 20 miles per charging period.

We created scenarios of 5 and 10 scooters per passenger car trip, and 5, 10, 20 and 40 scooters per trip for the large service vehicle.

Based on information provided by industry sources, we assumed that the average scooter is serviced after 14 miles of use.

The results are shown in Table 7.
As might be expected the method with the lowest emissions for servicing, (3.7 g CO_2/mi), is the use of the largest capacity vehicle to collect the largest number of scooters at a time, traveling the shortest distance.

Now we can calculate the total carbon dioxide generated for a single scooter by adding the Manufacturing, (Table 5), and Operating, (Table 6), values to those for Servicing, (Table 7), with the values for the combined results being shown in Table 8.

Table 8. Emissions Generated by a Scooter, CO2 Footprint, g C02/mi

Miles/Round Tri	Scooters/Trip: Passenger Vehicle 5	Passenger Vehicle 10	Large Service Vehicle 5	Large Service Vehicle 10	Large Service Vehicle 20	Large Service Vehicle 40
2	180.2	172.0	193.4	178.6	171.2	167.5
5	204.7	184.2	237.9	200.8	182.3	173.1
10	245.6	204.7	312.0	237.9	200.8	182.3
20	327.3	245.6	460.1	312.0	237.9	200.8

CALCULATE THE NET CARBON FOOTPRINT IMPACT OF E-SCOOTERS

The net carbon dioxide impact of e-scooters is determined by calculating the difference between the carbon dioxide created by scooters and the carbon dioxide their use eliminates. This can be accomplished by subtracting from the values in the table above, 97.9 g CO_2/ scooter mile, the amount that scooters eliminate from other modes that riders would have used if scooters were not available, as is shown in Table 8. The net carbon footprint impact results are shown in Table 9 below. A negative number indicates a net reduction in CO_2 generation by the industry and those cells are highlighted in green. A **positive** number indicates a net **increase** in CO_2 generation by the industry and those cells are highlighted in **red**. **Our results indicate very clearly, that the**

Table 9. Net Carbon Footprint Impact, CO2, g CO2/scooter mi by service type

Miles/Round Trip	Scooters/Trip: Passenger Vehicle 5	Passenger Vehicle 10	Large Service Vehicle 5	Large Service Vehicle 10	Large Service Vehicle 20	Large Service Vehicle 40
2	82.3	74.1	95.5	80.7	73.3	69.6
5	106.8	86.3	140.0	102.9	84.4	75.2
10	147.7	106.8	214.1	140.0	102.9	84.4
20	229.4	147.7	362.2	214.1	140.0	102.9

motorized scooter rental industry, <u>as it is currently operating in San Diego</u>, does not reduce the city's net CO_2 emissions, instead it increases them.

In the following section we estimate the amount the industry is adding to the city's carbon footprint annually.

ANNUAL INCREASE IN NET CARBON EMISSIONS BY THE INDUSTRY IN SAN DIEGO

For an estimate of the annual impact of the industry on the carbon footprint of San Diego, we start with a case in which half the scooters are serviced by passenger vehicles carrying 5 scooters/10 mile round trip and half by large service vehicles carrying 20 scooters per 10 mile trip. This yields an overall net increase in CO_2 production of 121.9 g/scooter mile. In September 2018 Bird stated to the City of San Diego's Public Safety and Livable Neighborhoods committee that its users had travelled 2,488,613 miles over 230 days of operation. That results in a net increase of nearly 750,000 pounds of carbon. This contrasts sharply with Bird's estimate of 2.2 million pounds reduction, an incorrect result based on faulty assumptions. But this is only for one company and only for its introductory period, when it was building its fleet. It does not include the amount of pollution resulting from the other brands, nor does it account for the growth in the number of scooters that has occurred. Clearly, the industry in San Diego is currently polluting at the rate of well over one million pounds of CO_2 annually.

Based on 2.9 trips per day and 1.3 miles per trip each scooter pollutes at the net rate of about 1 pound of CO_2 per day. A fleet of 3,000 pollutes at the net rate of 1 million pounds per year. The size of the fleet is not known and is constantly changing. Discussion with a variety of people familiar with the industry leads to an estimate of it's combined fleet at between 25,000 and 50,000. If correct, this would result in a net pollution of approximately 10 to 15 million pounds per year caused by the industry's San Diego business. A midrange value is 12.5 million pounds or approximately 5,700 MT per annum.

