BERKELEY CITY COUNCIL FACILITIES, INFRASTRUCTURE, TRANSPORTATION, ENVIRONMENT & SUSTAINABILITY COMMITTEE

REGULAR MEETING

Wednesday, July 20, 2022
2:30 PM

Committee Members:

Councilmembers Terry Taplin, Rigel Robinson, and Kate Harrison
Alternate: Councilmember Sophie Hahn

PUBLIC ADVISORY: THIS MEETING WILL BE CONDUCTED EXCLUSIVELY THROUGH VIDEOCONFERENCE AND TELECONFERENCE

Pursuant to Government Code Section 54953(e) and the state declared emergency, this meeting of the City Council Facilities, Infrastructure, Transportation, Environment & Sustainability Committee will be conducted exclusively through teleconference and Zoom videoconference. The COVID-19 state of emergency continues to directly impact the ability of the members to meet safely in person and presents imminent risks to the health of attendees. Therefore, no physical meeting location will be available.

To access the meeting remotely using the internet: Join from a PC, Mac, iPad, iPhone, or Android device: Use URL https://cityofberkeley-info.zoomgov.com/j/1605318273. If you do not wish for your name to appear on the screen, then use the drop down menu and click on "rename" to rename yourself to be anonymous. To request to speak, use the “raise hand” icon on the screen.

To join by phone: Dial **1-669-254-5252 or 1-833-568-8864 (Toll Free)** and Enter Meeting ID: **160 531 8273.** If you wish to comment during the public comment portion of the agenda, press *9 and wait to be recognized by the Chair.

Written communications submitted by mail or e-mail to the Facilities, Infrastructure, Transportation, Environment & Sustainability Committee by 5:00 p.m. the Friday before the Committee meeting will be distributed to the members of the Committee in advance of the meeting and retained as part of the official record.

AGENDA

Roll Call

Public Comment on Non-Agenda Matters

Minutes for Approval

Draft minutes for the Committee's consideration and approval.

1. Minutes – July 6, 2022

Committee Action Items

The public may comment on each item listed on the agenda for action as the item is taken up. The Chair will determine the number of persons interested in speaking on each item. Up to ten (10) speakers may speak for two minutes. If there are more than ten persons interested in speaking, the Chair may limit the public comment for all speakers to one minute per speaker. Speakers are permitted to yield their time to one other speaker, however no one speaker shall have more than four minutes.

Following review and discussion of the items listed below, the Committee may continue an item to a future committee meeting, or refer the item to the City Council.

2. Regulation of Autonomous Vehicles *(Item contains revised material)*
From: Councilmember Taplin (Author)
Referred: May 9, 2022
Due: October 24, 2022
Recommendation: Refer to the City Attorney the assessment of the legal abilities and opportunities for the City Council to regulate the operation, sale, and testing of autonomous vehicles (AVs) within the City of Berkeley and report to the Facilities, Infrastructure, Transportation, Environment and Sustainability Committee (FITES) on all findings.
Financial Implications: Staff time
Contact: Terry Taplin, Councilmember, District 2, (510) 981-7120

3. Adopt an Ordinance Adding a New Chapter 12.01 to the Berkeley Municipal Code Establishing Emergency Greenhouse Gas Limits, Process for Updated Climate Action Plan, Monitoring, Evaluation, Reporting and Regional Collaboration
From: Councilmember Harrison (Author), Councilmember Bartlett (Co-Sponsor) and Councilmember Hahn (Co-Sponsor)
Referred: November 15, 2021
Due: July 31, 2022
Recommendation: 1. Adopt an ordinance adding a new Chapter 12.01 to the Berkeley Municipal Code (BMC) establishing Emergency Greenhouse Gas Limits with an effective date of [ ], 2022.
2. Refer to the FY23-24 Budget Process $[ ] consistent with implementing the requirements of Sections 12.01.040, 12.01.050, 12.01.060.
Financial Implications: See report
Contact: Kate Harrison, Councilmember, District 4, (510) 981-7140

Unscheduled Items

These items are not scheduled for discussion or action at this meeting. The Committee may schedule these items to the Action Calendar of a future Committee meeting.

4. Refer to the City Manager to Prioritize Establishment of Impact/Mitigation Fees to Address Disproportionate Private and Public Utility Impact to the Public Right of Way
From: Councilmember Harrison (Author)
Referred: February 22, 2021
Due: September 30, 2022
Recommendation: In order to ensure equitable support of the public right of way by private and public entities that use City facilities, refer to the City Manager and City Attorney to prioritize the following in consultation with the Facilities, Infrastructure, Transportation, Environment, & Sustainability Committee:
1. establish impact and/or mitigation fees to address disproportionate private impacts to the public right of way, such as our roads and utility poles; and
2. establish transfers between sewer, waste, or other utilities as appropriate to address impacts to the public right of way.
Financial Implications: See report
Contact: Kate Harrison, Councilmember, District 4, (510) 981-7140

5. Adopt an Ordinance Adding a Chapter 11.62 to the Berkeley Municipal Code to Regulate Plastic Bags at Retail and Food Service Establishments *(Item contains revised material)*
From: Councilmembers Harrison and Hahn
Referred: November 25, 2019
Due: September 30, 2022
Recommendation: Adopt an ordinance adding a Chapter 11.62 to the Berkeley Municipal Code to regulate plastic bags at retail and food service establishments.
Financial Implications: See report
Contact: Kate Harrison, Councilmember, District 4, (510) 981-7140

6. Referral Response: Community Outreach and Education Events on Proposed Regulations for the Use of Carryout and Pre-checkout Bags
From: Energy Commission
Referred: March 28, 2022
Due: September 3, 2022
Recommendation: The Energy Commission recommends that the City Council refer this matter to the forthcoming Commission on Climate and the Environment Commission, once it is established. The Energy Commission also recommends that the City Council first allocate and appropriate funding for City staff and local community partners to conduct due diligence and analysis regarding the proposed ordinance, and consider funding a pilot project with a large grocery venue.
Financial Implications: See report
Contact: Billi Romain, Commission Secretary, (510) 981-7400

Items for Future Agendas

- **Discussion of items to be added to future agendas**

Adjournment

Written communications addressed to the Facilities, Infrastructure, Transportation, Environment & Sustainability Committee and submitted to the City Clerk Department will be distributed to the Committee prior to the meeting.

This meeting will be conducted in accordance with the Brown Act, Government Code Section 54953. Members of the City Council who are not members of the standing committee may attend a standing committee meeting even if it results in a quorum being present, provided that the non-members only act as observers and do not participate in the meeting. If only one member of the Council who is not a member of the committee is present for the meeting, the member may participate in the meeting because less than a quorum of the full Council is present. Any member of the public may attend this meeting. Questions regarding this matter may be addressed to Mark Numainville, City Clerk, (510) 981-6900.

COMMUNICATION ACCESS INFORMATION:
To request a disability-related accommodation(s) to participate in the meeting, including auxiliary aids or services, please contact the Disability Services specialist at (510) 981-6418 (V) or (510) 981-6347 (TDD) at least three business days before the meeting date.

I hereby certify that the agenda for this meeting of the Standing Committee of the Berkeley City Council was posted at the display case located near the walkway in front of the Maudelle Shirek Building, 2134 Martin Luther King Jr. Way, as well as on the City's website, on Thursday, July 14, 2022.

Mark Numainville, City Clerk

Communications

Communications submitted to City Council Policy Committees are on file in the City Clerk Department at 2180 Milvia Street, 1st Floor, Berkeley, CA, and are available upon request by contacting the City Clerk Department at (510) 981-6908 or policycommittee@cityofberkeley.info.

BERKELEY CITY COUNCIL FACILITIES, INFRASTRUCTURE, TRANSPORTATION, ENVIRONMENT & SUSTAINABILITY COMMITTEE
REGULAR MEETING MINUTES

Wednesday, July 6, 2022
2:30 PM

Committee Members:

Councilmembers Terry Taplin, Rigel Robinson, and Kate Harrison
Alternate: Councilmember Sophie Hahn

PUBLIC ADVISORY: THIS MEETING WILL BE CONDUCTED EXCLUSIVELY THROUGH VIDEOCONFERENCE AND TELECONFERENCE

Pursuant to Government Code Section 54953(e) and the state declared emergency, this meeting of the City Council Facilities, Infrastructure, Transportation, Environment & Sustainability Committee will be conducted exclusively through teleconference and Zoom videoconference. The COVID-19 state of emergency continues to directly impact the ability of the members to meet safely in person and presents imminent risks to the health of attendees. Therefore, no physical meeting location will be available.

To access the meeting remotely using the internet: Join from a PC, Mac, iPad, iPhone, or Android device: Use URL https://us02web.zoom.us/j/86158614605. If you do not wish for your name to appear on the screen, then use the drop down menu and click on "rename" to rename yourself to be anonymous. To request to speak, use the “raise hand” icon on the screen.

To join by phone: Dial **1-669-900-9128 or 1-877-853-5257 (Toll Free)** and Enter Meeting ID: **861 5861 4605.** If you wish to comment during the public comment portion of the agenda, press *9 and wait to be recognized by the Chair.

Written communications submitted by mail or e-mail to the Facilities, Infrastructure, Transportation, Environment & Sustainability Committee by 5:00 p.m. the Friday before the Committee meeting will be distributed to the members of the Committee in advance of the meeting and retained as part of the official record.

MINUTES

Roll Call: 2:32 pm.

Present: Robinson, Harrison

Absent: Taplin

Councilmember Taplin arrived at 2:34 pm.

Public Comment on Non-Agenda Matters: 2 speakers.

Minutes for Approval

Draft minutes for the Committee's consideration and approval.

1. **Minutes – June 1, 2022**
   Action: M/S/C (Robinson/Taplin) to approve the June 1, 2022 minutes.
   Vote: Ayes – Taplin, Robinson; Noes – None; Abstain – Harrison; Absent – None.

Committee Action Items

The public may comment on each item listed on the agenda for action as the item is taken up. The Chair will determine the number of persons interested in speaking on each item. Up to ten (10) speakers may speak for two minutes. If there are more than ten persons interested in speaking, the Chair may limit the public comment for all speakers to one minute per speaker. Speakers are permitted to yield their time to one other speaker, however no one speaker shall have more than four minutes.

Following review and discussion of the items listed below, the Committee may continue an item to a future committee meeting, or refer the item to the City Council.

2. **Adopt an Ordinance Adding a Chapter 11.62 to the Berkeley Municipal Code to Regulate Plastic Bags at Retail and Food Service Establishments**
   From: Councilmembers Harrison and Hahn
   Referred: November 25, 2019
   Due: September 30, 2022
   Recommendation: Adopt an ordinance adding a Chapter 11.62 to the Berkeley Municipal Code to regulate plastic bags at retail and food service establishments.
   Financial Implications: See report
   Contact: Kate Harrison, Councilmember, District 4, (510) 981-7140
   Action: 1 speaker. Discussion held. Item continued to a future meeting.

Committee Action Items

3. **Referral Response: Community Outreach and Education Events on Proposed Regulations for the Use of Carryout and Pre-checkout Bags**
From: Energy Commission
Referred: March 28, 2022
Due: September 3, 2022
Recommendation: The Energy Commission recommends that the City Council refer this matter to the forthcoming Commission on Climate and the Environment Commission, once it is established. The Energy Commission also recommends that the City Council first allocate and appropriate funding for City staff and local community partners to conduct due diligence and analysis regarding the proposed ordinance, and consider funding a pilot project with a large grocery venue.
Financial Implications: See report
Contact: Billi Romain, Commission Secretary, (510) 981-7400
Action: 0 speakers. No discussion held. Item continued to a future meeting.

4. **Adopt an Ordinance Adding a New Chapter 12.01 to the Berkeley Municipal Code Establishing Emergency Greenhouse Gas Limits, Process for Updated Climate Action Plan, Monitoring, Evaluation, Reporting and Regional Collaboration**
From: Councilmember Harrison (Author), Councilmember Bartlett (Co-Sponsor) and Councilmember Hahn (Co-Sponsor)
Referred: November 15, 2021
Due: July 31, 2022
Recommendation: 1. Adopt an ordinance adding a new Chapter 12.01 to the Berkeley Municipal Code (BMC) establishing Emergency Greenhouse Gas Limits with an effective date of [   ], 2022.
2. Refer to the FY23-24 Budget Process $[   ] consistent with implementing the requirements of Sections 12.01.040, 12.01.050, 12.01.060.
Financial Implications: See report
Contact: Kate Harrison, Councilmember, District 4, (510) 981-7140
Action: 2 speakers. Discussion held. Item continued to a future meeting.

Unscheduled Items

These items are not scheduled for discussion or action at this meeting. The Committee may schedule these items to the Action Calendar of a future Committee meeting.

5. **Refer to the City Manager to Prioritize Establishment of Impact/Mitigation Fees to Address Disproportionate Private and Public Utility Impact to the Public Right of Way**
From: Councilmember Harrison (Author)
Referred: February 22, 2021
Due: September 30, 2022
Recommendation: In order to ensure equitable support of the public right of way by private and public entities that use City facilities, refer to the City Manager and City Attorney to prioritize the following in consultation with the Facilities, Infrastructure, Transportation, Environment, & Sustainability Committee:
1. establish impact and/or mitigation fees to address disproportionate private impacts to the public right of way, such as our roads and utility poles; and
2. establish transfers between sewer, waste, or other utilities as appropriate to address impacts to the public right of way.
Financial Implications: See report
Contact: Kate Harrison, Councilmember, District 4, (510) 981-7140

6. **Regulation of Autonomous Vehicles**
From: Councilmember Taplin (Author)
Referred: May 9, 2022
Due: October 24, 2022
Recommendation: Refer to the City Attorney the assessment of the legal abilities and opportunities for the City Council to regulate the operation, sale, and testing of autonomous vehicles (AVs) within the City of Berkeley and report to the Facilities, Infrastructure, Transportation, Environment and Sustainability Committee (FITES) on all findings.
Financial Implications: Staff time
Contact: Terry Taplin, Councilmember, District 2, (510) 981-7120

Items for Future Agendas

- None

Adjournment

Action: M/S/C (Harrison/Robinson) to adjourn the meeting.
Vote: All Ayes

Adjourned at 3:18 p.m.

I hereby certify that this is a true and correct record of the Facilities, Infrastructure, Transportation, Environment & Sustainability Committee meeting held on July 6, 2022.

____

Sarah K. Bunting, Assistant City Clerk

Communications

Communications submitted to City Council Policy Committees are on file in the City Clerk Department at 2180 Milvia Street, 1st Floor, Berkeley, CA, and are available upon request by contacting the City Clerk Department at (510) 981-6908 or policycommittee@cityofberkeley.info.

BERKELEY CITY COUNCILMEMBER TERRY TAPLIN DISTRICT 2

CONSENT CALENDAR
May 24th, 2022

To: Honorable Mayor and Members of the City Council

From: Councilmember Terry Taplin

Subject: Regulation of Autonomous Vehicles

RECOMMENDATION

Refer to the City Attorney the assessment of the legal abilities and opportunities for the City Council to regulate the operation, sale, and testing of autonomous vehicles (AVs) within the City of Berkeley and report to the Facilities, Infrastructure, Transportation, Environment and Sustainability Committee (FITES) on all findings.

CURRENT SITUATION AND ITS EFFECTS

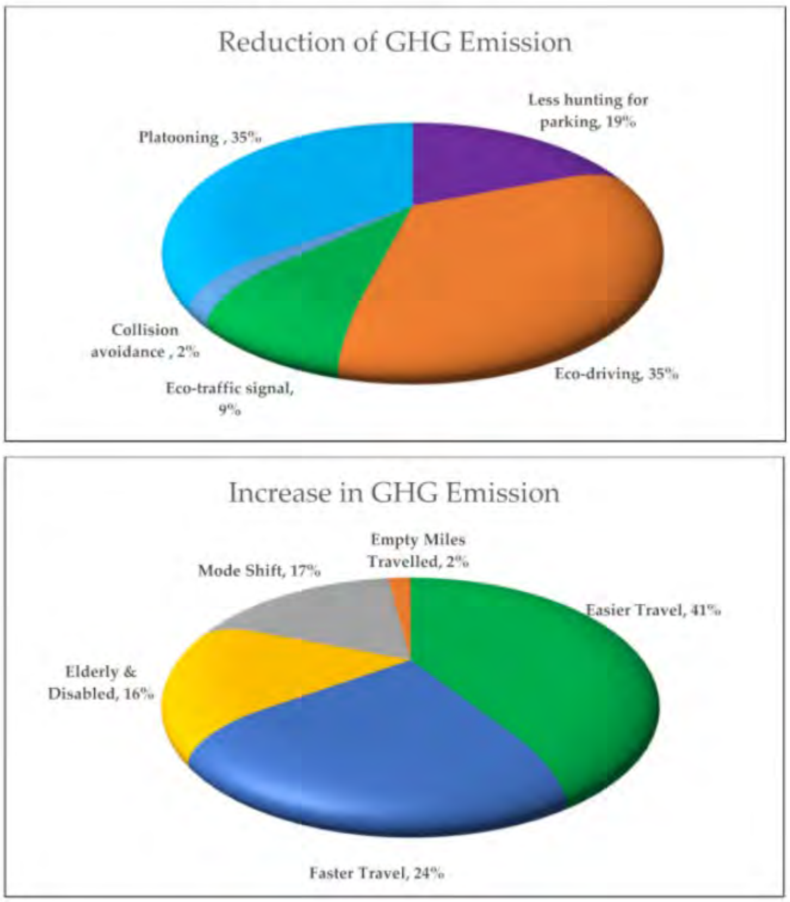
Autonomous vehicles, better known as driverless cars, are an emerging technology with such potential to transform our transportation system that it inspires great optimism as well as an equal amount of trepidation. Advocates and opponents of the technology agree that the full automation of personal automobiles will have enormous ripple effects throughout our society, impacting the job market, public safety, energy consumption, and our every understanding of how we design our cities and transportation systems. Those pursuing AV technology view removing the variable of human error from personal vehicle transportation as the solution to congestion, fuel efficiency, and traffic accidents themselves. Proponents of AVs also see driverless cars as a valuable resource for persons with disabilities who cannot currently drive personal vehicles, expanding the mobility options for millions.[1] Others are more suspicious of driverless cars.

Some studies suggest any gains made by AVs in reducing congestion and traffic accidents could very well be neutralized by an induced demand for this exciting new transportation method.[2] Furthermore, the introduction of truly autonomous vehicles into the market at a time when environmental and street safety advocates are pushing for a decline in all kinds of personal vehicle mode-shares could undo decades of work to reduce car dependency. Of particular concern to the City of Berkeley will be the impact that AVs have on greenhouse gas emissions. On one hand, reduced driving time searching for parking, the potential for autonomous driving to be more fuel-efficient,

[1] Faisal, Asif, et al. "Understanding autonomous vehicles." Journal of transport and land use 12.1 (2019): 45-72.

[2] Medina-Tapia, Marcos, and Francesc Robusté. "Implementation of connected and autonomous vehicles in cities could have neutral effects on the total travel time costs: modeling and analysis for a circular city." Sustainability 11.2 (2019): 482.

reduced congestion, and disruptions to the decision-making systems that encourage the unnecessary growth in size of modern personal vehicles could very well reduce emissions. On the other hand, easier and faster travel and the widening of accessibility that fully autonomous vehicles will bring may boost car mode-share beyond levels consistent with our climate needs.[3] While difficult to know for certain, "it is quite possible that AVs could be more energy-efficient, thereby reducing the GHG by functional unit-basis as per-passenger-mile (ppm); however, the overall gain related to transportation GHG emissions could be swamped by a surge in increased vehicle miles traveled (VMT)"[4]. Whether driverless cars revolutionize transportation for better or worse, policymakers must be prepared for an influx of these new vehicles.



Potential impacts of autonomous vehicles on greenhouse gas emissions.[5]

According to recent data provided by the California Department of Motor Vehicles, 2021 was a record-setting year for miles driven by test-autonomous vehicles (AVs) in California.[6] Despite the sudden growth in AVs on public roads in recent years, municipal

[3] Massar, Moneim, et al. "Impacts of autonomous vehicles on greenhouse gas emissions—positive or negative?." International Journal of Environmental Research and Public Health 18.11 (2021): 5567.

[4] Massar, Moneim, et al.

[5] Massar, Moneim, et al.

[6] https://techcrunch.com/2022/02/10/fewer-autonomous-vehicle-companies-in-california-drive-millions-more-miles-in-testing/

governments have limited control over the regulation of AV testing and little access to basic information on the testing itself. This will pose a growing concern to local policymakers in the coming years as AV testing continues to spread. In California, AV testing oversight belongs to the DMV and the California Public Utilities Commission. This concentration of regulatory power at the state level makes it difficult to even determine the number of AV tests that have been conducted on Berkeley's streets, particularly because the DMV and CPUC do not require that AV companies report the whereabouts of their vehicles.[7] In order for the City to plan for the introduction of AVs onto public roads, use what limited regulatory abilities may be available, and lobby the state government to expand its oversight power, the Berkeley City Council must be made aware of all legal options for setting both AV testing rules and rules for functional AVs in a future where testing is complete and AVs are commercially available.

Beyond the testing of AVs that is expected to continue for many years, Berkeley must be prepared for a scenario where AVs are widely sold and threaten many of the City's transportation and climate goals. For the sake of safer streets and a reduction of fossil fuel emissions, the City of Berkeley is pursuing a growth in non-car transportation mode shares in its transportation, infrastructure, and planning policies. This pursuit may easily be threatened by the sudden availability of self-driving cars. The option for drivers to choose a vehicle that offers the present day convenience of an automobile with an added reduction in the actual requirement to drive the vehicle carries the possibility of undoing any progress made if no preemptive regulatory policies are made. While it will be many years before self-driving cars are available or even common on Berkeley's streets, the City must proceed with transportation planning that is cautious with AVs and committed to a future where cars are not the largest mode-share.

RATIONALE FOR RECOMMENDATION

It is important for the City of Berkeley to have a clear understanding of its exact responsibilities when it comes to autonomous vehicles and where state and federal bodies hold most power. With that knowledge, the City Council can lobby the state government and federal agencies both for more power over the regulation of driverless cars as well as for specific policies that Council determines should be enacted but lacks the power to do alone.

FISCAL IMPACTS

Staff time for the referral response.

ENVIRONMENTAL IMPACTS

Reducing the use of automobiles on Berkeley's streets is a critical task for the reduction of the City's fossil fuel emissions, an immense share of which come from private vehicle emissions.[8]

---

[7] https://www.sfexaminer.com/findings/how-san-francisco-became-an-autonomous-vehicle-test-course/

[8] https://berkeleyca.gov/sites/default/files/2022-01/Berkeley-Climate-Action-Plan.pdf~~https://www.cityofberkeley.info/Clerk/City_Council/2018/12_Dec/Documents/2018-12-06_WS_Item_01_Climate_Action_Plan_Update_pdf.aspx~~

CONTACT
Terry Taplin, Councilmember, District 2, (510) 981-7120

ATTACHMENTS

1. Understanding Autonomous Vehicles
2. ~~1.~~2. Impacts of Autonomous Vehicles on Greenhouse Gas Emissions—Positive or Negative?

JTLU

Understanding autonomous vehicles

Author(s): Asif Faisal, Md Kamruzzaman, Tan Yigitcanlar and Graham Currie

Source: *Journal of Transport and Land Use*, Vol. 12, No. 1 (2019), pp. 45-72

Published by: Journal of Transport and Land Use

Stable URL: https://www.jstor.org/stable/10.2307/26911258

The Journal of Transport and Land Use http://jtlu.org
Vol. 12 No. 1 [2019] pp. 45–72

JTLU

Understanding autonomous vehicles: A systematic literature review on capability, impact, planning and policy

Asif Faisal
Queensland University of Technology
asifiqbalmohammad.faisal@hdr.qut.edu.au

Tan Yigitcanlar
Queensland University of Technology
tan.yigitcanlar@qut.edu.au

Md Kamruzzaman
Monash University
md.kamruzzaman@monash.edu

Graham Currie
Monash University
graham.currie@monash.edu

Abstract: Advancement in automated driving technology has created opportunities for smart urban mobility. Automated vehicles are now a popular topic with the rise of the smart city agenda. However, legislators, urban administrators, policymakers, and planners are unprepared to deal with the possible disruption of autonomous vehicles, which potentially could replace conventional transport. There is a lack of knowledge on how the new capabilities will disrupt and which policy strategies are needed to address such disruption. This paper aims to determine where we are, where we are headed, what the likely impacts of a wider uptake could be, and what needs to be done to generate desired smart urban mobility outcomes. The methodology includes a systematic review of the existing evidence base to understand capability, impact, planning, and policy issues associated with autonomous vehicles. The review reveals the trajectories of technological development, disruptive effects caused by such development, strategies to address the disruptions, and possible gaps in the literature. The paper develops a framework outlining the inter-links among driving forces, uptake factors, impacts and possible interventions. It concludes by advocating the necessity of preparing our cities for autonomous vehicles, although a wider uptake may take quite some time.

Article history:
Received: March 28, 2018
Received in revised form: November 6, 2018
Accepted: November 6, 2018
Available online: January 28, 2019

1 Introduction

The convergence of technology and the city is seen as a possible remedy to overcome the challenges of urbanization such as climate change, congestion, and greenhouse gas (GHG) emissions (Yigitcanlar, 2016). Transport, as an integral part of the city, is responsible for about a quarter to one-third of GHG emissions (Kamruzzaman, Hine, & Yigicanlar, 2015; Arbolino, Carlucci, Cira, Loppolo, & Yigicanlar, 2017; Yigitcanlar, Foth, & Kamruzzaman, 2018). Technology in the name of smart urban mobility is

http://dx.doi.org/10.5198/jtlu.2019.1405
ISSN: 1938-7849

The *Journal of Transport and Land Use* is the official journal of the World Society for Transport and Land Use (WSTLUR) and is published and sponsored by the University of Minnesota Center for Transportation Studies.

becoming a key concept of the contemporary urban policy agenda to address the undesirable effects of transport (Creutzig et al., 2015; Perveen, Yigicanlar, Kamruzzaman, & Hayes, 2017; Perveen, Kamruzzaman, & Yigicanlar, 2017, 2018; Yigitcanlar & Kamruzzaman, 2018b).

As originally conceived within the smart cities agenda (Yigitcanlar, 2015; Lara, Costa Furlani, & Yiticanlaar, 2016; Trindade et al., 2017; Chang, Sabatini-Marques, da Costa, Selig, & Yigicanlar, 2018; Yigitcanlar et al., 2018a), the smart urban mobility concept is characterized by an integration of sustainable and smart vehicular technologies, and cooperative intelligent transport systems (ITS) through cloud-servers and big-data-based vehicular networks (Kim, Moom, & Suh, 2015). In other words, smart urban mobility is conceptualized as urban traffic services combined with smart technologies (Chun & Lee, 2015). Undoubtedly one of the most advanced applications that utilizes numerous ITS tools as a part of the smart urban transport system is autonomous vehicle (AV)—a.k.a. automated car, self-driving car or driverless car (Spyropoulou, Penttinen, Karlaftis, Vaa, & Golias, 2008; Chong et al., 2013; Olaverri-Monreal, 2016).

The basic concept of road vehicle automation refers to the replacement of some or all of the human labor of driving by electronic and/or mechanical devices (Shladover, 2018). Origins of the automated driving technology can be traced back to the early 20th century. At that time, the technology was concentrated on autonomous speed, break, lane control, and other basic cruise control aspects (Shladover, Su, & Lu, 2012; Anderson et al., 2014; Arnaout & Arnaout, 2014; Pendleton et al., 2017). However, only during the last decade or so, incubating conditions of the Digital and 4th Industrial Revolutions gave birth to rapid technological advancements in the field; resulting in numerous prototype AVs being trailed on the roads (Christie, Koymans, Chanard, Lasgouttes, & Kaufmann, 2016).

Many research articles have been published in the academic literature describing the technological advancement of AVs (Denaro, Zmud, Shladover, Smith, & Lappin, 2014). However, academic literature outlining the AV induced disruptions (both positive and negative) in cities and how policies are being introduced to promote or address various disruptive effects is fairly limited (Bagloee, Tavana, Asadi, & Oliver, 2016; Gruel & Stanford, 2016; Truong, De Gruyter, Currie, & Delbosc, 2017), despite a recent prediction suggests that by 2045, AVs would account for up to half of all road travel (Bansal & Kockelman, 2017; Litman, 2017). Even more so, there is no study, to our knowledge, in the academic literature that critically scrutinizes the state of AVs from a combined perspective focusing on its capability, impact and existing/potential policy interventions to reduce/foster the disruptive effects.

Against this backdrop, this paper aims to determine where we are at, where we are headed to, what the likely impacts of wider AV uptake could be, and what needs to be done for AVs to generate desired smart urban mobility outcomes—with a particular focus on the capability, impact and policy. In order to achieve this aim, the study undertakes a systematic review of the literature on AVs published in peer-reviewed journals. The review concentrates on the following research objectives: (a) Highlighting the main findings and contributions of the reviewed literature; (b) Mapping out the relationships among the capability, impact, planning interventions, and pre-deployment policy to accommodate AVs as well as to reduce the undesirable effects of AVs; (c) Determining the gaps in the literature and pointing out directions for prospective research. A key outcome of this research is the development of an AV driving forces, uptake factors, impacts and interventions framework.

2 Autonomous vehicles in a nutshell

2.1 Historical background

Vehicle automation was originally envisioned as early as in 1918 (Pendleton et al., 2017), and the first concept of automated vehicle was exhibited by General Motors in 1939 (Shladover, 2018). The initial phase of research and development (R&D) was jointly initiated by General Motors and Radio Corporation of America Sarnoff Laboratory in the 1950s (Shladover, 2018). From 1964 to 2003, several other R&D programs were operational in the US, Europe, and Japan under individual and joint initiatives of different government institutes and academia to develop automated bus and truck platoons, super-smart vehicle systems, and video image processing of driving scene recognition (Shladover, 2018). AV research was accelerated through the Defense Advanced Research Projects Agency's (DARPA) Grand Challenges Program in the US in 2004. The challenges resulted in AVs capable of traversing dessert terrain in 2005, and in 2007. Researchers also managed to place AVs on urban roads through the DARPA's Urban Challenge Program (Pendleton et al., 2017; Shladover, 2018). Since then, R&D continued at a fast pace in both academia and industrial settings.

Volvo, for instance, started its journey to autonomous driving in 2006, introduced its full autonomous test vehicle in 2017, and has plans to bring its unsupervised AV to the market by 2021. Tech giant Google started its journey towards full AVs in 2009, and by 2017 Google's AV fleet, WAYMO, has completed three million miles driving within four US states. In 2014, TESLA announced that its car will be capable of self-driving about 90% of the time. Today, all TESLA models are equipped with self-driving capability. By 2020, Audi, BMW, Mercedes-Benz and Nissan are expecting to have their AVs in the market.

Bloomberg (2017) provides an inventory of how cities around the globe are preparing for the transition to a world with AVs. According to this study, 36 cities were hosting AV tests, or have committed to doing so in the near future; where 18 other cities are undertaking long-range surveys of the regulatory, planning, and governance issues associated with AVs, but have not yet started piloting. The inventory considers of those piloting cities that were partnering on tests of a variety of AV products, including retrofitted autos and brand-new vehicles like conveyors (small, cart-sized AVs that travel on sidewalks). Testbed locations are generally isolated places from the rest of the city, such as technology parks, college campuses, urban renewal districts, highways, and former international mega-event sites. Therefore, as stated by Bloomberg (2017), while these trials are happening, they are not yet tackling the full challenges of navigating through complex urban environments. Table 1 lists the cities that are piloting (hosting AV tests or have committed to doing so in the near future) or preparing (undertaking long-range surveys of the regulatory, planning, and governance issues raised by AVs, but have not yet started piloting) themselves for an AV uptake.

Table 1. List of cities testing or in preparation for AVs (Bloomberg, 2017)

Piloting cities	Piloting cities (continued)	Preparing cities
Adelaide, AU	Melbourne, AU	Auckland, NZ
Amsterdam, NL	Oslo, NO	Buenos Aires, AR
Austin, US	Paris, FR	Cambridge, US
Boston, US	Pittsburgh, US	Columbus, US
Bristol, UK	Reno, US	Denver, US
Chandler, US	Rotterdam, NL	Dublin, US
Chiba City, JP	San Antonio, US	Los Angeles, US
Detroit, US	San Francisco, US	Montréal, CA
Dubai, UAE	San Jose, US	Nashville, US
Edmonton, CA	Seongnam, KR	Orlando, US
Eindhoven, NL	Singapore	Palo Alto, US
Gothenburg, SE	Toronto, CA	Portland, US
Haarlem, NL	Wageningen, NL	Rionegro, CO
Helsinki, FI	Washington, DC, US	Sacramento, US
Las Vegas, US	West Midlands, UK	Santa Monica, US
London, UK	Wuhan, CN	Seattle, US
Lyon, FR	Wuhu, CN	São Paulo, BR
Milton Keynes, UK	Zhuzhou, CN	Tel Aviv, IL

2.2 Autonomous technology

In line with the automation concept, a taxonomy of 4-level of vehicle automation was developed by the National Highway Traffic Safety Administration (NHTSA) in 2013 (Wadud, MaKenzie, & Leiby, 2016), and a 5-level automation was introduced by the Society of Automotive Engineers International (SAE) in 2014—later on updated in 2016 (Coppola & Morisio, 2016; SAE, 2016a, 2016b; Snyder, 2016; Milakis, van Arem, & van Wee, 2017). In 2016, NHTSA adopted SAE's taxonomy and automation levels (NHTSA, 2016). SAE's taxonomy and automation levels have become an industry standard, and also frequently referred in the academic literature (Rubin, 2016; Scheltes & de Almeida Correia, 2017; Walker & Marchau, 2017; Shladover, 2018). Table 2 describes the operational functions included in automated driving system (ADS), and the role of human driver at each level of vehicle automation.

Table 2. Taxonomy of road vehicle automation derived from SAE (2016a)

Level of automation	Automated driving system		Human driver	
	Operational function	Capability	Operational function	Capability
Level 1 (most functions are controlled by driver)	Control: lateral and longitudinal	In some driving modes	Localisation Perception Planning Management	In all driving modes
Level 2 (at least one driver assistance system is automated)	Control: lateral and longitudinal	In some driving modes	Localisation Perception Planning Management	In all driving modes
Level 3 (driver is able to shift safety-critical functions to vehicle)	Control: lateral and longitudinal Localisation Perception Planning	In some driving modes	Management	In all driving modes
Level 4 (fully-autonomous, but not in every driving scenario)	Control: lateral and longitudinal Localisation Perception Planning Management	In some driving modes	n/a	n/a
Level 5 (fully-autonomous, vehicle's performance is equal that of human driver in every driving scenario)	Control: lateral and longitudinal Localisation Perception Planning Management	In all driving modes	n/a	n/a

In theory, an automated vehicle system can only be termed as an "autonomous" system, when all the dynamic driving tasks, at all driving environment, can be performed by the vehicle's automated system. According to the Federal Automated Vehicles Policy of the US Department of Transportation, a vehicle is denoted as AV if it has levels 3-5 automated systems (DoT, 2016). However, these levels of autonomy are not strictly maintained in the literature and any level of autonomy is referred to as autonomous (Shladover, 2018). Throughout this paper, the term AV will refer to the levels 3-5 automated systems only.

Driving requires a variety of functions, including localization, perception, planning, control, and management (Coppola & Morisio, 2016). Information acquisition is a prerequisite to localization, and perception. If all of these functions, including information acquisition, are available in a vehicle, it could definitely be termed as an AV. If any AV has to communicate with other infrastructures to collect information, or to negotiate its maneuvers, it is termed as connected autonomous vehicle (CAV) (Shladover, 2018), and when any manually driven vehicle, whether manual or automated, has to communicate with other infrastructures to collect information, or to negotiate its maneuvers, it is termed as connected vehicle (CV) (Hendrickson, Biehler, & Mashayekh, 2014; Coppola & Morisio, 2016). Therefore, CV technology is complimentary or has synergistic effect on the implementation of AV to some extent (Shladover, 2018), though connectivity is not a mandatory feature of AVs (Hendrickson et al., 2014).

2.3 Perceived benefits

AVs are expected to be operational both as private and as commercial vehicle (Heinrichs, 2016; Collingwood, 2017; Wadud, 2017). One of the perceived advantages and flexibility of autonomous private car over the conventional private car is that it can simultaneously be used among all members in a family. Commercial AVs could be operated as taxi, bus, and freight services. AV taxis can provide service as a combination of conventional car-sharing and taxi services, which is referred to as shared AV (SAV) or driverless taxi (Fagnant & Kockelman, 2014; Krueger, Rashidi, & Rose, 2016).

Perception prevails that driverless taxi is likely to complement/supplement traditional public transit service, and it can potentially replace the private car and conventional taxis because SAVs are expected to be relatively inexpensive and facilitating opportunity for multitasking during a ride (Malokin, Circella, & Mokhtarian, 2015; Krueger et al., 2016; Milakis, Snelder, van Arem, Homem, & van Wee, 2017). In spite of having cooperation within the fleet, conventional taxi drivers seek to maximize individual profit, overruling minimum wait time and less passenger kilometers travelled (PKT), as identified by the fleet cooperation (Boesch, Ciari, & Axhausen, 2016).

Some transport network companies (TNC), such as Uber and Lyft, have been trying to develop a model similar to SAVs in their operations. However, in this model, human drivers are still responsible for routing, relocation, operation times, and many other decision-making factors. On the contrary, 100% central control system of SAV can overcome the limitations of conventional taxi services. Thus, SAV can ensure more system-optimal and overall profit-maximizing network with a higher service level and lower empty travel cost with respect to conventional taxi services, and TNCs (Fagnant, Kockelman, & Bansal, 2015). With a comprehensive ICT integration, SAV could facilitate dynamic ridesharing (DRS). Hence, SAV can either provide service with DRS or without DRS facility (Krueger et al., 2016).

The barriers to traditional ridesharing service could be overcome through the introduction of DRS (Krueger et al., 2016) or driverless taxi (Martinez & Viegas, 2017). The concept of "mobility-as-a-service" (MaaS) can also be accommodated with the introduction of SAV and DRS. Commercial operations like taxi, bus and freight service can benefit from automation through the postponement of driver costs (Wadud, 2017). Deployment of autonomous private car or taxi may reduce parking demand at urban core locations, repurposing those spaces for the use of other economic activity and in turn, it may act to increase urban density in central business district (CBD) locations (Bagloee et al., 2016; Levine, Segev, & Thode, 2017).

In contrast, reliability, comfort, and reduced perceived value of time may encourage long commute distances, contributing to urban sprawl and influencing real-estate values in ex-urban areas (Heinrichs, 2016; Rubin, 2016; Snyder, 2016). Integration of platooning features in freight and bus services, with the help of autonomous and cooperative technology, can play a vital role in increasing road capacity. These are few prominent and divergent examples of AV, considering its diversity in use.

The technological advancement and potential benefits of AVs, as discussed above, are linked together (Heinrichs, 2016). How are these benefits likely to be translated in the form and structure of urban systems? This research compiles evidence from published literature to address this question.

3 Methodology

This research applies a systematic review of the literature to achieve the research aim and objectives. A systematic literature review follows an explicit protocol for higher data reliability and for shaping the diversity of knowledge in a specific research field (Rowley & Slack, 2004; Brereton, Kitchenham, Budgen, Turner, & Khalil, 2007; Bask & Rajahonka, 2017). It aims at abating bias through comprehensive literature searches and delivers an evaluation trajectory for the reviewer verdicts, procedures and inferences (Burgess, Singh, & Koroglu, 2006; Bask & Rajahonka, 2017). The review involves three major activities: (a) Planning; (b) Realization or review; (c) Reporting and presentation (Tranfield, Denyer, & Smart, 2003; Bask & Rajahonka, 2017; Oliveira et al., 2017).

The above three activities were undertaken according to the methodological principles recommended by Oliveira, Márcio de Almeida et al. (2016) and Oliveria, Albergaria De Mello Bandeira et al. (2017): (a) Planning activity consists of identifying the need for revision (why), purpose of the review (what), and developing the protocol of the review (how, when and where); (b) Review activity including identification, selection, and inclusion of papers, evaluation of the selected papers, extraction of data and information, and synthesis of data; (c) Reporting and presentation includes preparing reports, and presenting results.

Firstly, a research plan involving the research aim and objectives, keywords, and a set of inclusion and exclusion criteria was developed. Research objectives were framed, to explore links among various aspects of AVs and thus to recognize promising areas for future research. As the keyword, we decided to use "autonomous vehicle" OR "automated vehicle" OR "driverless car" OR "self-driving car". To focus on the research objectives, we identified the inclusion criteria—peer-reviewed research articles in English language. An online search was conducted using a university library search engine that connects to 393 different databases including ScienceDirect, Scopus, Web of Science, Wiley online library, directory of open access journals (DOAJ), and so on. Edited or authored books, articles published in other languages, grey literature such as government or industry reports and non-academic research, and editorial papers were not included in the review. The search included only peer-reviewed and full text journal articles available online—procedia papers are considered as journal articles, due to relatively limited numbers of journal articles published on the topic.

Secondly, the search was conducted in January 2018 for journal articles published between January 2000 and January 2018. The review focused on the post-2000 articles due to limited studies focused on AVs prior to this date—particularly on the impact, planning and policy issues. Several thematic searches were specified through a combination of multiple keywords. The keywords used in all thematic searches were divided into two parts: The first part (specified by first parentheses) was directed to the title of the articles, and the second part was directed to the abstract. The resultant search items were initially checked by reading the abstract and then by reading the full-text in order to verify their scope against the research objectives.

The first thematic search was conducted using the search tag of ("autonomous vehicle" OR "automated vehicle" OR "driverless car" OR "self-driving car") AND ("control" OR "management" OR "localization" OR "lane change" OR "maneuver" OR "platooning" OR "merging" OR "crash avoidance" OR "cruise control" OR "navigation" OR "car-sharing" OR "multitasking" OR "valet parking" OR "capabilities" OR "features") to identify studies that focus on the AV capabilities. The search resulted in 616 papers, which were reduced to 49 articles after checking the abstract and further reduced to 16 articles after reading the full-text.

The next thematic search was conducted using the search tag of ("autonomous vehicle" OR "automated vehicle" OR "driverless car" OR "self-driving car") AND ("influence" OR "impact" OR "implication" OR "effect" OR "planning") keywords to identify articles that focus on the AV impacts. The search resulted in 154 papers. We have gone through the abstracts of these papers and limited the selection to 51 articles. After reading the full papers to make sure that they actually fit into our scope of interest, the selection was limited to 33 journal articles.