CONCLUSION

The conservative analysis conducted, indicates that it is highly unlikely that the creation of a commercial micro-mobility rental industry in San Diego has reduced carbon dioxide emissions. Rather, the data suggest that **<u>the industry has increased the carbon dioxide emissions of San Diego. Rather than helping the City of San Diego achieve it's Climate Action Plan[25] it is actually hindering it in doing so.</u>**

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[25] https://www.sandiego.gov/sustainability/climate-action-plan

This conclusion is reflected by the recently published analysis of Matt Chester[26] who states:

> ”it appears likely that the proliferation of dockless electric scooter programs– as they exist now– offer a tenuous benefit to aggregate transportation emissions depending on how frequently they do serve as one-to-one replacements for driving, but at worst they end up accounting for a greater overall emissions per mile.”

Our analysis has been conservative in a number of ways:

- It applies data from the PBOT of Portland, OR, a city with a lower proportion of tourists than San Diego.
- We treated low emissions alternatives to cars as equivalent to one tenth of a car.
- We treated the Other category as equivalent to a car.
- We adopted conservative estimates for auto tire life.
- We excluded the carbon footprint of scooter charging devices.
- We excluded the carbon footprint of relocating scooters.

As a result, the results probably underestimate the degree to which the industry is increasing the carbon footprint of San Diego.

The CAP goal for GHGs is to reduce the output of San Diego from 13 $MMTCO_2e$ to just over 6 $MMTCO_2e$ over the twenty-five years from 2010 to 2035. The intermediate goal for 2020 is to reduce them to just over 10 $MMTCO_2e$. In 2017, the City’s GHG emissions did not decline. In February 2018, the industry entered the San Diego market. During 2018, our estimate of the net impact of the industry on San Diego’s GHG emissions is that it **increased them by 5700 MT, (0.0057 $MMTCO_2e$).**

Our analysis suggests why this is the case:

- Limited use for commuting rather than entertainment - low value for T.
- A significant proportion of scooter use replaces zero emissions alternatives like walking - low value for R. Note that the CAP seeks to increase the proportion of journeys achieved through walking, but the misuse and misplacement of the industry’s vehicles is having a negative impact on people’s willingness to walk.
- The short lifespan and fragility of the vehicles leads to frequent replacement - high manufacturing emissions per mile of use.
- Possible inefficiencies in the servicing system such as:
    - The frequency of recharging.
    - The lack of replaceable batteries.
    - The lack of solar-powered recharging stations.

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26 http://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/

Our analysis is of an industry, in which a technology has been provided using a business model common to the companies in the industry. Thus, one should not take this to mean that e-scooters are inherently less green than other forms of transportation, nor does it mean that e-scooters could not play a valuable role in reducing emissions.

USAGE

One of the largest factors responsible for the higher CO_2 emissions from e-scooters in this analysis is the way they are used. Their extensive use for fun and entertainment creates new rides that detract from the environmental benefit they otherwise could provide.

REPLACEMENT

Another significant factor is the current low level of replacement by scooter users of high carbon-emitting journeys. Of particular concern to us as an advocacy group for walking in safety, is the high proportion of scooter usage reported in Portland that replaced walking, about one third, and the negative impact that scooter misuse and misplacement has on the desire of others to walk because of the fear it engenders.

LIFESPAN

The short e-scooter life is also a detractor for their environmental performance. Scooters suffer a lot of abuse from both their users and handling during service. The Internet is rife with examples of vandalism of e-scooters. Although some companies have begun to switch to ostensibly more robust designs, our sources suggest that these are extending the vehicle life spans from 1-2 months to 3-4 months. A longer lifespan will improve the carbon footprint of any vehicle, all other things being equal, but this increase is not the 12 months that has been claimed by the companies. As noted earlier in this report, a more robust and durable scooter will likely require more materials in its manufacture and thus will likely weigh more, thus increasing the carbon footprint of its manufacture.

RECHARGING

The current process for recharging scooters is inefficient from a carbon footprint standpoint. Rather than the current process, in which scooters need to be located, collected and brought to place where they are recharged and then moved again to be placed at the start of a day, a solar powered charging station, such as available from Swift Mile[27], offers a more efficient system that reduces the emissions associated with the process. According to Swift Mile, their stations have a 10 year life, weigh 115 pounds, comprising 87% steel and 13% aluminum, require twice monthly servicing, primarily to clean the solar panels~~, a~~ **. A** service person in a metropolitan area can service 500 stations in a 50 mile driving circuit in one day. If you assume that one charging station charges two scooters per day, restoring an average of 14 miles of service to each scooter, this process of

[27] One of the authors saw the Swift Mile solar-powered charging station displayed at the LA CoMotion conference in November 2018, and we have chosen to use this as an example of an alternative to the current charging process. Neither of the authors have any involvement with Swift Mile nor have received nor will receive any compensation from them for including them in this report.

recharging scooters creates 2.5 g CO_2 per scooter mile, compared to the estimated 60 g CO_2 per scooter mile from the current process. Thus, this type of scooter charging process could eliminate 95% of the scooter carbon footprint that results from the charging process.