We conducted next search in the database using the search tag of ("autonomous vehicle" OR "automated vehicle" OR "driverless car" OR "self-driving car") AND ("policy" OR "law" OR "legislation" OR "legal") to identify papers that focus on the AV policies. The search resulted in 159 papers in total, which were screened through by reading the abstract (resulted in 29 articles) and full-text (resulted in 12 articles).

In total, 61 journal articles (peer-reviewed and full text available online) fulfilled our selection criteria, and these papers were then read again and reviewed. Following the selection, we categorized the reviewed papers according to subthemes. Then, we extracted data from the reviewed papers in tables, formulated according to the three subthemes (Appendix Tables A-C). Each table contained the following information against each of the selected article: name of authors, year of publication, title of the article, name of the journal, research aim/objectives, theoretical perspective/framework, method, and main findings.

Then, we discussed and linked up the individual findings of each subtheme into one. Some reviewed papers were discarded at this stage that did not match directly with the subthemes. This helped us to understand where we are at, where we are headed to, what the likely impacts of wider AV uptake are, and what needs to be done for AV to generate desired smart urban mobility outcomes.

The final stage of the review process was to write up and present our findings in the format of a literature review paper. In this process, some relevant literature, although not meeting the pre-determined selection criteria, are included as supporting material to better appreciate the background context and discuss the findings—e.g., books, book chapters, government policies, and online reports. With these, the total number of the reviewed and cited references is increased to over 150.

4 Results

4.1 General observations

In reviewing the literature, technological advancement, policy and legislation analysis, transport modelling and simulation, surveys and interviews, scenario analysis, and case study investigations were found to be the main techniques for qualitative and quantitative analyses in the reviewed 61 papers. These studies are assembled under three broad categories, namely: (a) AV capability—containing 16 studies; (b) AV impact and planning interventions—containing 33 papers; (c) AV policy—containing 12 articles. Review efforts found only 1 paper (peer-reviewed journal article) in the area of planning interventions. This indicates that there exists a gap in the literature in the planning area.

Papers in the AV capability category mainly discussed: (a) How AV operates on public roads; (b) What type of AV capabilities are currently available; (c) What sort of hardware and software are responsible for AV operation; (d) Barriers against the uptake of AV technology; (e) What type of benefits are offered by the AV capabilities.

Articles in the AV impact and planning interventions category mainly elaborated: (a) How perceived value of travel time changes; (b) What type of capacity implications might evolve; (c) How AVs will contribute to reduce road traffic accidents; (d) How AVs might increase or decrease congestion and delay; (e) Whether AVs will enhance or reduce GHG emissions; (f) How employment sector will be affected; (g) How public health can be benefited from AV deployment; (h) How SAVs can contribute in changing car ownership model; (i) How urban land use might be affected due to changes in parking demand, changes in travel time, changes in travel distance; (j) How capital investment decision will be affected. (k) What sort of planning interventions might be required to accommodate disruptions or to control disruptions. The impacts typically cover economic, societal, environmental, and political and governance aspects.

Papers in the AV policy category mainly examined: (a) How conflict can be avoided in between national/federal and state governments in formulating laws; (b) What the jurisdiction of national/federal and state governments should be; (c) How governments, industries, scholars, and professionals can negotiate and agree on formulating laws on liability and privacy; (d) Which organization should standardize or certify technology; (e) Which vehicle should get priority on the road; (f) What should be the new pricing mechanism to manage vehicle kilometers travelled (VKT).

The reviewed literature, in all categories, illustrate that research on AV is mainly limited to developed countries such as the US, the Netherlands, the UK, Canada, Australia, Israel, Germany, Italy, Singapore, Russia, Poland. This finding shows parallels with the AV piloting and preparing cities listed in Table 1. The oldest article reviewed in this study dates back to 2012 (Smith, 2012). Although there were other articles published prior to 2012, Smith's (2012) paper was the earliest published article that satisfied the selection criteria of this research. The majority of papers were published in 2016 onwards (84%)—indicating an exponential growth trend of research on this topic.

4.2 Capabilities

According to many, since the invention of the automobile technology about a century ago, the biggest change to personal mobility is happening right now with AVs (Volvo, 2017). In the presence of autonomous driving technology and capabilities, mobility is predicted to be safer, sustainable, and more convenient, as ADS of an AV will replace the human driver for all sort of dynamic driving tasks in some or all roadway and environmental conditions (Shladover, 2018). When AVs attain the capability of replacing human driver, it actually can perform five basic operational functions through its ADS—localization, perception, planning, control, and management (Coppola & Morisio, 2016; Pendleton et al., 2017). In doing so, AVs will possess certain technological features, advantages or capabilities over a conventional or human driven vehicle. These include platooning, fuel efficiency, eco-driving, adaptive cruise control with queue assist, crash avoidance, lane keeping, lane changing, valet parking or park assist pilot, traffic sign and signal identification, cyclist and pedestrian detection, and safe maneuvering at intersections (Anderson et al., 2014).

At a particular time, the predicted benefit offered by individual AV feature will largely depend on the AV price, acceptance, operational mode (private or shared), AV share in the traffic mix, level of automation in the traffic mix, and fuel efficiency (Diakaki, Papageorgiou, Papar]michail, & Nikolos, 2015; Davidson & Spinoulas, 2016; Daziano, Sarrias, & Leard, 2017; Piao et al., 2016; Chen, Gonder, Young, & Wood, 2017). These are seen as the influencing parameters of an AV scenario (Correia, & van Arem, 2016; Davidson & Spinoulas, 2016). AVs, however, might present a future full of nightmares resulting from different combinations within these parameters, especially if there do not exist adequate planning interventions.

A summary of the literature in this area is presented in Appendix Table A and discussed below.

- Platooning: Highly random and fluctuating car-following behaviors of human drivers are one of the main factors to prompt accidents, oscillations, and traffic congestion. This results in low efficiency in traffic flows and severe environmental impact in many urban regions (Hoogendoorn, van Arem, & Hoogendorn, 2014).

  To overcome these issues, Gong, Shen and Du (2016) developed a novel platoon car-following control scheme that modelled an interconnected dynamic platoon system of CAVs and AVs. Their proposed scheme effectively reduces disturbance transmission of speed errors and relative spacing from the leading vehicle to following vehicles along the platoon. This means that this scheme accomplishes the "string stability" of the platoon. In some other studies, it is also shown that the performance of the conventional cooperative adaptive cruise control (CACC) scheme is outperformed by the developed car-following control scheme in the capacity of achieving stable and smoother traffic flows and traffic oscillations reduction (van Arem, van Driel, & Visser, 2006; Gong et al., 2016).

  With the help of multi-platooning of AVs, Fernandes & Nunes (2012) performed another study to address the urban traffic congestion issue. In this study, they conceptualized design of a multi-platoon communicant AVs to travel along a dedicated lane, where AVs can exit from platoons to offline station and merge back into platoons along the main track following novel algorithms. According to the algorithms, inter-platoon leaders' constant spacing are ensured and offline station vehicles are allowed to leave and join the platoon on main track cooperatively. Simulation results of several scenarios confirmed that proposed algorithms guarantee high traffic capacity and vehicle density and reduce traffic congestion. Validation results of these features also proved that the proposed algorithms enable a clear benefit of a platooning system in comparison to bus- and light-rail-based transit systems (Fernandes & Nunes, 2012).

It is observed from the simulation models of Gong et al. (2016) and Fernandes & Nunes (2012), connectivity among the AVs within a platoon is a prerequisite to form a stable platoon string.

- Merging or Mandatory Lane Change: Most freeway congestion results from traffic oscillations (or stop-and-go) near freeway ramps, caused by merging activities (Zhou et al., 2017). Freeway sections near ramps are considered as the bottlenecks of the freeway system. In a merging situation, if different ratios of AVs equipped with longitudinal and lateral detecting technology, and advance cruise control (ACC) are penetrated on freeway with human driven vehicles, cooperative intelligent driver model (CIDM) of AVs could practically improve the freeway performance (Xiao & Gao, 2010; Zhou et al., 2017). The results from an experiment show that with an increased AV penetration on freeways, standard deviation of speed dispersion or oscillation caused by merged-in vehicle could be reduced progressively, i.e., road safety could be improved. It also shows that when the safe time gap is less than 1.0 second, AVs can improve travel efficiency by minimizing travel time (Zhou, Qu, & Jin, 2017).

  Altche, Qian, and de la Fortelle (2017) assumed a nearer plausible traffic scenario, where all vehicles have semi-autonomous features (ACC, automated braking and accelerating, lane keeping assistance), and are driven by human drivers. In such a scenario, a supervised coordination framework can remove the risk of collision or deadlocks with vehicles arriving from sides, either at intersections or roundabouts, or when merging on freeways (Dresner & Stone, 2008; Zohdy & Rakha, 2016). This framework mainly overrides human control inputs when they would become unsafe and create blocked situation in the defined supervisory area at intersections, roundabout, or merging points.

  Xie, Zhang, Gartner, & Arsava (2017) performed an optimization-based ramp control strategy in a CAV and AV environment to evaluate the performance of freeway due to presence of merging vehicle. Results of nine different combination of freeway and ramp vehicle inputs (veh/h) under three ramp control cases demonstrate that "optimal ramp control model" outperforms two other control cases: "gradual speed limit" and "do nothing" with regards to performance measurement indicators—average delay time, vehicle throughput and average speed (Xie et al., 2017). It is observed that all the three types of freeway merging algorithms, mentioned above can improve speed dispersion on freeway, road safety, travel efficiency, congestion level, average delay time, vehicle throughput, and average speed in a merging situation with the help of different level of autonomous features of AVs with or without V2V and V2I connectivity.
- Lane Changing: To progress towards a fully automated highway driving, the riskiest component added to the advanced driver assistance systems (ADAS) of an AV is lane changing maneuver. This maneuver is the riskiest and challenging in the sense that it involves ego vehicle's (vehicle under consideration, i.e., AV in this case) path change in the presence of other moving vehicles all around it as well as it has to consider changes in both the longitudinal and lateral velocity of the ego vehicle (Nilsson, Brannstrom, Coelingh, & Fredriksson, 2017). During the lane change attempt by a human driver, there are possibilities of collision with at least four vehicles—front and rear vehicles in the same lane, and front and following vehicles in the target lane (Bai, Quan, Fu, Gan, & Wang, 2017; Nilsson et

al., 2017). This sort of collisions can be avoided by selecting an inter-vehicle traffic gap and time instance to perform the lane change maneuver by executing a novel lane change maneuver algorithm in a mixed highway traffic environment with both human drivers and AVs with or without V2V and V2I communication (Nilsson et al., 2017), or in an AV only environment through vehicle to vehicle communication among the vehicles (Bai et al., 2017).

The collisions lead to probable consequences of loss of lives and traffic congestion. In addition to that, due to lack of determining a safe inter-vehicle gap and time instance to perform the maneuver, there exists oscillation, travel delay and capacity reduction in traffic flow (Nilsson et al., 2017). Automated lane changes can address about 4-10% of all accidents that are caused by human error (Luo, Xiang, Cao, & Li, 2015). Uncoordinated lane-changing and exiting behaviors by AVs can also considerably interrupt traffic flow by slowing down other vehicles, or even in worse scenario, by inviting accidents (Meissner, Chantem, & Heaslip, 2016; Talebpour & Mahmassani, 2016). Cooperative lane-changing of AV can ensure improvement of traffic stability, homogeneity, and efficiency, and reduction in traffic congestion (Nie et al., 2016).

- Valet Parking: Autonomous or valet parking is an obvious component of driver assistance technologies (Brookhuis, de Waard, & Janssen, 2001; Li & Shao, 2015). Three sequential steps- circumstance recognition, open-loop (when controller does not require verification of system output or modification of command to the system) motion planning and, closed-loop (information flows around a feedback loop) control execution, are responsible for successful autonomous parking (Lee et al., 2009; Li & Shao, 2015). AVs will not be capable of delivering its full benefits without having this feature as every trip has to be started from and end at a parking place. Relevant products have already been made available in the market by many of the original equipment manufacturers such as Tesla, Volvo, Audi, BMW, Ford, Land Rover, Mercedes-Benz, Nissan, and Toyota (Li & Shao, 2015).

Valet or auto-pilot parking features of AVs are expected to find cheap or free parking spaces after dropping off the passenger. This in turn saves travel time or cost for commuters or passengers because the passengers do not require: (a) Cruising for a parking space; (b) Walking to the vehicle to pick up; (c) Paying for costly parking (Zhang, Guhathakurta, Fang, & Zhang, 2015). Valet parking has also a number of technical advantages over traditional human-driven parking. It is capable of: (a) Avoiding dynamic obstacles; (b) Moving in the narrow passage parking areas; (c) Parking in a narrower space; (d) Ensuring optimization of gear changes; (e) Avoiding crash occurrence; (f) Finding fastest and shortest parking path; (g) Minimizing search time for parking spot (Fagnant & Kockelman, 2015).

The abovementioned significant AV capabilities have the capacity to induce or affect certain transport system variables (TSV) and as a consequence these variables will disrupt environment, investment, health, employment, infrastructure design, and land-use options. Some of the effects may contribute to the society in a better way, while society may be worse off in others. Timely control of TSV through adoption of short-, mid-, and long-term planning and policy options by concerned national, state and local governments can help in materializing wider AV deployment if this is considered appropriate (Coppola & Morisio, 2016).

4.3 Impact and planning interventions

The extent of AVs' impacts to the society largely depends on their share in the total vehicle fleet (Pinjari & Menon, 2013; Litman, 2017) and level of the AV uptake and usage differentiated by—(a) Light use: private or shared (Gruel & Stanford, 2016; Heinrichs, 2016; Dia, & Javanshour, 2017); (b) Heavy use: bus (Smolnicki & Sołtys, 2016) or freight (Wadud, 2017). Impacts begin with a shift in transport demand and supply variables equilibrium (Childress, Nicholos, Charlton, & Coe, 2015; Rubin, 2016), necessitating obvious adjustments in planning with new ideas, and innovations (Zakharenko, 2016).

The impacts, from a system level to societal level may have ripple effect on each other at multiple levels (Milakis, van Arem, & van Wee, 2017).

The probable areas of influence at a transport system level (either on supply side or demand side), include VKT, PKT, vehicle hours travelled (VHT), value of time (VOT), speed, capacity, headway, traffic flow, delay, travel cost, vehicle operating cost (VOC). These will further affect planning parameters in general such as infrastructure design, transport modelling, capital investment, car ownership, land use, employment, energy consumption, traffic safety and public health, environment (Dixit, Chand, & Nair, 2016). Planning authorities at local and state levels have to cope with the expected disruption in certain cases and impose planning and policy measures to control rest of the disruptions.

A summary of the literature in this area is presented in Appendix Table B and discussed below.

- Infrastructure Design: Road infrastructure will require new design criteria as lateral and longitudinal capacity of the roadway might be changed due to lane keeping and platooning respectively. Lane width might be reclaimed due to more accuracy in maintaining lateral alignment (Smith, 2012). To improve network performance and vehicle throughput, AVs might require dedicated road network in certain areas (Chen, He, Yin, & Du, 2017). Considering the impacts on infrastructure design, literature suggests the following planning recommendations (Hendrickson et al., 2014): (a) Pavement marking may require repainting; (b) No changes are expected in the design of clear zone; (c) Radio advisories and ITS message signs may or may not be obsolete depending on the presence of connectivity in automation; (d) Dedicated short range communications (DSRC) locations for traffic signals have to be identified and prioritized in case of automation with connectivity.
- Car Ownership: Flexibility of SAV and its operation would reduce operational and fixed cost and thereby reduce car ownership (Milakis, van Arem, & van Wee, 2017). The results of an agent-based modelling of different SAV scenarios indicate that each SAV can replace around eleven conventional cars (Fagnant & Kockelman, 2014). Due to exclusion of driver's talent and time, driverless taxi or autonomous car sharing program paves the way to be a cheaper travel option and may discourage traditional car ownership (Bagloee et al., 2016). Though this may be highly unlikely, some visions of pooled/shared ownership of AVs suggest that there could be no need to own private motor vehicles at all in the future (Levin & Boyles, 2015)—also see Ma, Zheng, and Wolfson (2015) for a model on real-time city-scale ridesharing. Planners may replace numbers of conventional on-street and off-street parking facilities by ensuring provision of few suburban multistory garages. They may also execute pickup and drop off points for AVs near transport hubs by eliminating existing paid and unpaid parking lots. This will promote tech- and transit-oriented developments (TTOD).
- Employment: Reduction of traffic congestion, travel time savings, and lower transportation costs of goods could be achieved at the expense of individuals, currently employed in building, driving, and maintenance of automobiles (Crayton & Meier, 2017). Spilling effects in labor market might be a reality due to falloffs in certain related jobs, like diver licensing, traffic policing, and insurance sales (Crayton & Meier, 2017). Moreover, a future with fewer vehicles would also lead to fewer jobs in the automotive industry as a whole (Snyder, 2016). In contrast, Gill, Kirk, Godsmark, & Flemming (2015) predicted potential employment gains in three sectors up to 15%—conversion of parking facilities related construction, roads and highways modification, and IT product and services. State or federal governments might declare rehabilitation package, especially for the abundant drivers of taxi, bus and commercial vehicles. Governments might also arrange specific training depending on the eligibility of drivers so that they can find a job in new sectors. Currently employed automobile technicians and mechanics can be trained up for new technology and this will help them to be remain in the same track without losing job. Automobile industries can also support government's novel initiatives with financial contribution.

- Energy Consumption and Emissions: Practically, fuel/energy consumption of any transport mode depends on travel activity performed by that mode and energy intensity (consumption per kilometer) of that particular mode, and emission is the product of energy consumption and fuel carbon content (Wadud et al., 2016). Automation might plausibly reduce road transport energy consumption and GHG emissions by approximately half—or nearly double them depending on automation level, AV features, use type, and policy intervention (Wadud et al., 2016).

  Litman (2017) predicts that a major share of AVs in road transport will contribute to energy conservation by 2040-2060. Chen, He et al. (2017) indicate that vehicle automation may contribute 45% savings on fuel consumption in optimistic scenario and 30% fuel consumption in pessimistic scenario. Another study shows a 37% of energy savings is possible when AVs are used in conjunction with public transport in lieu of personal car (Moorthy, De Kleine, Keoleian, Good, & Lewis, 2017). On the other hand, large share of SAV fleet could improve fuel efficiency by abandoning highspeed and rapid acceleration of car (Milakis, van Arem, & van Wee, 2017). Liu, Kockelman, Boesch, & Ciari (2017) show that introduction of SAV systems can save 22.4% of total distance-based fuel consumption and this savings cannot be negated by extra VKT.

  Large share of SAV fleet could also limit emissions by abandoning highspeed and rapid acceleration of car (Milakis, van Arem, & van Wee, 2017). Possibility of total distance-based (lifecycle and driving cycle) savings of GHG emissions is 16.8-42.7% due to introduction of SAV systems, and this savings cannot be negated by extra VKT due to AV's advancement, eco-technologies, and change in energy source (Liu et al., 2017). Another study in Lisbon city shows that replacement of conventional private car, taxi and bus by self-driving shared taxi and taxi-bus, keeping existing metro service could contribute in reducing carbon emissions (Martinez et al., 2017). It is also estimated that electric driven autonomous taxis could significantly reduce GHG emissions in 2030 with respect to current conventional and hybrid vehicles (Greenblatt & Saxena, 2015). Smith (2012) predicted reduction of emissions per VKT with an overall increase in total emissions.

  It can be summarized that automation related road transport energy consumption and emission figures are still uncertain in their magnitude. This is because energy consumption and emissions are generally not a direct consequence of automation, rather it is affected by changes in vehicle operations, vehicle design, choice of energy, policy intervention, or transportation system design, which are more indirectly facilitated by automation (Wadud et al., 2016). Policymakers probably have to consider VKT based pricing to substitute earlier fuel tax, if energy source is shifted from fossil fuel to electricity. This is a step toward safeguarding government's financial revenue on the eve of electric vehicle. Government can also promote green vehicle operation by allowing less tax on vehicle purchase price and by reducing vehicle registration fee.
- Traffic Safety and Public Health: Until now, no empirical proof is established about the overall safety advantages of AVs (Winkle, 2016). Most of the investigation related to AVs' potential for crash protection was performed considering assumed AV deployment and market penetration scenarios. These assumptions were based on expert estimates, third-party forecasts and relevant database.

  The German In-Depth Accident Study (GIDAS) and NHTSA crash databases show approximately 93% of road crashes happen due to human error, and it has been speculated that this figure might be completely ruled out in case of full automation of vehicles. Even level 0, and level 1 features of AVs have the potential to minimize one third of the traffic accidents (Bagolee et al., 2016). Daimler, manufacturer of Mercedes-Benz, published a forecasting models on vehicle-safety and crash research in 2010, which suggests increased automation can result in a reduction of crashes by 10% by 2020, 50% by 2050, 71% by 2060, and a total reduction by 2070 (Winkle, 2016). A US study projected that conversion of 10% and 90% of US vehicle fleet to AV would respectively act to reduce annual crashes by 0.2 and 4.2 million, and it could respectively save 1,100 and 21,700 human lives annually (Collingwoood, 2017).

Yet, adjustments of driving behavior in relation to levels 1-3 automation features may invite accidents in many cases (Milakis, van Arem, & van Wee, 2017). However, new crash risks may emerge due to automated system failures in certain cases, and road users may favor additional risk-taking behavior assuming the AV system's perceived and actual competencies (Litman, 2017). By assuring road safety through higher level of AVs, ripple effect of accident related tangible and intangible costs like medical costs, legal costs, insurance and administrative costs, emergency service costs, workplace losses, and property damages can be minimized (Bagolee et al., 2016). This will help federal or state governments to reconsider their budgets in the near future.

- Capital Investment: AVs might act to reduce proposed existing road expansion investment as platooning might significantly increase road capacity—as much as five times by one source (Fernandes & Nunes, 2012). That is why, the literature recommends re-evaluating planned road system capacity enhancement projects before making final investment decision. It has also been suggested that ITS and level of service (LOS) investment projects are assessed for compatibility with CAV fleets (Hendrickson et al., 2014).
- Land Use: AVs will either promote urbanization or promote suburbanization. In reality, transport network will tend to flow in between these two scenarios, depending on transport and urban planning policy, prevailing local conditions, and dissemination of different driverless mobility solutions (Smolnicki & Sołtys, 2016).

At the regional level, accessibility improvements through lower generalized cost of transport due to vehicle automation will result in ex-urbanization to remote areas of former inner city, leading to attractive green urban sprawl surrounding metropolitan regions (Bagolee et al., 2016; Crayton et al., 2017; Milakis, van Arem, & van Wee, 2017) with lower house prices (Heinrichs, 2016), and decline in rent outside CBD (Zakharenko, 2016). AVs' favor towards urban sprawl may prove transit service superfluous except for dense urban areas (Meyer, Becker, Bösch, & Axhausen, 2017). Urban sprawl is also subject to availability of land and land-use policies (Yigitcanlar & Kamruzzaman, 2014; Milakis, van Arem, & van Wee, 2017).

At the urban/local level, presence of commuting AVs and SAVs (with or without dynamic ride sharing) may free up daytime downtown on-street and off-street parking spaces (Bagolee et al., 2016; Heinrichs, 2016; Zakharenko, 2016; Milakis, van Arem, & van Wee, 2017). Different spatial distribution of urban parking demand will be evolved against different SAV operation strategies and client's preferences (Zhang et al., 2015). The results of an agent-based model show that the clients adopting SAV system in lieu of conventional private car can eliminate up to 90% of parking demand at a low market penetration rate of 2% (Zhang et al., 2015). On the other hand, SAVs have the potential to tackle the transport related-social exclusion (Duvarci, Yigitcanlar, & MizoKami, 2015; Kamruzzaman, Yigitcanlar, Yang, & Mohamed, 2016; Yigitcanlar, Mohamed, Kamruzzaman, & Piracha, 2018).

Driving robots' capability of valet parking may promote neighborhood parking zones or collective garages in the inner-city districts. The presence of auto-valet garages will allow more vehicles to be parked and creates the possibility of increasing density of urban core areas by repurposing released parking spaces due to less demand for parking in CBD areas (Heinrichs, 2016). The saved off-street parking spaces could be repurposed for infill residential and commercial development, allowing increase in economic activity to contribute to the further CBD density (Bagolee et al., 2016; Milakis, van Arem, & van Wee, 2017), and the saved on-street spaces could be transformed into HOV lanes, bus lanes, cycle lanes, or new public spaces (Milakis, van Arem, & van Wee, 2017).

Possibility of significant increase in road capacity through platooning—as much as five times (Fernandes & Nunes, 2012) could save road spaces that might be reallocated to other travel modes—like buses, cycling and walking. In an ideal condition, where all the vehicles in roads are fully autonomous, highway capacity might increase around 100% (Farmer, 2016).

Regulatory body may think about limiting the projected increased AV traffic. Because in presence of public transit, under certain conditions AVs will connect to the transit without entering CBD (Zakharenko, 2016). Local and state government authorities have to decide whether they will allow or limit urban sprawl. It should be exclusively bounded by city's land-use policy. Moreover, most of the state and local authorities should decide reallocation of city's road space and parking spaces depending on nature of travel pattern and traffic behavior in a new form of traffic mix.

Considering too many aspects of AV impacts, Isaac (2016) recommended generalized medium- to long-term planning activities. Medium- and long-term planning activities include: (a) Updating transport model with new assumptions; (b) Forecasting financial revenues; (c) Designating traffic lanes for simultaneous operation of AV and/or conventional automobile; (d) Updating traffic signs and markings; (e) Reducing lane widths; (f) Adjusting speed limits, traffic signal locations and timing; (g) Eliminating or reducing parking spaces and add more drop off/pick up locations; (h) Reclaiming city center surface parking lots for potential future developments; (i) Reclaiming right-of-way for people and other mode of transport; (j) Doubling use of the suburb on-street parking areas as charging stations; (k) Developing new predictive models for pavement maintenance.

4.4 Pre-deployment policy

Higher level of vehicle automation poses regulatory challenges for the AV manufacturing countries (Nowakowski, Shladover, Chan, & Tan 2015). The uptake of a new technology like AV should be regulated through federal and state governments' pre-deployment policy. Major regulating policies are revolving around testing and deployment, cybersecurity and privacy, liabilities and insurance, ethics, and repair/maintenance and calibration. Proactive actions in this regard may ensure rapid AV uptake in some jurisdictions and reactive or inert actions may delay the whole uptake process in some other jurisdictions. As an example, AV legislation and policies in the US, the Netherlands, the UK and Sweden are paving the way for other countries (Nowakowski et al., 2015, Vellinga, 2017). However, the first fatal crash by a self-driving UBER involving pedestrian in the US proves that more research, development, legislation and planning are needed for a safer and wider AV uptake.

A summary of the literature in this area is presented in Appendix Table C and discussed below.

- Testing and Deployment: Two main aspects in relation to AV operation, to be bounded by regulation, are testing and deployment. These two main challenges are linked with devising regulations in this particular area to ensure safety without hindering innovation, and defining meaningful requirements or standards without having such technical standards for ADS in place (Nowakowski et al., 2015). Another significant concern focuses on how to maintain legal consistency in different jurisdictions to avoid confrontation with AV manufacturers and to encourage innovation (Vellinga, 2017). Around the globe, policymakers are yet to establish such a consistent legal ground for AV design, testing and deployment. Regulating bodies and practiced legal instruments used by these bodies are also different from each other. Some authorities follow "binding regulation," some follow "non-binding regulation," and some other follow "granting exemption" (Vellinga, 2017).

  In the US, technology aspects of vehicle safety are regulated by federal government agency, and other safety aspects related to vehicle registration and driver's training, evaluation, and licensing are the functions of state government (Nowakowski, Shladover, & Chan, 2016; Vellinga, 2017), but in the UK and the Netherlands, federal government agencies regulate all aspects of vehicle safety for testing and deployment (Vellinga, 2017). Currently, the US federal government agency NHTSA and the UK Department of Transport (DoT) is in favor of non-binding test and deployment regulations for AV under the cover of national policy and code of practice respectively. On the contrary, one of the US states, California has binding legislations in place to regulate the testing and deployment of AVs. Against the backdrop of binding and non-binding regulations and policy, Dutch Vehicle Authority (RDW) granted exemptions to AV from certain laws under certain conditions.

NHTSA provides guidance for both manufacturers and states, though these are not mandatory to abide by. Manufactures involved in designing, developing, testing and selling should follow the NHTSA policy and guidance to ensure safe testing and deployment of AVs on public roads, and states should follow the policy to prevent inconsistencies in AV laws and regulations among the states. The main exception of the UK Code of Practice over NHTSA policy is that it also addresses the requirements about the test driver. RDW grants the exemption to AV testing on public roads with test specific conditions once all the functionalities to be tested are passed on test track. Both the "binding regulations" and "exemption under conditions" are legally binding for manufacturers to ensure safety during testing (Vellinga, 2017). Though "exemption under conditions" poses legal uncertainty for manufacturers, it flourishes technical developments. On the other hand, non-binding regulation can guide manufacturers or testing organizations to adjust with continuous changes in regulation with advancement in technology (Maurer, Gerdes, Lenz, & Winner, 2016).

- Privacy and Cybersecurity: AV will essentially be equipped with tracing technology to recognize accident causing factors and consequently to mitigate product liability (Bruin, 2016). At the same time, AV equipped with such technology might have serious impact on information privacy of the persons in side or around such vehicles. Manufacturers should be held responsible if AV fails to comply with laws associated with protection of personal data (Bruin, 2016). Privacy mainly relates to control over autonomy, information, and surveillance when it comes to AV (Glancy, 2012). Personal autonomy is one's ability to make choices independently about oneself. Use of AV inherently affect autonomy by taking over human control in the way people move one place to another (Collingwood, 2017). Personal information privacy can be violated as AV will collect, store, use, own, transfer, or destroy data/information due to improper or non-existent disclosure control (Collingwood, 2017).

As an example, transmission of present location, past travel pattern, and future travel plan could compromise privacy of AV user. Personal information collection through comprehensive legal and illegal AV tracking will affect privacy associated with surveillance. To protect the privacy associated with AV, generated data ownership pattern and limit of onward data transmission and its usage have to be finalized in the upcoming data privacy act of different countries. To protect the different privacy interests, legislators and regulators should have answers of following questions—Why it is collected, what will be the uses of personal data. How long data should be preserved. Who can and cannot have access to it. Glancy (2012) argued that, without suitable legal safeguards for privacy, AV could face challenges of "market resistance" from prospective users who recognize AV as threats to their privacy.

On the other hand, at the advent of increased computerization and networking, AVs are accumulating autonomous capabilities and are inviting cyber-threats as permanent allies (Yagdereli, Gemci, & Aktas, 2015). One of the main cause of ADS failure is cyber-attacks and software and hardware defects. Hence, this system should be equipped with such defensive system that can respond automatically and dynamically to deliberate and inadvertent attacks and defects (Yagdereli et al., 2015). A cybersecurity system should primarily safeguard on-board data storage, data sharing (Lee, 2017). Cybersecurity concerns should be bounded by regulatory action to protect consumer interests and promote future growth against autonomous unmanned system vulnerabilities. Considering rapid growth and interstate nature of AV technology, Lee (2017) emphasizes federal government to take charge of formulating nationwide regulatory framework for communications, privacy, and cybersecurity pertaining to this technology. Within the federal framework, states and industry should conduct experiment and develop self-regulation. In line with formulated regulations AV cybersecurity requirements should be determined and documented in the systems' requirements documents and it should be done before the design of the system (Yagdereli et al., 2015).

- Liability and Insurance: Data obtained through on-board vehicular systems and sensors of ADS can provide sufficient details of an accident to determine many liability decisions with high degree of precision (Dhar, 2016). This will help to identify "at-fault" driver or vehicle and ensure quick processing of insurance payment to victim. This accurate identification of accident related physical factors to environmental factors to human factors would eventually quash delays and litigation costs linked with tort laws and also exclude necessity for no-fault insurance, which is alive at dozens of US states at the moment.

  Though emergence of AV makes fault identification accurate and smoother than before, it also raises a big question: who will be held responsible for the accident: driver (till SAE level 3), owner, operator, or manufacturer. ADS of AVs serve generally a robotic function and raises novel issues in criminal law as robot can malfunction and cause serious harm to people and property. As robotic systems are inappropriate for criminal punishment, humans who produce, program, and deploy robots should be subject to criminal punishment if the robots are intentionally used to cause harm to others (Gless, Silverman, & Weigend, 2016). However, Gless et al. (2016) advocates in favor of limiting the liability of vehicle operators, if they undermine to initiate reasonable measures to control the risk originated from ADS.

  In the US, states are responsible for liability regimes and insurance (Vellinga, 2017). The Californian draft AV Express Terms suggested that the manufacturer should be held responsible in case of collision or accidents caused by AV and that has to be covered by proper insurance. The Dutch law intended to hold the possessor of AV liable for development risks as they cannot invoke the defense that can be called on by the manufacturer (Vellinga, 2017). The UK proposal discussed first party insurance option for the victim but it did not suggest any other substantial changes in liability rules (UK Parliament, 2016). In this case, victim, regardless of liability, can claim from his insurer and later, insurer can recover the amount from the manufacturer—if manufacturer is found liable. Sweden is practicing first party insurance model since 1975 (Schellekens, 2015).

  If the liability of human driver or owner of the car would shift to manufacturer in case of collision, this might slow down the progress of AV development (Vellinga, 2017). In addition to this, insurance companies may become less interested to insure the high risk of AVs. This issue can be addressed by limiting the amount of damages one can claim due to the fault of AV. In parallel government could be a reinsurer to encourage the insurance companies to insure AVs (Vellinga, 2017).

5 Discussion and conclusion

Within the contemporary smart city debate, AVs represent a way to create an ideal city form and developments in the autonomous driving technology have the potential to bring smart mobility to our rapidly urbanizing world; but for others AV is a branding hoax (Yigitcanlar & Lee, 2014; Yigitcanlar & Kamruzzaman, 2018a). Despite a large body of recent literature on AV's, only a limited number of studies have outlined the disruptive effects that AV might bring on city planning and society in general. This paper, through a systematic review of the literature, aimed to determine the current state of research literature on AV technology, the future direction that this technology is leading to, how the changes are likely to affect our day-to-day travel behavior and long-term changes in the structure of our cities, and what would be the likely policy tools for a smooth transitioning of the technology.

As the literature suggests, AVs' major disruptions in our cities will be in urban transport, land use, employment, parking, car ownership, infrastructure design, capital investment decisions, sustainability, mobility, and traffic safety. It is clear from this study that preparing our cities for AVs through progressive planning is critical to achieving the benefits and to address the resulting disruption. On the eve of rising AV demand, local and state governments should be equipped with better policy and planning tools to accommodate AV technology and its impacts. In parallel, timely interventions from international, national/federal and state levels in terms of regulating, standardizing and certifying this technology and approval of appropriate legislative measures to ensure testing, deployment, privacy, security, and liability issues are addressed. These are discussed in the following sub-sections in detail.

5.1 Driving forces, uptake factors, impacts and interventions framework

This paper has investigated the AV phenomenon from the perspectives of AV capability, impact and planning interventions, and pre-deployment policy. Research area covered under this study is only a small part of a broader framework. Based on the findings of the reviewed papers, the study synthesized a broader framework—for AV driving forces, uptake factors, impacts and interventions—illustrated in Figure 1 and discussed below.

Any new innovation demands external thrust or driving forces from social, political, economic, environmental, and technological sectors that might push forward or pull back the key factors responsible for uptake of that very new innovation. With the help of a force matrix, by awarding score against uncertainty and impact of each force, most influential forces behind the key uptake factors can be ranked. Future plausible scenarios of any new technological innovation uptake are the product of multiple combinations of the highly ranked influential driving forces. In the case of AV uptake, relevant driving forces are technological advancements, economic conditions, customer attitudes, environmental conditions, and government policies. Plausible AV scenarios emerged through any two high ranked influential forces might be termed as AVs in boom, in demand, in standby, or in doubt. The prominent uptake factors under any plausible AV scenario that might lead to changes in values of transport system level variables are AV type, AV growth trend, AV automation level, AV fuel type, AV capabilities, and so on.

Each future plausible AV scenario generally owns a set of AV supply parameters that can act as input parameters for transport modelling. Inclusion of these new modelling input parameters in existing transport modelling exercise can signify impact of AV uptake patterns through expected changes in output parameters. From the modelling output one can identify the changes in demand parameters from scenario to scenario at transport system level. The demand parameters value might roam around VKT, individual driving speed, per capita distance travelled, per capita generalized cost, per capita travel item, parking demand, per capita travel cost, and mode share by trips. This will dictate the quantitative and qualitative changes in societal parameters—see societal impact box in Figure 1.

Finally, decision-makers and planners have to counteract with intervening planning and policy initiatives in the necessary disruptive areas so that optimum benefits from AV can be realized for a city. In this case, the framework highlights some of the prospective areas of planning and policy interest. These are congestion pricing, lane width reduction, new modelling assumptions, on-street charging points, reduction in on- and off-street parking spaces, introduction of zonal parking garages, adjusting signal location and timings, adjusting speed limits, and optimizing AV share.

As the paper investigated the AV phenomenon from the perspectives of capability, impact, planning interventions, and pre-deployment policies, it focused on few of the selective parameters from each block of the described framework. In relation to the framework, this paper mainly researched one of the driving forces vigorously—pre-deployment government policy. The reviewed pre-deployment government policies are—testing and deployment, privacy and cybersecurity, and liability and insurance. Out of the mentioned uptake and penetration factors, we elaborated the capabilities of AV. The reviewed areas of capabilities are platooning, merging, lane changing, and valet parking. In the area of AV's societal impacts and counter measure to negotiate those impacts, the paper reviewed infrastructure design, car ownership, employment, energy consumption and emission, traffic safety and public health, capital investment, and land use.

By analyzing our research area, it is understood that pre-deployment government policy and AV capabilities have lot of contributions in assuming or estimating transport model input parameters. On the other hand, changes in model output parameters can be directly or indirectly translated into societal impact or disruptions. This will ultimately lead to short-, medium-, and, long-term planning and policy interventions at the local, regional, and state levels to address various disruptions or the impacts of AVs.

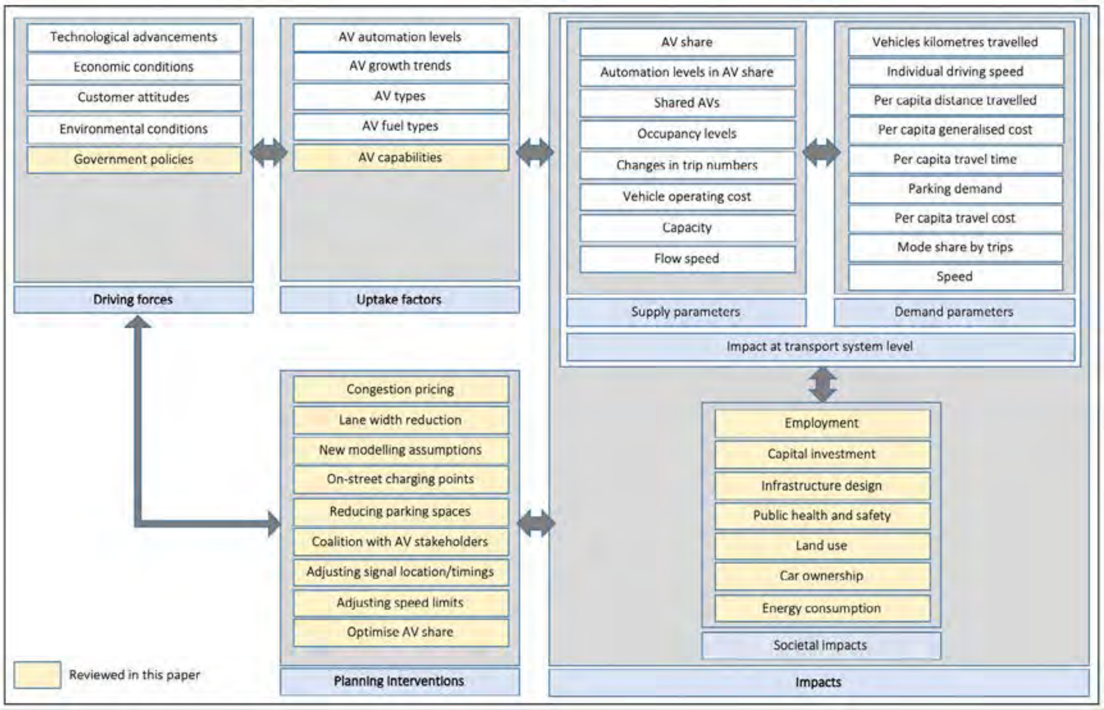


Figure 1. AV driving forces, uptake factors, impacts and interventions framework

5.2 Research implications

The review of the literature suggests that most studies to date are optimistic about the potential benefits that AVs might bring to cities. Rarely have these assumptions been critically examined. In many cases the potential benefits as being advocated are more theory than practice. For example, almost all studies accepted the crash reduction rate (by 90%) with AVs because human error is responsible for most crashes. They assume that when humans are not in charge of driving, crashes would not happen; a rather heroic assumption. These studies do not consider a myriad of issues that can might cause an AV to be involved in a crash such as software failure, factors that are not included within the AVs' artificial intelligence, failure to recognize a new street layout pattern, and so on.

Additionally, frequently claimed benefits of AVs in the literature are that they will reduce congestion through optimum use of road spaces using the platooning technology. These studies rarely consider the scenario that an effective platooning will only work if all AVs are travelling from a defined origin to a defined destination in a dedicated lane. However, trip origins and destinations vary from person to person which implies that AVs will have to frequently change lanes for entry and exit. Moreover, if a non-AV enters into a platoon, the efficiency of platooning will reduce. More importantly, the saved road spaces are likely to be occupied by the induced trips expected to be generated by less mobile people today. Furthermore, the passenger multitasking benefits within AVs may act to increase suburbanization and urban sprawl resulting in additional VKT, and ultimately consume more road space. The prevailing implication that AV's will increase sharing including higher car occupancy also seem weak and should be explored using research on human factors and by investigating AV trial outcomes.