INDIVIDUAL OWNERSHIP

As a technology, in principle, e-scooters could be green. An alternative to the rental industry is individual ownership. An individual, who owns a scooter and uses it primarily for transportation instead of a car, could significantly reduce his or her own carbon footprint. Having responsibility for an e-scooter would encourage the user to take better care of it, which will extend its life, reducing the CO_2/mile created by manufacture. It will also eradicate the need for collecting and redistributing the scooter for the recharging process. An owner who uses a scooter 75% of the time as transportation and cares for it so that its useful life is extended to 5 months will provide a savings of 444 g CO_2/ scooter mile.

So, the way that the City of San Diego governs the industry could have a significant influence on whether or not they are a positive or negative factor on the city's carbon footprint

Along with this report, we have created a detailed Excel tool that enables modifying the data in it to assess how different scenarios might impact carbon dioxide emissions. We are happy to share that too with the City of San Diego.

APPENDIX

What can San Diego do to have a more environmentally friendly scooter program? Our analysis suggests that the answer is not simple and that a single fix to the problem is unlikely to be successful. The tool we have built to assess various scenarios is available to the City of San Diego. We have applied it to the questions stated below to provide some examples of how it might be used.

1. **Policy**

One of the reasons that e-scooters have a larger than would be expected damaging impact on CO_2 production is that a large portion of their use is for joy riding and entertainment rather than for legitimate passenger car replacement. A policy change could alter this. For example, a program could be established to subsidize their use for to and from work transportation, and raise the price for other rentals to pay for the subsidy. If the percentage of legitimate passenger car substitutions was doubled, how would that impact the scooter carbon footprint?

2. **Manufacturing**

If a more durable scooter was made, say by adding 5 pounds of stainless steel which extends its life to 5 months, how would that impact the scooter carbon footprint?

3. Operating

If the production of electricity was changed so that 100% of the electricity comes from carbon-free sources how would that impact the scooter carbon footprint?

4. Service

Charging stations might be installed and incentives offered to users to dock at them. How would that impact the scooter carbon footprint if it reduced the driving associated with servicing scooters by 50%?

The charts below in Figure 4 show the results of the analysis for those questions.

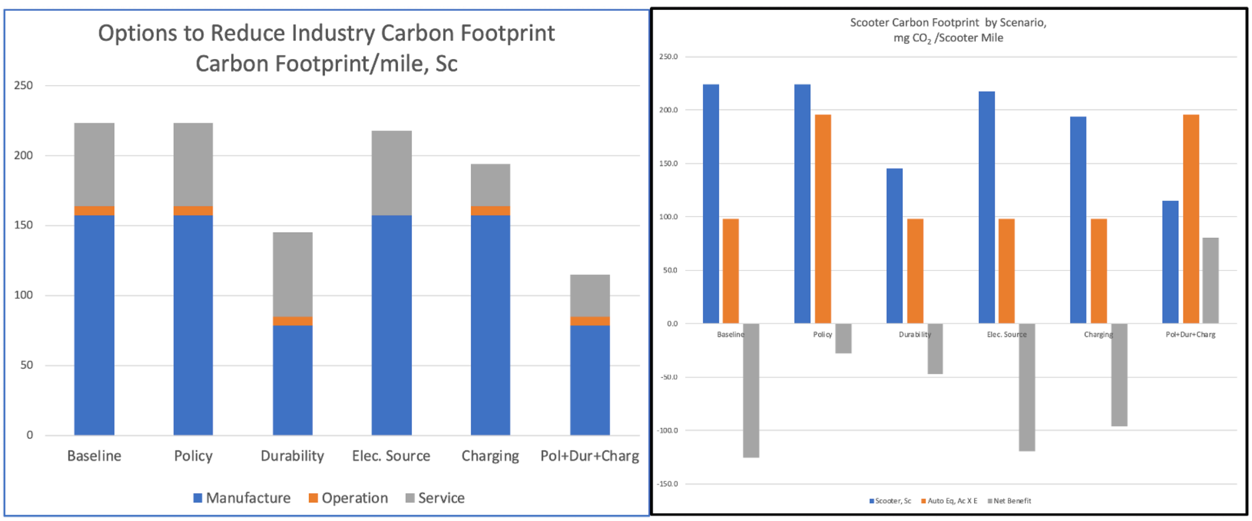

Figure 4

It is clear from the chart that no single fix gives scooters a carbon neutral footprint.

It is also clear that, because the operation of scooters contributes so little to their carbon footprint, changing the energy source of the electricity used to charge them has little impact.

However, a combination measures that moved scooters from a role as a carnival ride to a role of passenger vehicle transportation replacement, combined with a more carbon efficient charging process could make them carbon neutral, and perhaps even carbon friendly.

Safe *Walk*ways
February 12th. 2019