The findings of the review also suggest that effective policy can: (a) Reduce the reliance on traditional vehicles (including AVs); (b) Foster the use of autonomous public transport vehicles (AVPT); (c) Discourage and reduce sprawling development. These are elaborated below:

- In terms of policy to reduce traditional low occupancy private motor vehicle dependency there is a significant supporting literature (Banister, 1997; Newman & Kenworthy, 1999; Yigitcanlar, Fabian, & Coiacetto, 2008; Kamruzzaman, Yigitcanlar, Washington, & Currie, 2014). The policy and planning aspects discussed in the urban and transport planning and urban studies literatures without a specific focus on AVs are also relevant to the AV context (Firnkorn & Müller, 2015; Newman & Kenworthy, 2015). This indicates that there is still a need for further conceptual and empirical explorations for figuring out how to develop and implement AV-related policies and plans to obtain desired outcomes.
- As for the policy to increase the patronage of AVPTs, there is limited research and knowledge. Will the factors (both pull and push) influencing public transport patronage be valid for AVPTs with the widespread deployment of personal AVs or SAVs? The common logic suggests that AVPTs patronage would increase only in the case of convenience of private motor vehicle or private AV is offered. The convenience factors include access to public transport stops (Murray, Davis, Stimson, & Ferreira, 1998; Yigitcanlar, Sipe, Evens, & Pitot, 2007), weather and climatic conditions to access and use public transport (Kashfi, Bunker, & Yigitcanlar, 2015a, 2015b), travel time, cost and in-vehicle conditions (Beirão & Cabral, 2007). Owczarzak and Zak (2015) built a decision model based on the concept of public transportation on demand based on AVs. They find reliability and safety of AVPTs (unlike traditional determinants such as fare, and travel time) will be the key determinants of user acceptance and thus increased patronage (Lamondia, Fagnant, Qu, Barrett, & Kockelman, 2016; Becker & Axhausen, 2017). Similarly, Payre, Cestac, and Delhomme (2014) highlight the importance of acceptance of the technology in its wider roll out. This calls for further empirical investigations both on user confidence and policy formulation aspects of AVPTs.
- In terms of policy to discourage and reduce the sprawling urban development, there is not much research besides some warnings and speculations. For instance, Lari, Douma, and Onyiah (2015) warned us that the decreased travel costs in terms of time and energy (as may be generated by AVs) could result in people living further from urban centers, which would likely to create urban sprawl. The sprawl issue seems to be the biggest challenge for urban policy and planning, hence, there is an urgent need for empirical studies to model the impacts of AVs on our cities, and then develop competent planning policies and actions to address these challenges. Urban policy makers should take this issue seriously.

5.3 Limitations and research directions

The following research limitations should be considered: (a) Exclusion of literature outside the peer-reviewed full text articles available online, might limit the spectrum of the review as a relatively new field AV research has been mostly published in conference proceedings, book chapters, and white papers; (b)

Selection of the search keywords might omit inclusion of some relevant literature; (c) The authors' unconscious bias might have an impact on the execution of the review, and interpretation of the findings; (d) The methodological approach is limited to a manually handled literature review technique; further analytical techniques could have been considered—such as scientometrics, content analysis, cognitive mapping, and concept clustering—to generate a clearer picture of the investigated topic.

As indicated by Yigitcanlar, Currie, and Kamruzzaman. (2017), through the convergence of automation, electrification and ride-sharing technologies, AVs could significantly reshape real estate, urban development and city planning—as the automobile did in the last century. This transformation creates an opportunity for planners to make our cities more citizen-centered by bringing back the human-scale and walkable city practices that motor vehicle domination removed. How well prepared are urban planners, however, to mitigate the disruptive impacts on our cities? Do we yet even understand what these disruptions and their implications are? This review of the literature reveals that presently, urban planning as a profession is largely unprepared for AVs. Urban and transport planners need to be aware, smart and proactive about the potential impacts, particularly in terms of the potential for renewed urban sprawl. A future involving widespread use of AVs presents both land-use opportunities and challenges. Progressive outcomes will require an objective assessment of their complex land-use, economic and community influences on our evolving cities. We, hence, advocate the necessity of preparing our cities for AVs and generating desired smart urban mobility outcomes—through appropriate policies, timely legislations, and accurate planning standards and guidelines—even a wider uptake might take quite some time.

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors. The authors thank the Editor-in-Chief Prof. David M. Levinson and anonymous referees for their invaluable comments on an earlier version of the manuscript.

References

Altche, F., Qian, X., & De La Fortelle, A. (2017). An algorithm for supervised driving of cooperative semi-autonomous vehicles. *IEEE Transactions on Intelligent Transportation Systems, 18*, 3527–3539.

Anderson, J. M., Nidhi, K., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). *Autonomous vehicle technology*. Santa Monica, CA: Rand Corp.

Arbolino, R., Carlucci, F., Cira, A., Ioppolo, G., & Yigitcanlar, T. (2017). Efficiency of the EU regulation on greenhouse gas emissions in Italy. *Ecological Indicators, 81*, 115–123.

Arnaout, G., & Arnaout, J. P. (2014). Exploring the effects of cooperative adaptive cruise control on highway traffic flow using microscopic traffic simulation. *Transportation Planning and Technology, 37*, 186–199.

Bagloee, S. A., Tavana, M., Asadi, M., & Oliver, T. (2016). Autonomous vehicles. *Journal of Modern Transportation, 24*, 284–303.

Bai, W., Quan, J., Fu, L., Gan, X., & Wang, X. (2017). Online fair allocation in autonomous vehicle sharing. In *GLOBECOM 2017-2017 IEEE Global Communications Conference* (pp. 1-6), Singapore.

Banister, D. (1997). Reducing the need to travel. *Environment and Planning B, 24,* 437–449.

Bansal, P., & Kockelman, K. M. (2017). Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies. *Transportation Research Part A, 95*, 49–63.

Bask, A., & Rajahonka, M. (2017). The role of environmental sustainability in the freight transport mode choice: A systematic literature review with focus on the EU. *International Journal of Physical Distribution and Logistics Management, 47*, 560–602.

Becker, F., & Axhausen, K. W. (2017). Literature review on surveys investigating the acceptance of automated vehicles. *Transportation, 44*, 1293–1306.

Beirão, G., & Cabral, J. S. (2007). Understanding attitudes towards public transport and private car. *Transport Policy, 14*, 478–489.

Bloomberg. (2017). *Is your city getting ready for AVs?* Retrieved from http://avsincities.bloomberg.org/global-atlas

Boesch, P. M., Ciari, F., & Axhausen, K. W. (2016). Autonomous vehicle fleet sizes required to serve different levels of demand. *Transportation Research Record, 2542*, 111–119.

Brereton, P., Kitchenham, B. A., Budgen, D., Turner, M., & Khalil, M. (2007). Lessons from applying the systematic literature review process within the software engineering domain. *Journal of Systems and Software, 80*, 571–583.

Brookhuis, K., de Waard, D., & Janssen, W. (2001). Behavioral impacts of advanced driver assistance systems: An overview. *European Journal of Transport and Infrastructure Research, 1*, 245–253.

Bruin, R. D. (2016). Autonomous intelligent cars on the European intersection of liability and privacy. *European Journal of Risk Regulation, 7*, 485.

Burgess, K., Singh, P. J., & Koroglu, R. (2006). Supply chain management. I*nternational Journal of Operations and Production Management, 26*, 703–729.

Chang, D. L., Sabatini-Marques, J., da Costa, E. M., Selig, P. M., & Yigitcanlar, T. (2018). Knowledge-based, smart and sustainable cities. *Journal of Open Innovation, 4*, 5.

Chen, Y., Gonder, J., Young, S., & Wood, E. (2017). Quantifying autonomous vehicles national fuel consumption impacts. *Transportation Research Part A*. doi.org/10.1016/j.tra.2017.10.012

Chen, Z. B., He, F., Yin, Y. F., & Du, Y. C. (2017). Optimal design of autonomous vehicle zones in transportation networks. *Transportation Research Part B, 99*, 44–61.

Childress, S., Nichols, B., Charlton, B., & Coe, S. (2015). Using an activity-based model to explore the potential impacts of automated vehicles. *Transportation Research Record, 2493*, 99–106.

Chong, Z. J., Qin, B., Bandyopadhyay, T., Wongpiromsarn, T., Rebsamen, B., Dai, P., & Ang Jr, M. H.

(2013). Autonomy for mobility on demand. In S. Lee, H. Cho, K. J. Yoon, & J. Lee (Eds.), *Intelligent autonomous systems 12*, (pp. 671–682). Berlin: Springer, Berlin.

Christie, D., Koymans, A., Chanard, T., Lasgouttes, J. M., & Kaufmann, V. (2016). Pioneering driverless electric vehicles in Europe. *Transportation Research Procedia, 13*, 30–39.

Chun, B. T., & Lee, S. H. (2015). Review on ITS in smart city. *Advanced Science and Technology Letters, 98*, 52–54.

Collingwood, L. (2017). Privacy implications and liability issues of autonomous vehicles. *Information and Communications Technology Law, 26*, 32–45.

Coppola, R., & Morisio, M. (2016). Connected car. *ACM Computing Surveys, 49*, 46.

Correia, G. H. de A., & van Arem, B. (2016). Solving the user optimum privately-owned automated vehicles assignment problem UO-POAVAP: A model to explore the impacts of self-driving vehicles on urban mobility. *Transportation Research Part B, 87*, 64–88.

Crayton, T. J., & Meier, B. M. (2017). Autonomous vehicles. *Journal of Transport and Health, 6*, 245–252.

Creutzig, F., Jochem, P., Edelenbosch, O. Y., Mattauch, L., van Vuuren, D. P., McCollum, D., & Minx, J. (2015). *Transport. Science, 350*, 911–912.

Davidson, P., & Spinoulas, A. (2016). Driving alone versus riding together. *Road and Transport Research, 253*, 51–66.

Daziano, R. A., Sarrias, M., & Leard, B. (2017). Are consumers willing to pay to let cars drive for them? *Transportation Research Part C, 78*, 150–164.

Denaro, R. P., Zmud, J., Shladover, S., Smith, B. W., & Lappin, J. (2014). Automated vehicle technology. *King Coal Highway, 292*, 19–24.

Dhar, V. (2016). Equity, safety, and privacy in the autonomous vehicle era. *Computer, 49*, 80–83.

Dia, H., & Javanshour, F. (2017). Autonomous shared mobility-on-demand. *Transportation Research Procedia, 22*, 285–296.

Diakaki, C., Papageorgiou, M., Papamichail, I., & Nikolos, I. (2015). Overview and analysis of vehicle automation and communication systems from a motorway traffic management perspective. *Transportation Research Part A, 75*, 147–165.

Dixit, V. V, Chand, S., & Nair, D. J. (2016). Autonomous vehicles: *Disengagements, accidents and reaction times. PLoS One, 11*, e0168054.

DoT. (2016). *Federal automated vehicles policy: Accelerating the next revolution in roadway safety*. Washington, DC: US Department of Transport (DoT).

Dresner, K., & Stone, P. (2008). A multiagent approach to autonomous intersection management. *Journal of Artificial Intelligence Research, 31*, 591–656.

Duvarci, Y., Yigitcanlar, T., & Mizokami, S. (2015). Transportation disadvantage impedance indexing. *Journal of Transport Geography, 48*, 61–75.

Fagnant, D. J., & Kockelman, K. M. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research Part C, 40*, 1–13.

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations for capitalizing on self-driven vehicles. *Transportation Research Part A, 77*, 167–181.

Fagnant, D. J., Kockelman, K. M., & Bansal, P. (2015). Operations of shared autonomous vehicle fleet for Austin, Texas, market. *Transportation Research Record, 2536*, 98–106.

Farmer, D. L. (2016). Autonomous vehicles: The implications on urban transportation and traffic flow theory. *Institute of Transportation Engineers Journal, 86*, 34–37.

Fernandes, P., & Nunes, U. (2012). Platooning with IVC-enabled autonomous vehicles: Strategies to mitigate communication delays, improve safety and traffic flow. *IEEE Transactions on Intelligent Transportation Systems, 13*, 91–106.

Firnkorn, J., & Müller, M. (2015). Free-floating electric carsharing-fleets in smart cities. *Environmental Science and Policy, 45*, 30–40.

Gill, V., Kirk, B., Godsmark, P., & Flemming, B. (2015). *Automated vehicles.* Ottawa: The Conference Board of Canada.

Glancy, D. J. (2012). Privacy in autonomous vehicles. *Santa Clara Law Review, 52*, 1171–1239.

Gless, S., Silverman, E., & Weigend, T. (2016). If robots cause harm, who is to blame? *New Criminal Law Review, 19*, 412–436.

Gong, S., Shen, J., & Du, L. (2016). Constrained optimization and distributed computation-based car following control of a connected and autonomous vehicle platoon. *Transportation Research Part B, 94*, 314–334.

Greenblatt, J. B., & Saxena, S. (2015). Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles. *Nature Climate Change, 5*, 860–863.

Gruel, W., & Stanford, J. M. (2016). Assessing the long-term effects of autonomous vehicles. T*ransportation Research Procedia, 13*, 18–29.

Heinrichs, D. (2016). Autonomous driving and urban land use. In: M. Maurer, J. C. Gerdes, B. Lenz, & H. Winner. (Eds.), *Autonomous driving: Technical, legal and social aspects* (pp. 213–231). Berlin: Springer.

Hendrickson, C., Biehler, A., & Mashayekh, Y. (2014). *Connected and autonomous vehicles 2040 vision*. Harrisburg, PA: Pennsylvania Department of Transportation.

Hoogendoorn, R., van Arem, B., & Hoogendoorn, S. (2014). Automated driving, traffic flow efficiency and human factors: A literature review. *Transportation Research Record, 2422*, 113–120.

Isaac, L. (2016). How local governments can plan for autonomous vehicles. In G. Meyer & S. Beiker (Eds.), *Road vehicle automation 3,* (pp. 59-70). Berlin: Springer.

Kamruzzaman, M., Yigitcanlar, T., Washington, S., & Currie, G. (2014). Australian baby boomers switched to more environmentally friendly modes of transport during the global financial crisis. *International Journal of Environmental Science and Technology, 11*, 2133–2144.

Kamruzzaman, M., Hine, J., & Yigitcanlar, T. (2015). Investigating the link between carbon dioxide emissions and transport related social exclusion in rural Northern Ireland. *International Journal of Environmental Science and Technology, 12*, 3463–3478.

Kamruzzaman, M., Yigitcanlar, T., Yang, J., & Mohamed, A. (2016). *Measures of transport-related social exclusion. Sustainability, 8*, 696.

Kashfi, S., Bunker, J., & Yigitcanlar, T. (2015a). Effects of transit quality of service characteristics on daily bus ridership. *Transportation Research Record, 2535*, 55–64.

Kashfi, S., Bunker, J., & Yigitcanlar, T. (2015b). Understanding the effects of complex seasonality on suburban daily transit ridership. *Journal of Transport Geography, 46*, 67–80.

Kim, J., Moon, Y. J., & Suh, I. S. (2015). Smart mobility strategy in Korea on sustainability, safety and efficiency toward 2025. *IEEE Intelligent Transportation Systems Magazine, 7*, 58–67.

Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). Preferences for shared autonomous vehicles. T*ransportation Research Part C, 69*, 343–355.

Lamondia, J. J., Fagnant, D. J., Qu, H., Barrett, J., & Kockelman, K. (2016). Shifts in long-distance travel mode due to automated vehicles and travel survey analysis. *Transportation Research Record, 2566*, 1–11.

Lara, A., Costa, E., Furlani, T., & Yigitcanlar, T. (2016). Smartness that matters: Comprehensive and human-centered characterization of smart cities. *Journal of Open Innovation, 2*, 8.

Lari, A., Douma, F., & Onyiah, I. (2015). Self-driving vehicles and policy implications. *Minnesota Jour-*

nal of Law Science and Technology, 16, 735.

Lee, C. (2017). Grabbing the wheel early: Moving forward on cybersecurity and privacy protections for driverless cars. *Federal Communications Law Journal, 69*, 25–52.

Lee, C. K., Lin, C. L., & Shiu, B. M. (2009). Autonomous vehicle parking using hybrid artificial intelligent approach. *Journal of Intelligent and Robotic Systems, 56*, 319-343.

Levin, M. W., & Boyles, S. D. (2015). Effects of autonomous vehicle ownership on trip, mode, and route choice. *Transportation Research Record, 2493*, 29–38.

Levine, M. L., Segev, L. L., & Thode, S. F. (2017). A largely unnoticed impact on real estate. *Appraisal Journal, 85*, 51–59.

Li, B., & Shao, Z. (2015). A unified motion planning method for parking an autonomous vehicle in the presence of irregularly placed obstacles. *Knowledge-Based Systems, 86*, 11–20.

Litman, T. (2017). *Autonomous vehicle implementation predictions.* Victoria, BC: Victoria Transport Policy Institute.

Liu, J., Kockelman, K. M., Boesch, P. M., & Ciari, F. (2017). Tracking a system of shared autonomous vehicles across the Austin, Texas, network using agent-based simulation. *Transportation, 44*, 1261–1278.

Luo, Y., Xiang, Y., Cao, K., & Li, K. (2016). A dynamic automated lane change maneuver based on vehicle-to-vehicle communication. *Transportation Research Part C, 62*, 87–102.

Ma, S., Zheng, Y., & Wolfson, O. (2015). Real-time city-scale taxi ridesharing. *IEEE Transactions on Knowledge and Data Engineering, 27*, 1782–1795.

Malokin, A., Circella, G., & Mokhtarian, P. L. (2015). How do activities conducted while commuting influence mode choice? Testing public transportation advantage and autonomous vehicle scenarios. In *94th Annual Meeting of the Transportation Research Board,* Washington DC, January 11–15.

Martinez, L. M., & Viegas, J. M. (2017). Assessing the impacts of deploying a shared self-driving urban mobility system: An agent-based model applied to the city of Lisbon, Portugal. *International Journal of Transportation Science and Technology, 6*, 13–27.

Maurer, M., Gerdes, J. C., Lenz, B., & Winner, H. (Eds.). (2016). *Autonomous driving: Technical, legal and social aspects*. Berlin: Springer.

Meissner, E., Chantem, T., & Heaslip, K. (2016). Optimizing departures of automated vehicles from highways while maintaining mainline capacity. *IEEE Transactions on Intelligent Transportation Systems, 17*, 3498–3511.

Meyer, J., Becker, H., Bösch, P. M., & Axhausen, K. W. (2017). Autonomous vehicles. *Research in Transportation Economics, 62*, 80–91.

Milakis, D., van Arem, B., & van Wee, G. (2017). Policy and society related implications of automated driving: A review of literature and directions for future research. *Journal of Intelligent Transportation Systems, 21*, 324–348.

Milakis, D., Snelder, M., van Arem, B., Homem, G., & van Wee, G. (2017). Development and transport implications of automated vehicles in the Netherlands. *European Journal of Transport and Infrastructure Research, 17*, 63–85.

Moorthy, A., De Kleine, R., Keoleian, G., Good, J., & Lewis, G. (2017). Shared autonomous vehicles as a sustainable solution to the last mile problem. *SAE International Journal of Passenger Cars-Electronic and Electrical Systems, 10*, 328–336.

Murray, A. T., Davis, R., Stimson, R. J., & Ferreira, L. (1998). Public transportation access. *Transportation Research Part D, 3*, 319–328.

Newman, P., & Kenworthy, J. (1999). *Sustainability and cities*. New York: Island Press.

Newman, P., & Kenworthy, J. (Eds.) (2015). *The end of automobile dependence*. New York: Island Press.

NHTSA. (2016). Federal automated vehicles policy. Retrieved from https://www.transportation.gov/

AV/federal-automated-vehicles-policy-september-2016

Nie, J., Zhang, J., Ding, W., Wan, X., Chen, X., & Ran, B. (2016). Decentralized cooperative lane-changing decision-making for connected autonomous vehicles. *IEEE Access, 4*, 9413–9420.

Nilsson, J., Brannstrom, M., Coelingh, E., & Fredriksson, J. (2017). Lane change maneuvers for automated vehicles. *IEEE Transactions on Intelligent Transportation Systems, 18*, 1087–1096.

Nowakowski, C., Shladover, S. E., Chan, C. Y., & Tan, H. S. (2015). Development of California regulations to govern testing and operation of automated driving systems. *Transportation Research Record, 2489*, 137–144.

Nowakowski, C., Shladover, S. E., & Chan, C. Y. (2016). Determining the readiness of automated driving systems for public operation development of behavioral competency requirements. *Transportation Research Record, 2559*, 65–72.

Olaverri-Monreal, C. (2016). Autonomous vehicles and smart mobility related technologies. *Infocommunications Journal, 8*, 17–24.

Oliveira, C. M., Márcio de Almeida, D. A., de Mello, A. L., do Couto Assumpção, F., Dos Santos Gonçalves, F., & Gonçalves, D. N. (2016). Identificando os desafios e as boas práticas para o transporte urbano de cargas, por meio de uma revisão bibliográfica sistemática. *Transportes, 24*, 9–19.

Oliveira, C. M., Albergaria De Mello Bandeira, R., Vasconcelos Goes, G., Schmitz Gonçalves, D. N., & D'Agosto, M. D. (2017). Sustainable vehicles-based alternatives in last mile distribution of urban freight transport: A systematic literature review. *Sustainability, 9*, 1324.

Owczarzak, Ł., & Żak, J. (2015). Design of passenger public transportation solutions based on autonomous vehicles and their multiple criteria comparison with traditional forms of passenger transportation. *Transportation Research Procedia, 10*, 472–482.

Payre, W., Cestac, J., & Delhomme, P. (2014). Intention to use a fully automated car. *Transportation Research Part F, 27*, 252–263.

Pendleton, S. D., Andersen, H., Du, X., Shen, X., Meghjani, M., Eng, Y. H., & Ang, M. H. (2017). Perception, planning, control, and coordination for autonomous vehicles. *Machines, 5*, 6.

Perveen, S., Yigitcanlar, T., Kamruzzaman, M., & Hayes, J. (2017). Evaluating transport externalities of urban growth. *International Journal of Environmental Science and Technology, 14*, 663–678.

Perveen, S., Kamruzzaman, M., & Yigitcanlar, T. (2017). Developing policy scenarios for sustainable urban growth management. *Sustainability, 9,* 1787.

Perveen, S., Kamruzzaman, M., & Yigitcanlar, T. (2018). What to assess to model the transport impacts of urban growth? A Delphi approach to review the space-time suitability of transport indicators. *International Journal of Sustainable Transportation*. doi.org/10.1080/15568318.2018.1491077

Piao, J., McDonald, M., Hounsell, N., Graindorge, M., Graindorge, T., & Malhene, N. (2016). Public views towards implementation of automated vehicles in urban areas. *Transportation Research Procedia, 14*, 2168–2177.

Pinjari, A. R., & Menon, N. (2013). *Highway capacity impacts of autonomous vehicles*. Tampa, FL: Center for Urban Transportation Research.

Rowley, J., & Slack, F. (2004). Conducting a literature review. *Management Research News, 27*, 31–39.

Rubin, J. (2016). Connected autonomous vehicles: Travel behavior and energy use. In G. Meyer & S. Beiker (Eds.), *Road vehicle automation 3*, (pp. 151–162). Berlin: Springer.

SAE. (2016a). *Automated driving.* Retrieved from https://www.sae.org/misc/pdfs/automated_driving.pdf

SAE. (2016b). Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles. Retrieved from http://standards.sae.org/j3016_201609

Schellekens, M. (2015). Self-driving cars and the chilling effect of liability law. *Computer Law and Secu-*

rity Review, 31, 506–517.

Scheltes, A., & de Almeida Correia, G. H. (2017). Exploring the use of automated vehicles as last mile connection of train trips through an agent-based simulation model. *International Journal of Transportation Science and Technology, 6*, 28–41.

Shladover, S. E., Su, D., Lu, X. Y. (2012). Impacts of cooperative adaptive cruise control on freeway traffic flow. *Transportation Research Record, 2324*, 63–70.

Shladover, S. E. (2018). Connected and automated vehicle systems. *Journal of Intelligent Transportation Systems, 22*, 190–200.

Smith, B. W. (2012). Managing autonomous transportation demand. *Santa Clara Law Review, 52*, 1401–1422.

Smolnicki, P. M., & Sołtys, J. (2016). Driverless mobility. *Procedia Engineering, 161,* 2184–2190.

Snyder, R. (2016). Implications of autonomous vehicles: A planner's perspective. *Institute of Transportation Engineers Journal, 86*, 25–28.

Spyropoulou, I., Penttinen, M., Karlaftis, M., Vaa, T., & Golias, J. (2008). ITS solutions and accident risks: Prospective and limitations. *Transport Reviews, 28,* 549–572.

Talebpour, A., & Mahmassani, H. S. (2016). Influence of connected and autonomous vehicles on traffic flow stability and throughput. *Transportation Research Part C, 7*1, 143–163.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management, 14,* 207–222.

Trindade, E., Hinnig, M., Costa, E., Sabatini-Marques, J., Bastos, R., & Yigitcanlar, T. (2017). Sustainable development of smart cities. *Journal of Open Innovation, 3*, 11.

Truong, L. T., De Gruyter, C., Currie, G., & Delbosc, A. (2017). Estimating the trip generation impacts of autonomous vehicles on car travel in Victoria. *Transportation, 44*, 1279–1292.

UK Parliament. (2016). Vehicle technology and automation bill. Retrieved from https://publications.parliament.uk/pa/bills/cbill/2016-2017/0143/cbill_2016-20170143_en_2.htm

van Arem, B., van Driel, C., & Visser, R. (2006). The impact of co-operative adaptive cruise control on traffic flow characteristics. I*EEE Transactions on Intelligent Transportation Systems, 7*, 429–436.

Vellinga, N. E. (2017). From the testing to the deployment of self-driving cars. *Computer Law and Security Review, 33*, 847–863.

Volvo. (2017). Autonomous driving. Retrieved from https://www.volvocars.com/intl/about/our-innovation-brands/intellisafe/autonomous-driving

Wadud, Z., MacKenzie, D., & Leiby, P. (2016). Help or hindrance? *Transportation Research Part A, 86,* 1–18.

Wadud, Z. (2017). Fully automated vehicles. *Transportation Research Part A, 101,* 163–176.

Walker, W. E., & Marchau, V. A. (2017). Dynamic adaptive policymaking for the sustainable city. *International Journal of Transportation Science and Technology, 6*, 1–12.

Winkle, T. (2016). Safety benefits of automated vehicles. In M. Winner (Ed.), *Autonomous driving* (pp. 335–364). Berlin: Springer.

Xiao, L., & Gao, F. (2010). A comprehensive review of the development of adaptive cruise control systems. *Vehicle System Dynamics, 48*, 1167–1192.

Xie, Y., Zhang, H., Gartner, N. H., & Arsava, T. (2017). Collaborative merging strategy for freeway ramp operations in a connected and autonomous vehicles environment. *Journal of Intelligent Transportation Systems, 21*, 136–147.

Yağdereli, E., Gemci, C., & Aktaş, A. Z. (2015). A study on cyber-security of autonomous and unmanned vehicles. *Journal of Defense Modeling and Simulation, 12*, 369–381.

Yigitcanlar, T., Sipe, N., Evans, R., & Pitot, M. (2007). A GIS-based land use and public transport accessibility indexing model. *Australian Planner, 44*, 30-37.

Yigitcanlar, T., Fabian, L., & Coiacetto, E. (2008). Challenges to urban transport sustainability and smart transport in a tourist city. *Open Transportation Journal, 1*, 19–36.

Yigitcanlar, T., & Kamruzzaman, M. (2014). Investigating the interplay between transport, land use and the environment: A review of the literature. *International Journal of Environmental Science and Technology, 11*, 2121–2132.

Yigitcanlar, T., & Lee, S. (2014). Korean ubiquitous-eco-city. *Technological Forecasting and Social Change, 89*, 100–114.

Yigitcanlar, T. (2015). Smart cities: An effective urban development and management model? *Australian Planner, 52*, 27–34.

Yigitcanlar, T. (2016). *Technology and the city: Systems, applications and implications*. New York: Routledge.

Yigitcanlar, T., Currie, G., & Kamruzzaman, M. (2017). *Driverless vehicles could bring out the best—or worst—in our cities by transforming land use.* Retrieved from https://theconversation.com/driverless-vehicles-could-bring-out-the-best-or-worst-in-our-cities-by-transforming-land-use-84127

Yigitcanlar, T., & Kamruzzaman, M. (2018a). Does smart city policy lead to sustainability of cities? *Land Use Policy, 73*, 49–58.

Yigitcanlar, T., & Kamruzzaman, M. (2018b). Smart cities and mobility: Does the smartness of Australian cities lead to sustainable commuting patterns? *Journal of Urban Technology*. doi.org/10.1080/10630732.2018.1476794

Yigitcanlar, T., Kamruzzaman, M., Buys, L., Ioppolo, G., Sabatini-Marques, J., Costa, E., & Yun, J. (2018a). Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework. *Cities, 81*, 145–160.

Yigitcanlar, T., Foth, M., & Kamruzzaman, M. (2018b). Towards post-anthropocentric cities: Reconceptualizing smart cities to evade urban ecocide. *Journal of Urban Technology*. doi.org/10.1080/10630732.2018.1524249

Yigitcanlar, T., Mohamed, A., Kamruzzaman, M., & Piracha, A. (2018c). Understanding transport-related social exclusion: A multidimensional approach. *Urban Research and Policy*. doi.org/10.1080/08111146.2018.1533461

Zakharenko, R. (2016). Self-driving cars will change cities. *Regional Science and Urban Economics, 61*, 26–37.

Zhang, W., Guhathakurta, S., Fang, J., & Zhang, G. (2015). Exploring the impact of shared autonomous vehicles on urban parking demand: An agent-based simulation approach. *Sustainable Cities and Society, 19*, 34–45.

Zhou, M., Qu, X., & Jin, S. (2017). On the impact of cooperative autonomous vehicles in improving freeway merging. *IEEE Transactions on Intelligent Transportation Systems, 186*, 1422–1428.

Zohdy, I. A., & Rakha, H. A. (2016). Intersection management via vehicle connectivity: The intersection cooperative adaptive cruise control system concept. *Journal of Intelligent Transportation Systems, 20*, 17–32.

Appendix

Appendix available as a supplemental file at www.jtlu.org/index.php/jtlu/rt/suppFiles/1405/0.

International Journal of
Environmental Research and Public Health

MDPI

Review

Impacts of Autonomous Vehicles on Greenhouse Gas Emissions—Positive or Negative?

Moneim Massar [1], Imran Reza [1], Syed Masiur Rahman [2,*], Sheikh Muhammad Habib Abdullah [3], Arshad Jamal [1] and Fahad Saleh Al-Ismail [2,4,5]

1 Department of Civil & Environmental Engineering, College of Engineering and Applied Engineering, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia; g201705990@kfupm.edu.sa (M.M.); ireza@kfupm.edu.sa (I.R.); arshad.jamal@kfupm.edu.sa (A.J.)
2 Center for Environment & Water, Research Institute, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia; fsalismail@kfupm.edu.sa
3 Department of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka 1000, Bangladesh; habibce09@gmail.com
4 K.A. CARE Energy Research and Innovation Center (ERIC), King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia
5 Department of Electrical Engineering, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia
* Correspondence: smrahman@kfupm.edu.sa; Tel.: +966-13-860-2991

Abstract: The potential effects of autonomous vehicles (AVs) on greenhouse gas (GHG) emissions are uncertain, although numerous studies have been conducted to evaluate the impact. This paper aims to synthesize and review all the literature regarding the topic in a systematic manner to eliminate the bias and provide an overall insight, while incorporating some statistical analysis to provide an interval estimate of these studies. This paper addressed the effect of the positive and negative impacts reported in the literature in two categories of AVs: partial automation and full automation. The positive impacts represented in AVs' possibility to reduce GHG emission can be attributed to some factors, including eco-driving, eco traffic signal, platooning, and less hunting for parking. The increase in vehicle mile travel (VMT) due to (i) modal shift to AVs by captive passengers, including elderly and disabled people and (ii) easier travel compared to other modes will contribute to raising the GHG emissions. The result shows that eco-driving and platooning have the most significant contribution to reducing GHG emissions by 35%. On the other side, easier travel and faster travel significantly contribute to the increase of GHG emissions by 41.24%. Study findings reveal that the positive emission changes may not be realized at a lower AV penetration rate, where the maximum emission reduction might take place within 60–80% of AV penetration into the network.

Keywords: autonomous vehicle; GHG; emission; COVID-19; CLD; energy consumption; VMT

check for updates

Citation: Massar, M.; Reza, I.; Rahman, S.M.; Abdullah, S.M.H.; Jamal, A.; Al-Ismail, F.S. Impacts of Autonomous Vehicles on Greenhouse Gas Emissions—Positive or Negative?. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5567. https://doi.org/10.3390/ijerph18115567

Academic Editor: Farooq Sher

Received: 9 March 2021
Accepted: 29 April 2021
Published: 23 May 2021

1. Introduction

According to the United Nations Framework on Climate Change Convention, the transportation sector was responsible for 27% of US greenhouse gas (GHG) emissions in 2010 [1]. GHGs are one of the leading causes of the greenhouse effect worldwide [2]. They serve as artificial heat-trapping agents within the earth's atmosphere. From the perspective of road transportation, fuel sources such as diesel, natural gas, and gasoline produce different GHGs in the form of byproducts. Gaseous emissions resulting from burning these energy sources include methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O), which can last in the planet's atmosphere for several decades, causing continuous global warming [3]. These unregulated GHGs emissions disturb the natural gas cycles governing the planet and pose a significant threat to various flora and fauna types [4]. In European countries, the transport sector was responsible for 30.5% of GHG emissions and 12% contribution of GHG emissions from road transport in 2014 [5]. Another study conducted in China by Liu et al. predicted that the transport sector alone would account for 84.7% GHG emission by the year 2040 [6]. Rising concerns about the negative environmental externalities of road transportation activity and development have urged governments worldwide to assess transportation projects' environmental impacts before implementation. The modern automobile industry trend is to move towards the development of autonomous cars [7]. Multiple considerations are driving this change, including but not limited to improved safety, greater productivity, less fuel consumption and reduced traffic congestion [8,9]. Autonomous vehicles (AVs), also known as driverless or self-driving vehicles, are those vehicles that can operate without driver control the steering, accelerate or brake; the automation ranges from 0: no automation to 5: fully automated [10].

Existing literature on connected and autonomous vehicles mostly addresses their potential impact on the likelihood of traffic safety, travel behavior and congestion, as well as energy use. The effects of partially to fully automated vehicles on traffic performance and greenhouse gas emissions are still obscure. There are many uncertainties prevailing around the actual operation of fully automated vehicles. The Information Handling Services (IHS) Automotive experts reported that it is expected to happen by 2030. HIS estimates also suggest that globally the number of fully automated vehicles (AVs) in operation will be around 21 million in 2035 [11]. Another study reported that connected vehicles would strike the 250 million mark by 2020 [12]; a quarter of a billion cars in operation. A previous study also predicted that fully AVs be offered for auction before 2020 [13]. A projection is that AVs will dominate 20–40% of vehicle market share by 2030; however, it is believed that full-scale transition to AVs is likely to happen in stages over the coming few decades [14].

AVs are mainly equipped with contemporary car technologies, allowing computers to help in various driving operations and reduce human involvement to varying degrees. With rapid advances in communication, autonomous, and car technologies that have far-reaching effects on the transportation sector, it is critical to understand these technologies' role in achieving sustainable urban mobility goals. This involves the safe and smooth operation of people and goods movement in an environmentally friendly manner. The carbon emission rate from each transport mode is significantly influenced by an array of factors, like the type of fuel, vehicle type, and age, etc. Many studies investigated the impacts of the widespread adoption of AV technology [15,16]. The impacts considered air pollutants, including GHG emissions. AVs' introduction may contribute to increased ridesharing, traffic flow smoothing, platooning, efficient driving, efficient routing, eco traffic signal, and less hunting for parking [17–21]. As a result, the energy consumption will be less, contributing to the reduction of GHG emissions. A number of previous studies have investigated the role of AVs in improving transport sustainability by compressing energy use and GHG emissions. For example, one such estimation for the full automation developed by Wadud et al. considering the shared-vehicle scenario was based on the "Strong Responses" [22]. According to this concept, the maximum energy savings through car-sharing, eco-driving, right-sizing, and platooning are wholly neutralized by maximum energy increases from new user groups and higher speeds. In their study, Greenblatt and Shaheen explored the GHG reduction benefits of driverless taxis in the US and claimed that the deployment of each such taxi in the country would cause than 87–94% fewer emissions per vehicle-km trip by the year 2030 [23]. The authors also stated that each deployed driverless taxi in the same year would also cause a 63–82% reduction in GHG emissions than traditional fuel-driven and hybrid electric vehicles. Such reduction would primarily result from variations in three aspects: higher vehicle-km/vehicle/per-year increased fuel efficiency due to re-designed lighter/smaller vehicle sizes, less air friction, and reductions in GHG emissions through electricity consumption. On the other hand, AV may generate increased trips due to faster and more comfortable driving and new trips by captive passengers, such as elderly and disabled individuals [24].

Tomás et al. investigated the GHG implications of three different AV penetration rates (10, 20, and 30%) along an urban freeway corridor in the city of Porto, Portugal [25]. Authors used vehicle-specific power (VSP) and EEA-33 (environmental emergencies member countries) methodologies coupled with the VISSIM traffic model. It was noted that AVs yielded statistically low emission benefits at the corridor level at penetration rates less than 30%. In their study, Stasinopoulos et al. adopted a system dynamics approach and developed a stock and flow model to examine the GHG impacts of vehicle automation in various scenarios [26]. The study reported that emissions benefits of the transition to AVs might be negated by the inefficient use of AVs and induced demand. In another study, Wang et al. compared the fuel-cycle GHG emissions of AVs and vehicle electrification using an activity-based travel demand model for the Hamilton and Greater area [27]. It was concluded that full-scale induction of AVs would result in higher vehicle kilometers traveled, and hence, more GHG emissions are expected (2.5%). On the other hand, vehicle electrification may reduce vehicle emission intensities by approximately 11% and regional GHG emissions by over 5%. Hong and Zimmerman predicted that AVs can reduce GHG emissions by 20% compared to no-AV conditions in the year 2040, even under the worst-case scenario if vehicle automation provoked increased personal use with 85% vehicle fleet electrification [28]. A study conducted by Liu et al. also suggested that high AVs penetration rates in the long-term (by the year 2045) under optimistic scenarios will lead to a net reduction of GHG emissions [29].

This paper develops a landscape of multi-faceted issues related to GHG emissions from AV adoption at different levels by reviewing, synthesizing, analyzing, and comparing contrast research studies. While comparing the GHG emissions from AVs to its counterpart, fossil fuel vehicles (FFV) may have different attribute levels (e.g., gasoline-powered, eclectic, hydrogen-powered), this review study is only limited to the realm that both AVs and FFVs are only operated on fossil fuels. The study provides a causality analysis of GHG emissions from AVs from a holistic point of view. The primary objective of using a causal loop diagram (CLD) in our study is to understand the factors that can critically affect how the adoption of AVs may bring energy and GHG emission benefits to the transportation sector. CLD is used to see how these factors interact and influence the emission benefits of adopting AVs in the transport industry. Another section addressed the dynamics of GHG emissions during a global pandemic, focusing on travel behavior and how the individual vehicle ownership model may change in favor of adopting AVs.

The remainder of this paper is structured as below. Section 2 provides an overview of the study methodology. Section 3 presents a description of the causes of GHG reduction by AVs, while the possible causes of the increase of GHG emission by adopting AVs are discussed in Section 4. Section 5 illustrates the changes in GHG emission at different AV penetration levels. Section 6 covers a discussion of the relationship between energy consumption and GHG emission; two sub-sections of Section 6 shed light on the causal loops of GHG emission from AVs from a system perspective and changed travel behavior during a global pandemic, respectively. Finally, Section 7 summarizes the study findings with concluding remarks.

2. Methodology

The systematic review has a formal protocol describing the strategy proposed for conducting the examination, identifying questions and methods employed to carry out the analysis [30]. The review process used in this study comprises three steps:

1. Planning: Defining the research issue, setting the criteria, identifying the limitation and development of the overall protocol.
2. Execution: Selection of research in database, categorizing useful references and bibliography, abstract of published manuscript.
3. Analysis: Summarizing the selected articles and classifying it to fit the proposed protocol.

Various guidelines could manifest a systematic literature review. One of the popular methods is demonstrated by Kitchenham and Charters, a process that entails a number of tasks, including establishing a review protocol, identifying and selecting primary studies, extracting and synthesizing data, and finally, reporting study findings [31]. This paper focused on a systematic keyword search in the topic section of literature databases from disparate sources and repositories. The articles were searched for based on specific terms such as "autonomous vehicles,"; "self-driving car," and "driverless car" appeared in the title, keywords, and abstract in the journal database. However, care was taken to single out the articles which were not focused on autonomous driving related to extensive applications, testing, and research in robotics, underwater vehicles, unmanned aerial vehicles, etc. The effects of AV-generated GHG emissions are explicitly investigated to achieve an overall classification to identify current gaps in the scientific literature in the realm of AV-related publications for roads, traffic studies related to commuting. The year of publication timeline and number of citations were taken out of the equation in selecting the articles to maximize the number for consideration. Articles found in different databases were also identified for eliminating duplication. The flowchart presented (Figure 1) illustrates the methodology deployed in this study.

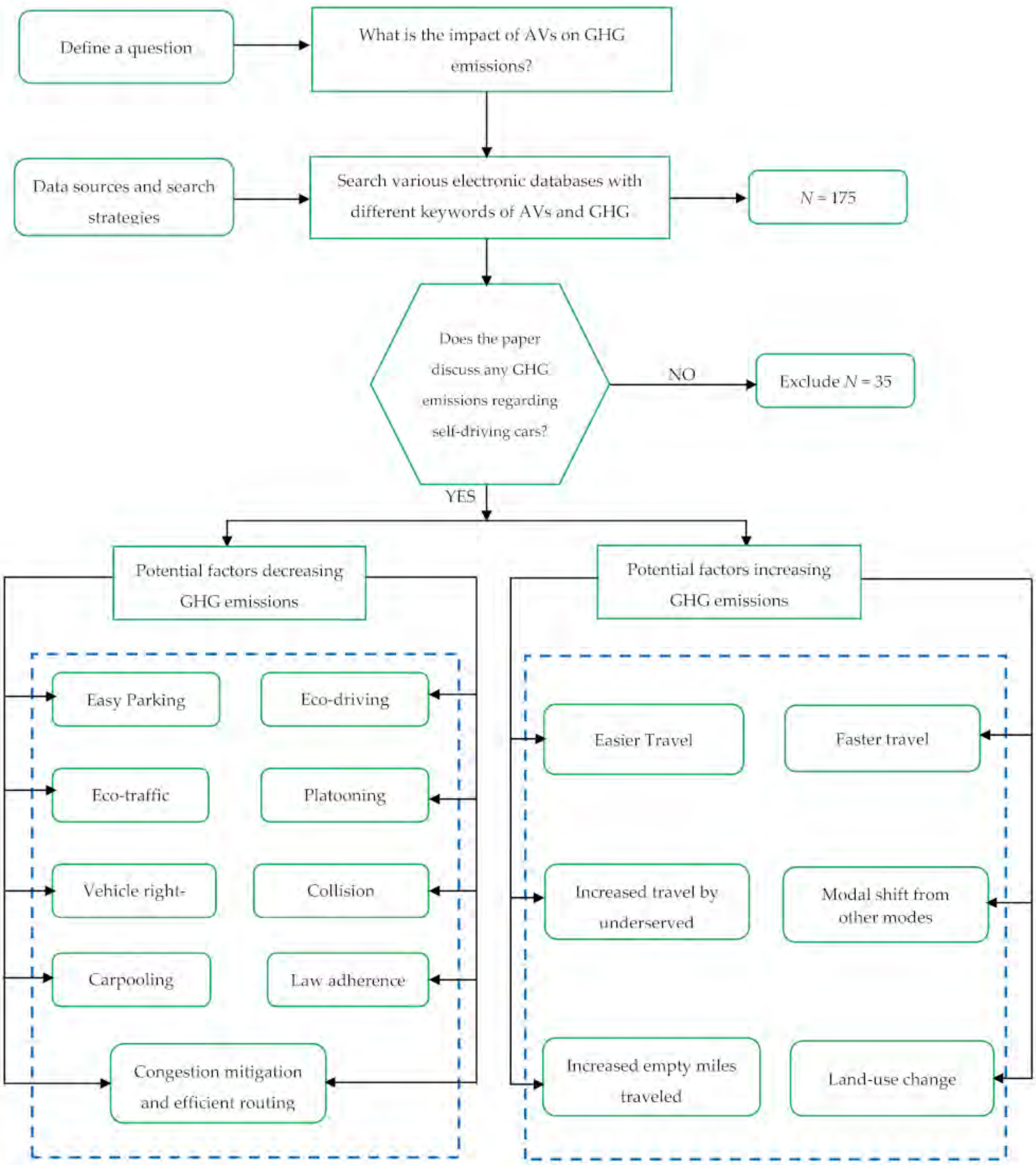


Figure 1. Methodology plan.

3. Causes of Reduction in GHG Emissions

This section provides a brief explanation of potential factors that are expected to reduce lower GHG emissions due to vehicle automation. Two types of vehicle automation strategies are considered, i.e., partial automation and full automation.

3.1. Easy Parking

Guccione and Holland identified that drivers looking for parking are responsible for about one-third of traffic in the city [32]. From the fuel efficiency point of view, a vehicle searching for parking leads to a double threat. Being on the road consumes extra fuel for itself; the additional traffic makes the other vehicle suffer by staying more on-road and ending up using undue fuel. Roadside parking maneuver also has an important share in cities carbon emission system [33]. Shoup added to the literature with an estimation of 2–11% of total emission in a CBD being caused by parking hunt [34]. Easy parking refers to parking spaces' availability through communication technologies that allow vehicles and infrastructure to exchange information, resulting in accurate parking information. In another study, Brown et al. estimated up to 5% of emissions in an average passenger car is attributed to the search for parking. Fully automated vehicles can achieve a 5–11% emission reduction from reduced circulation for parking in the cities [35]. Moriarty and Wang also estimated that parking space could be drastically reduced, and vehicles searching for parking could be cut down by 80% with shared ownership of AVs [10]. During peak traffic hours when congestion is high and off-peak travel periods, when most parking spaces may be occupied, the same reduction may occur. Partially automated vehicles would also minimize emissions due to improved ability to locate available parking spaces correctly; however, the projected savings could be lower, considering the lack of automatic implementation. In general, the easy parking feature of vehicle automation is expected to reduce GHG emissions depending upon various other factors, due to minimum vehicle idling and searching for suitable parking locations.

3.2. Eco-Driving

Eco-driving refers to efficient driving through maximizing speed and acceleration operating profiles. Eco-driving is often referred to as "Hypermiling," and is nothing but a set of driving skills practiced by enthusiastic drivers to push the fuel economy's limit by minimizing braking-acceleration cycles, as braking causes a waste of energy [15,36]. CAV technologies have the ability to leverage and extend such efficient driving benefits by enabling vehicles to incorporate eco-driving automatically. CAVs can coordinate with other vehicles with smarter communication capability to make integrated driving decisions that would optimize overall traffic flow conditions and support the entire driving platoon. Barth and Boriboonsoms deployed a traffic simulation model to determine the emission effects of coordinated eco-driving [15]. The coordinated eco-driving system takes advantage of a virtual traffic management center to monitor vehicles' speed and acceleration characteristics. They simulated a mixed fleet of vehicles on Southern California highways and estimated that carbon dioxide emissions reduction within a range of 10–20% could be achieved by eco-driving on congested highways. However, it has been noted that the reduction of emission starts to disappear as traffic approaches free flow. In a similar study, Barth demonstrated that a coordinated eco-driving system would minimize emissions by 5–10% in heavily congested road traffic [15]. Li and Gao conducted a series of micro-simulation modeling studies to investigate speed synchronization impacts in a connected environment [37]. Their primary objective was to establish an optimal control strategy to optimize fleet-level average fuel economy in a connected vehicle environment. The findings suggested that reducing 10% of GHG emissions could be achieved in such an arrangement.

Two research projects conducted at the Virginia Tech Transportation Institute estimated potential emissions impacts of vehicle-to-vehicle (V2V) communication and coordination [19,38]. The proposed method involved complex optimization models integrating road-characteristics, information of the lead vehicle, vehicle acceleration portfolio, and microscopic fuel consumption models to produce a fuel optimal speed profile for vehicles in the network. Optimal driving cycles may reduce energy consumption by 35–50% under oversaturated conditions if these conditions exist at all in reality [39]. It is well known that frequent stops and accelerations/decelerations operations contribute to significant fuel consumption. The eco-driving attribute of AVs facilitates smooth vehicle navigation through the network, due to smart communication with other vehicles, as well as highway infrastructure, which in turn lowers the GHG emissions.

3.3. Eco Traffic Signal

AVs can communicate with infrastructure on their own, particularly with traffic signals at intersections. This communication offers information to vehicles, which helps them change their driving pattern, thereby minimizing the number of stops at the intersection referred to as the eco traffic signal system. Li and Gao investigated optimal signal control strategies for fuel economy in a connected vehicle environment and showed that gasoline vehicles could achieve 10% emission reduction via such strategies [37]. Rakha et al. estimated potential emission impacts of vehicle-to-vehicle communication and signal coordination, and it turned out to be 8–23% emission savings depending on the vehicles' traveling attributes [19,40].

The potential to reduce fuel consumption and GHG emission at the intersection is very high, as vehicles traveling near intersections at lower speeds tend to consume more fuel [41]. Yelchuru and Waller adopted micro-simulation models to estimate vehicle emissions under connected eco-traffic signal timing and the associated optimal signal timing plans [42]. According to the study, under a fully connected protocol, 2–6% emission reduction can be achieved in an average passenger vehicle. Zimmerman et al. compared traffic patterns before and after a user information system was introduced at different signalized intersections in Phoenix, Arizona [43]. The empirical data reported that the delay was reduced by 6.2%, resulting in a 1.8% emission reduction using vehicle speed profile and energy consumption correlation. As mentioned, signalized intersections in urban areas have the huge potential to reduce GHG emissions at the network level. AVs are equipped with different sophisticated sensors for communication with roadway surroundings that can guide the drivers/vehicles to adjust the driving patterns, minimize stops and speed variance. All these factors will reduce fuel consumption and hence vehicular emissions.

3.4. Collision Avoidance

Human error accounts for more than 90% of accidents [44,45]. Collision avoidance systems in AVs are designed to provide necessary information ahead of time to the vehicle by means of well-designed vehicle mount sensors to avoid collisions. The sensors track nearby vehicles and objects to warn the system of preemptive maneuvers. In addition to the obvious individual advantages of accident avoidance, the system provides collective fuel-saving and environmental benefits by eliminating the chance of traffic congestion that might have arisen at a vehicle crash scene. According to Schrank et al., nationwide, 1.9% of GHG emission by the light duty vehicle (LDV) fleet was produced, due to the traffic congestion created at the accident spot [46]. Najm et al. integrated forward collision warning and adaptive cruise control functions to develop the ACAS for LDV applications [47]. The development of ACAS was based on an operational field test of 10 vehicle fleets driven by 66 drivers among diverse age and gender groups. The ACAS system has the potential to prevent about 10% of all rear-end crashes, which is expected to bring some indirect emission benefits. The collision avoidance attribute of both partial and full automation will reduce the GHG emissions, by preventing and minimizing jams and traffic congestion causing traffic accidents.

3.5. Platooning

The vehicle platooning concept refers to the practice of multiple vehicles trailing closely enough to minimize aerodynamic drag to save energy and reduce vehicle emissions.

Vehicle platooning can be safely and successfully implemented by leveraging automation and connectivity technologies. This strategy is particularly attractive considering that a significant portion of fuel consumption is attributed to confronting aerodynamic resistance while driving. Kasseris estimated that aerodynamic drag accounted for 50–75% of the tractive energy requirements for driving on a highway [48]. The shape of the vehicles in the convoy, distance headway, and order of the vehicles are the variables responsible for drag reduction in platooning. Since platooning advantage is more applicable to the vehicles in the middle of the pack, average fuel saving increases with the number of vehicles in the platoon. For two sedan cars running 1 m apart, the average reduction in drag has been estimated to be 10% [49]. Drag reductions ranging from 20% to 60% have been reported for platoons consisting of mixed vehicle types [50,51]. For a 3-truck platoon of freight trucks, Tsugawa has reported a 10% reduction in energy consumption at 80 km/h, with a 20 m gap between trucks; the reduction could reach up to 15% at 5 m gap [52]. The assumption that 50% tractive energy is used to overcome drag resistance could be combined to the advantage of vehicle platooning, which may yield an overwhelming 22.5–27.5% emission reduction. Zabat et al. also examined the potential of emission reduction in vehicle platooning through experiments done in a series of wind tunnels, along with numeric simulations using a passenger van [53]. They found that the average emission reduction per vehicle ranges from 10% to 30%, depending on the vehicles' space in the platoon, number of vehicles, and other variables. Another study confirmed that when 15 vehicles are driving 6–8 m apart, they may achieve optimum fuel saving in the platoon, however, such a gap is extremely unsafe for conventional human-driven cars, but entirely within the capacities of autonomous vehicles [54]. It may be argued from the present literature that AVs vehicle platooning will lead to lower GHG transport emissions, primarily due to drag reduction and lower speed fluctuations.

3.6. Vehicle Right-Sizing

Automation technologies have the potential to scale down the size of automobiles without compromising safety [22]. A significant improvement in fuel efficiency could be achieved by vehicle downsizing. The LDVs are designed to run on US roads with the least capacity of holding four passengers [22,55]. However, the average occupancy of these LDVs is only 1.67 in 2009 [56]. Once individual trip requirements are fulfilled, vehicle right-sizing can significantly reduce the average energy intensity. The vehicle size appropriation works best when it is coupled with car-sharing or carpooling. A fleet of shared AVs could easily supply the right-sized vehicle to meet passenger demand and discourage over-designed cars from being under-used [57]. MacKenzie et al. tested multiple conflicting influences on vehicle weight in terms of technological changes and functional improvement [58]. They indicated that progress in energy efficiency technology had been counterbalanced by increasing vehicle size and vehicle content. In particular, their study revealed that, for an average 2011 model car in the U.S., the safety-related features accounted for a total of 7.7% of the car's weight, and dislodging them could result in a 5.5% reduction in emission. In general, a reduction of 20% in vehicular weight is attributed to a 20% increase in fuel efficiency [59]. The engine power required and amount of fuel consumed during a trip are proportional to the size of a vehicle. With AVs technologies in practice, manufacturers can scale down the vehicle sizes, leading to substantial energy and GHG emission benefits.

3.7. Congestion Mitigation and Efficient Routing

As intermittent traffic experiences frequent stop-and-go and idling conditions, a car driving through heavy traffic will use more fuel, thus emitting more GHG than uncongested traffic. AVs will have the ability to coordinate with other vehicles and infrastructures (V2V and V2I) at the intersection, to improve the traffic flow and reduce the crash frequency that will result in less energy use and less GHG emission [22]. Bigazzi and Clifton's study indicated that internal combustion engines (ICEs) fail to maintain fuel efficiency in slow-moving traffic at a speed of 30 miles per hour or lower [60]. In contrast, Gas electric hybrid vehicles are less sensitive to speed variations and retain fuel efficiency roughly at 20 mph. Though vehicles with different powertrain respond differently to congestion, an AV essentially powered by electricity has a higher potential of reducing GHS.

V2I technology available in AVs could also reroute cars within the road network in case of an unexpected influx of traffic into the grid network generated from a sports/entertainment event [61]. A fully developed city's infrastructure is capable of receiving data from vehicles, anticipating traffic flows, and route vehicles with preference and faster routes given to emergency responders and school buses most efficiently [62]. Smart vehicle communication characteristics of AVs can give early warnings of traffic incidents and unanticipated traffic ahead. This will allow the vehicles to take optimal routes and smoothly flow through the network, and hence lower GHG emissions are released into the atmosphere.

3.8. Carpooling

The occupancy rate is a key factor for GHG emissions associated with existing car travel. Fewer passengers per vehicle will result in more vehicles running on the road than required, and this will result in emissions increasing by several folds. For instance, only 11% of Americans carpool to work, and a staggering average of 113.6 million people make solo trips to and from work daily [63]. AVs have the potential to emerge as a new paradigm of business model to leverage the benefit of ridesharing, which would bring about a modal shift from individually owned vehicles to shared mobility services. Such changes are expected to reduce transportation GHGs significantly. AVs will also provide the option of carpooling and ridesharing that can lower GHGs emissions by reducing the auto-ownership, and travel through other less convenient transport modes.

3.9. Traffic Law Adherence

Iglinksi and Babiak believe that autonomous vehicles will more strictly adhere to traffic laws as compared to the human driver, due to their integrated onboard programming logic [64]. AVs will be more likely to travel at posted speed limits designed to cater to optimal fuel efficiency, reducing GHGs considerably. Similarly, AVs will also strictly comply with traffic signals and thus reducing the nuisance and congestion created by human traffic. GHG reduction at different levels of vehicle automation reported in the literature are listed in Table 1.

Table 1. Reduction of GHG emission at different levels of vehicle automation.

Study	Level of Automation	Cause of Reduction in GHG	Results	Condition
Stephens (2016) [17]	Partial Automation	Driver profile and Traffic flow calming	0–10% 0–5%	During peak hours During non-peak hours
	Full Automation		10–21% 5–11%	During peak hours During non-peak hours
Barth and Boriboonsomsin (2009) [15]	Full Automation	Eco-driving	10–20% nearly 0%	Congested highway traffic. Free flow
Xia et al. (2013) [65]			5–10%	Under congested city traffic
Li and Gao (2013) [37]			10%	Under congested city traffic
Rakha (2012) [40]			8–23%	Under different speed, congestion level and design characteristics
Yelchuru (2014) [42]	Partial automation	Eco-traffic signal timing V2i/i2v communication	1.8–2%	City driving
	Full Automation		2–6%	City driving
Schrank et al. (2012) [46]	Partial Automation	Collision avoidance	0–0.95%	City driving
Stephens (2016) [17]	Full Automation		0–1.9%	

Table 1. *Cont.*

Study	Level of Automation	Cause of Reduction in GHG	Results	Condition
Stephens (2016) [17]	Partial Automation	Platooning	0–12.5%	During peak hours
Schito (2012) [50]	Full Automation		12.5–25%	During non-peak hours
			22.5–27.5%	During non-peak hours
Zabat et al. (1995) [53]			10% to 30%	During peak hours
			20–25%	During non-peak hours
Wadud et al. (2016) [22]			3% to 25%	During non-peak hours
Wadud et al. (2016) [22]	Full Automation	Vehicle/powertrain resizing	45%–	No condition mentioned
Burns et al. (2013) [66]			roughly 50%	
Shoup (2006) [34]	Full Automation	Less Hunting for Parking	2–11%	During city driving
Brown et al. (2014) [35]	Full Automation		5–11%	
Barth (2009) [15]	Partial Automation		2–5%	
Brown et al. (2014) [35]	Full Automation	Increase in Ridesharing	Roughly 12%	During city driving
Stephens (2016) [17]	Partial Automation	Faster travel	0–10%	During peak hours
	Full Automation		10–40%	During non-peak hours
Haan et al. (2007) [67]	Full Automation		20–40%	During non-peak hours
Brown et al. (2014) [35]	Full Automation		0–40%	During non-peak hours
	Partial Automation		0–10%	During non-peak hours
Stephens (2016) [17]	Partial Automation	Easier travel	4–13%	No condition mentioned
Stephens (2016) [17]	Full Automation		30–156%	Living farther
Childress et al. (2015) [68]	Full Automation		3.6–19.6%	Capacity will increase and value of travel time cost will reduce
Gucwa (2014) [69]	Partial Automation		4–8%	Living farther
Brown et al. (2014) [35]	Full Automation		50%	
MacKenzie et al. (2014) [58]	Partial Automation		4–13%	
Stephens (2016) [17]	Full Automation	Increased Travel by Underserved Populations	2–40%	Elderly and disabled would travel as much as drivers without medical conditions
MacKenzie et al. (2014) [58]	Partial Automation	Mode Shift from Walking, Transit and Regional Air	2–10%	No condition mentioned
Harper et al. (2016) [70]	Partial Automation		Up to 12%	
Brown et al. (2014) [35]	Full Automation		Up to 40%	
Fagnant and Kockelman (2014) [71]	Full Automation	Increased empty miles travelled	5% to 11%	On city driving

4. Causes of Increase in GHG Emissions

This section reviews some of the predominant factors that may increase GHG emissions due to vehicle automation. The impact of two-vehicle automation strategies, i.e., partial automation and full automation, will be discussed.

4.1. Easier Travel

Easier travel involves reaching destinations more quickly due to capacity increases and fewer crashes, and lower travel costs. Travel may be faster and more reliable if crashes and congestion are reduced, and travel demand may increase. Capacity would effectively increase by less congestion and fewer crash delays, which could also trigger increased travel. Using activity-based travel model-generated scenarios, Childress et al. analyzed possible changes in travel patterns in the Puget Sound region [68]. These evaluated scenarios were comprised of a 30% increase in roadway capacity, resulting in a 3.6% increase in emissions, and a 35% reduction for the highest-income households in the perceived value of travel time cost. In a different scenario, assuming everyone owned an automated vehicle (no shared one), which resulted in a 30% increase in roadway capacity and 50% less parking costs, along with a 19.6% increase in emissions. People may be more likely to drive in automated vehicles under congested conditions. Easier travel means that more and more people will be attracted to use AVs, especially during traffic congestion situations. Greater demand and increase in road capacity will ultimately lead to increased vehicular emissions.

4.2. Faster Travel

CAVs will be able to navigate and respond more quickly than human drivers with the state-of-the-art communication technology available onboard; it follows that AVs will be able to ride more safely at higher speeds than human drivers. AVs are expected to leverage V2V and V2I networks that communicate charted courses seamlessly to raise the speed limits on freeways [62]. To ensure a safe driving environment that accounts for operator reaction time, vehicle design, and road limitations, speed limits were initially imposed in the US, later changed at the federal level to minimize fuel consumption [32]. Therefore, an increase in fuel consumption is expected for increasing speed limits across the country due to AVs [22]. Considering driver's value of time analysis, Wadud et al. analyzed the possible repercussions of increased highway travel speeds due to automation technologies [22]. A typical car's speed-fuel consumption relationship was used to conclude that GHG emission of the highway could increase by 20–40% [72]. According to Brown et al., the increase in highway fuel use could be as high as 40% or more as a result of faster travel [73]. Brown et al. focused on travelers' time budgets based on Schafer et al.'s observation that different societies display the same willingness to travel [35,74]. They hypothesized that if people could travel faster, they might prefer to live further away from their regular destinations, only to promote urban sprawl. Ultimately, this might trigger a possible increase in emissions by 50%. The onboard vehicle communication and sensing technologies of AVs will require a higher posted speed limit at the network level. It is established that faster travel is accompanied by greater fuel consumption, and hence the rate of GHG emissions.

4.3. Increased Travel by Underserved Populations

Although access to mobility services to the disabled and people at dotage rendered by the AVs seems beneficial for society, it is likely to increase overall VMT. Due to the lack of adequate data on why some population groups travel less than others, it is difficult to forecast future travel patterns of those who are currently underserved. MacKenzie et al. observed from the 2014 National Household Travel Survey data that VMT for adults over 62 years old is much lower than the 42 years old group [58]. Fully automated vehicles could fulfill this travel demand. They estimated that increased travel could raise emissions by 2–10%. Harper et al. assumed that non-drivers would travel as much as drivers in each age group aged between 19–64; drivers with medical conditions are also expected to have similar travel patterns as drivers without medical conditions within each age group [70]. Dividing the sample population into three distinct groups of non-drivers 19 and older, elderly drivers without a medical condition, and drivers 19 and older with a medical condition, it was estimated that the underserved could increase emissions up to 12% by using fully automated vehicles. Examining data from the 2009 NHTS and the 2003 Bureau of Transportation Statistics publication "Freedom to Travel," Brown et al. estimated a 40% increase in GHG emission, If all age segments traveled close to the top decile in each segment [35]. The fact that AVs can be used by non-drivers, people without driving licenses or people with special needs will increase the road user population and hence the daily number of vehicle trips. However, although it may have several positive prospects, GHGs are expected to increase.

4.4. Mode Shift

The theory of travel behavior implies that the preference to use one mode over another is influenced by several variables, including, but not limited to, socio-economic status, age, gas price, urban form, and transportation options availability. Metropolitan Area Planning Council (MAPC) conducted a study in the Boston area, in which researchers found that those who use transit passes daily, or weekly, would replace transportation network companies for transit frequently. Frequent transit users are more likely to be willing to sacrifice the service in favor of a ride-sharing opportunity, even at a large difference in cost or forfeiting the money they already paid to avail the service [75]. A ride in a driver-less, fully autonomous vehicle will likely be cheaper [76,77]. New mobility services, and eventually autonomous vehicles, on the contrary, could increase ridership by solving the first-mile/last-mile problem and serving as a complement to mass transportation, thereby increasing GHG emissions. Shifting a staggering 56.5 billion miles (according to the National Transit Database for 2013) to vehicle-miles constitutes an increase in emissions of 2.0%. If it is assumed to be in city travel only, it accounts for an increase of 3.7% in city emission. Considering the change from air transport, an estimated 79.8 billion passenger miles traveled over domestic flights of less than 500 miles. Shifting all of these passenger-mile to non-shared vehicle-mile AVs in a possible scenario reflects a rise of 2.9% in emissions. However, this condition is projected to increase emissions only on highways. With AVs in operation at relatively lower journey costs than other transport modes, more and more people will be inclined to use AVs, which will also lead to high GHG emissions.

4.5. Increased Empty Miles Traveled

AVs have not been extensively studied for potential changes in vehicle travel without a passenger. A vehicle owner could send his driverless AV to pick up family members or send nearby locations beforehand to minimize wait time. An agent-based model of self-driving vehicles moving in a square grid representing an imperial city was used by Fagnant and Kockelman to investigate the travel patterns of users of a shared fleet of self-driving vehicles [71]. With some predefined available data from 2009 NHTS, they examined scenarios with varying trip generation rates, level of network congestion, neighborhood size and vehicle relocation strategies. Finally, the study concluded that almost 11 conventional vehicles could be replaced by a self-driving vehicle with an increase of 5–11% in emission for vehicle repositioning. Vehicle idling while waiting for the passengers' pick up from their destinations is the main source of increased vehicle miles traveled and resulting emissions.

4.6. Land Use Change

Since individuals are liberated from the pressure of being behind the wheel and can use the time for work or recreation instead, there is a likelihood that they can accept longer commutes. For example, Cervero and Murakami observed data from 370 urbanized areas in the U.S. They deployed structural equation modeling to determine the relationship of population density with VMT per capita and found that an increase in population density leads to a decrease in per capita VMT [78]. When it comes to urban form, they pointed out a vital issue: traditionally, societies have been more reluctant to relocate residential roads or emphasize keeping the roads in the first place when built [79]. These findings indicate that if the introduction of AVs increases the pressure of growth in suburban areas, an increase in GHG emissions could result as people are concentrated in areas that facilitate more auto travel. Access of AVs to remote and sub-urban areas will encourage the public to opt for longer commutes and frequent travel, which will ultimately cause increased vehicular emissions at the network level.

5. Change in GHG Emissions at Different AV Penetration Levels

This section investigates changes in emissions at different AV penetration levels using integrated traffic microsimulation and emission models. With better operating efficiency and improved powertrain technology, AVs are expected to yield overall emission benefits.

Stogios et al. designed a study to evaluate the potential impacts that AVs could offer under varying scenarios [80]. Under interrupted and uninterrupted traffic flow conditions, high and low traffic conditions were evaluated. This study integrated the use of VISSIM microscopic software with the MOVES emission model to assess vehicular emissions. Eight inbuilt car-following and two lane-changing parameters present within the VISSIM model are investigated, representing AV driving behavior. The high traffic volume is reflected by an increase of 50% increase of the demand, while low traffic volume is produced by reducing the demand by 50%. A set of simulations is completed in the VISSIM model with 10%, 30%, 50%, 70%, and 90% of AVs penetration rate to investigate the changes in emission from the base condition. The study revealed that headway time has the highest impact on emissions and average delay than other parameters. Maximum headway time representing a cautious driving behavior resulted in a 31% increase in overall emissions, while a shorter headway time resembling aggressive driving behavior reduces the emission by 10%. The growing penetration of AVs into the network within high-traffic conditions results in minor incremental changes in emission factors and the number of stops per vehicle. In contrast, aggressive AVs reduce the average number of stops and emissions with increased market penetration. The AV penetration rate results, however, are not as evident under low traffic conditions. That is to conclude from the study that AVs will offer the maximum benefits under congested traffic conditions.

Olia et al. deployed the PARAMICS microsimulation framework integrated with CMEM emission model to measure the vehicle emission at different market penetration of connected autonomous vehicles [81]. The CMEM model is capable of continuously estimating gas emissions and fuel consumption at the microscopic level. The emission and fuel consumption in the CMEM model vary based on vehicle type, age, fuel system, and emission control technology. The vehicles in this model were divided into three categories, unfamiliar non-connected, familiar non-connected and CVs to produce emission factors for CO_2, CO, NOx and HC. The results showed that with a gradual increase of CVs market penetration, the emission factors decreased. The maximum emission benefit could be realized at 50% CV penetration, where the GHG emission is reduced by 30% from the base condition.

Another study by Conlon and Lin attempted to quantify the changes in CO_2 emission as the AVs are gradually penetrated into a congested urban road network [82]. SUMO traffic microsimulation and Newton-based greenhouse gas model (NGM) emission model were integrated to estimate the emission for different AV penetration, ranging from 0% to 100% into the network with an interval of 10%. At an AV penetration rate lower than 30%, the total CO_2 emission had increased from the baseline of 0% AVs. The increase of total emission is explained by the difficulty in the interaction between human-driven vehicles (HDVs) and AVs. As the AVs penetration rate gradually increased, the study network started to realize the benefit of AVs in traffic operation, travel speed, and emission reduction. However, the emission reduction remained plateaued between a wide range of 40% to 90% AV penetration. Finally, at full AV penetration with no heterogeneity, the network was found to yield a maximum reduction of CO_2 emission of 4.08% from the base condition. The changes in emission at different AV penetration levels from different studies could be compared for better understanding (Figure 2). Existing literature in this regard suggests that noticeable emission benefits of AVs at the network level can be achieved at penetration rates ranging between 30% and 50%.

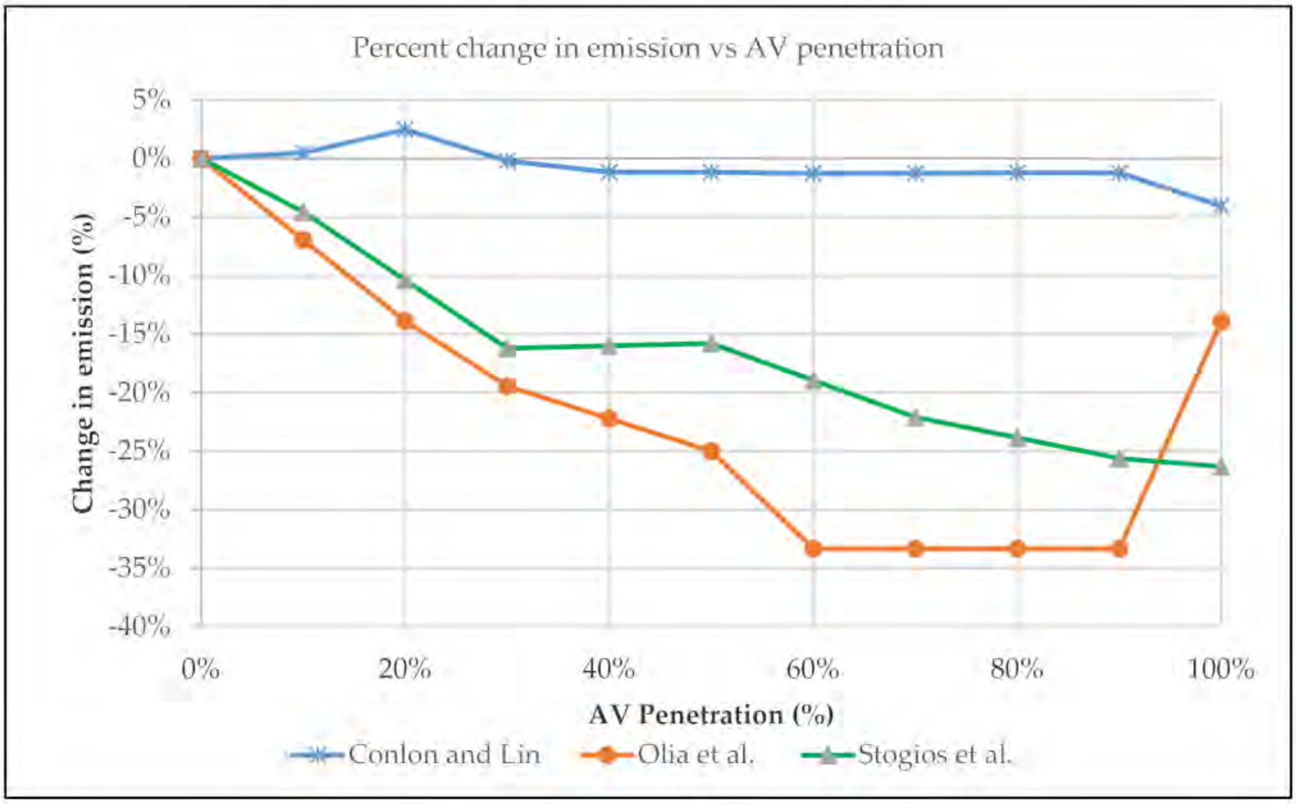


Figure 2. Emission changes by AV penetration [80–82].

6. Energy Consumption and GHG Emission

In recent years, the transportation sector has become the top GHG emitter surpassing electricity generation in the U.S. It accounted for approximately 28.5% of total atmospheric emissions in the country and continued to be the rapidly growing emissions source of any energy-related sector [83,84]. The global share of GHG from transportation is estimated to be around 24% of all emissions [85]. Passenger cars are accountable for 75% and 60% of transportation emissions worldwide and in the U.S., respectively [84,85]. The emergence of AVs can bring numerous energy and emission benefits, due to homogeneous traffic flows, lower highway congestion, lighter and smart vehicles shaped to minimize air resistance, minimum vehicle idling, the need for less powerful engines, etc. This would further enhance fuel efficiency and reduce emissions.

Similarly, shorter time spent searching for nearby parking and reduced needs for construction, operation, and maintenance of parking infrastructures could also bring various environmental benefits. Furthermore, the prospects that AVs serving passengers' demand for performing various activities will be larger than traditional vehicles cannot be excluded. Under such circumstances, larger vehicle sizes may somehow limit fuel efficiency gains. However, shared AVs may be programmed to continuously drive rather than looking for parking in the city's downtown until the next call for a ride, thus generating more emissions. This issue may be partially mitigated by programming the AVs to drive themselves outside of the downtown of an urban area where parking is free or relatively cheaper. However, this extra travel will lead to more energy consumption, creating more traffic congestion and subsequently producing more vehicular emissions.

In the literature, numerous studies have discussed the prospects of fuel energy saving through vehicle automation. For example, Wu et al. reported that the deployment of a fuel economy optimization system could offer the automated systems or human drivers with essential guidance about optimal deceleration/acceleration profiles, taking into account vehicle current speed and acceleration, as well as other information such as headway spacing, signs, and traffic lights [86]. The authors conducted a driving simulator experiment in an urban setting through a network of signalized intersections and noted a nearly 31% reduction in fuel consumption for drivers using the system. Likewise, Khondaker and Kattan reported that a variable speed limit control algorithm resulted in approximately 16% fuel savings compared to an uncontrolled scenario [87]. The proposed control system integrated real-time intelligence about individual driver behavior (like the level of compliance with the established speed limits, acceleration/deceleration) in the situation of 100% connected vehicles (CVs) environment. However, fuel savings were only marginal at a penetration rate of CVs below 50%. In their study, Li et al. demonstrated that under automated car-following scenarios, the application of a pulse-and-gliding (PnG) controller could offer up to 20% savings in fuel compared to a conventional linear-quadratic (LQ)-based controller [88]. Other field tests and simulation studies have also shown that various types of adaptive cruise controller (ACC) and cooperative adaptive cruise controller (CACC) vehicle control algorithms could significantly reduce fuel energy consumption [89–92].

Zohdy and Rakha designed a controller equipped with CACC that can guide the optimum course of vehicles in the context of the urban road intersections network [93]. The study compared the fuel consumption for their system with various intersection geometries, and noted that on average, 11%, 45%, and 33% fuel saving were obtained compared to conventional intersection control approaches of a roundabout all-way-stop and traffic signal, respectively. In their studies, Kamalanathsharma, and Rakha; Asadi and Vahidi, and Ala et al. reported that the CACC that uses vehicles to infrastructure (V2I) communication to optimize vehicle trajectories in the vicinity could lead to a reduction in a fuel energy saving of about 47%, 30%, and 19%, respectively [94–96]. A recent study conducted by Manzie et al. also reported that a road-vehicle environment where vehicles can exchange traffic flow information via inter-vehicle communication and sensors could achieve about 15–25% savings in fuel consumptions [97]. They further stated that this number could reach as high as 33%, depending on the amount and quality of traffic information that they can process and exchange.

Similarly, in another study, Wang et al. observed that a higher penetration rate of intelligent vehicles equipped with a longitudinal vehicle controller was associated with lower NO_x emissions in a congested platoon [98]. Bose and Ioannou reported that a fleet containing only 10% ACC-equipped vehicles could lower NO_x emissions by 1.5% CO and CO_2 emissions by up to 60% [99]. Choi and Bae examined the CO_2 emissions profiles for manual and CVs under lane changing operations [100]. The study found that CVs can lead to 7.1% less CO_2 emission, while lane change can maneuver faster to a slower lane. Likewise, lane change operations for CVs from a slower to a faster lane were associated with around 11.8% CO_2 emissions benefits. Fagnant and Kockelman conducted a larger-scale agent-based study. They replicated a mid-sized city scenario where nearly 3.5% of the total trips on a given day are undertaken by shared AVs [71].

These researchers observed that autonomous vehicles could have a significant positive effect on reducing various pollutants (i.e., SO_2, CO, NOx, volatile organic compounds (VOC), PM10, and GHG). VOCs and CO emissions were reduced the most, mainly due to the lower frequency of the vehicle's cold start. Effects on the particulate matter with a diameter less than 10 mm (PM10) and GHG were comparatively insignificant due to the need for additional trips that shared vehicles have to make to pick up and drop off passengers from different locations. However, it is worth mentioning that this simulation study was limited by the assumptions that automated vehicles in the fleet are not essentially powered by electricity, hybrid-electric, or running on alternative fuel and passengers would not make trips more frequently. The long-term effect of automated vehicle-related emission reduction could realize a very optimistic level, as indicated in a study by Greenblatt and Saxena that estimated the emission of shared electric autonomous taxis. The study found that the GHG reduction per vehicle per mile in 2030 could be 87–94% less than the emissions of gasoline-based internal combustion vehicles in 2014 and 63–82% less compared to hybrid-electric vehicle emissions in 2030 [101].

Brown et al. also predicted considerable energy-saving up to 91% per automated vehicle in 2030 in a framework that accounted for the highest impact of energy-saving factors (e.g., efficient travel, electrification and optimized vehicle weight) and increased energy use (e.g., increased travel distance by dependent traveler) [35]. However, the factors and to what extent they will offer emission benefit in the future remains an open question. As a result, the trade-off between energy savings and increased energy use from automated vehicles might fluctuate substantially.

Few studies have also argued that the benefit in emission reduction by AVs could be fully offset by increased travel, due to lower costs involved in travelling. A study by Taiebat et al. used microeconomic modeling and applied econometric techniques to analyze the travel and energy impacts of CAVs with respect to the price of fuel and travel time [102]. While increased fuel economy in CAVs reduces the amount of energy required per mile traveled, it also decreases the cost of travel, encouraging additional travel and leading to an energy "rebound effect." The elasticities of VMT demand with respect to fuel and time costs were estimated using the developed microeconomic model under income and time constraints. The forecasted travel demand for a typical household was estimated to increase by 2–47%. Numerous plausible scenarios involving changes in fuel economy and time costs resulted in an overall increase in energy consumption. In higher-income quantiles, backfire is more likely as the reduction in time cost is less appreciated in this class, only to offset the energy savings from CAVs. On average, a 38% reduction in time costs completely offsets a 20% increase in fuel economy provided by CAVs. Numerous researchers have also pointed out that the higher penetration of automated vehicles may actually increase the vehicle fleet number and contribute to the rise of GHGs in the environment [103]. The burgeoning number of automated on-demand mobility or ride-hailing services may lead to an enlargement of the number of vehicles in the fleet, increased VMTs and road congestion, and thereby increased fuel consumption and GHG emissions.

Synthesizing the result of all the previous studies, some charts could be developed to better understand and visualize the results of the level of GHG decrease or increase. The first graph (Figure 3) shows the factors that will increase emissions, while others are for the factors that will reduce the emission (Figure 4). In the last chart, Figure 5 demonstrates the result ranges for all research studies.

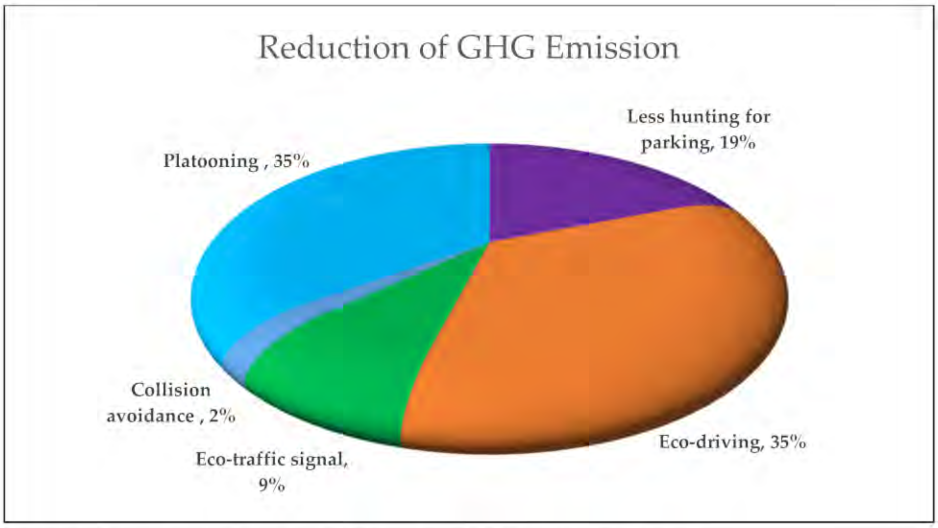


Figure 3. Average contribution of the causes on GHG emission reduction.

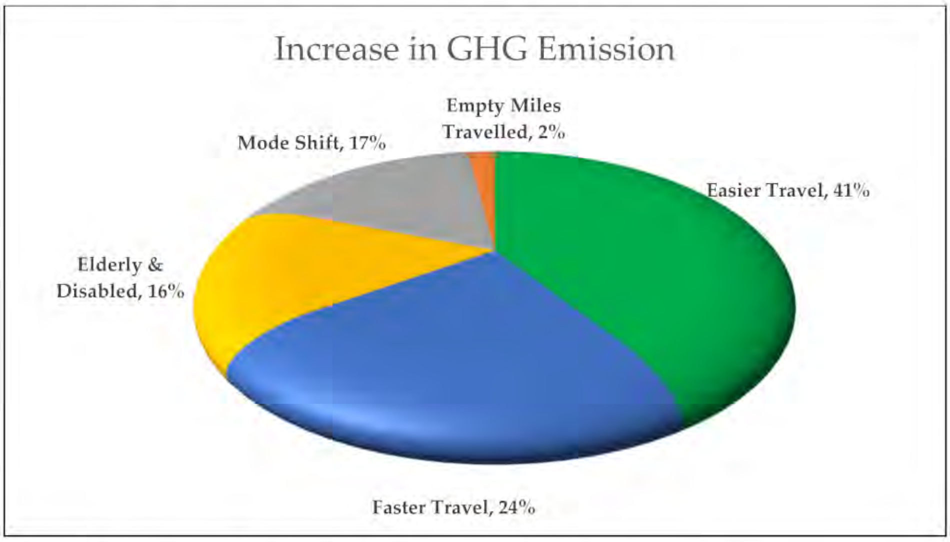


Figure 4. Average contribution of the causes on GHG emission increase.

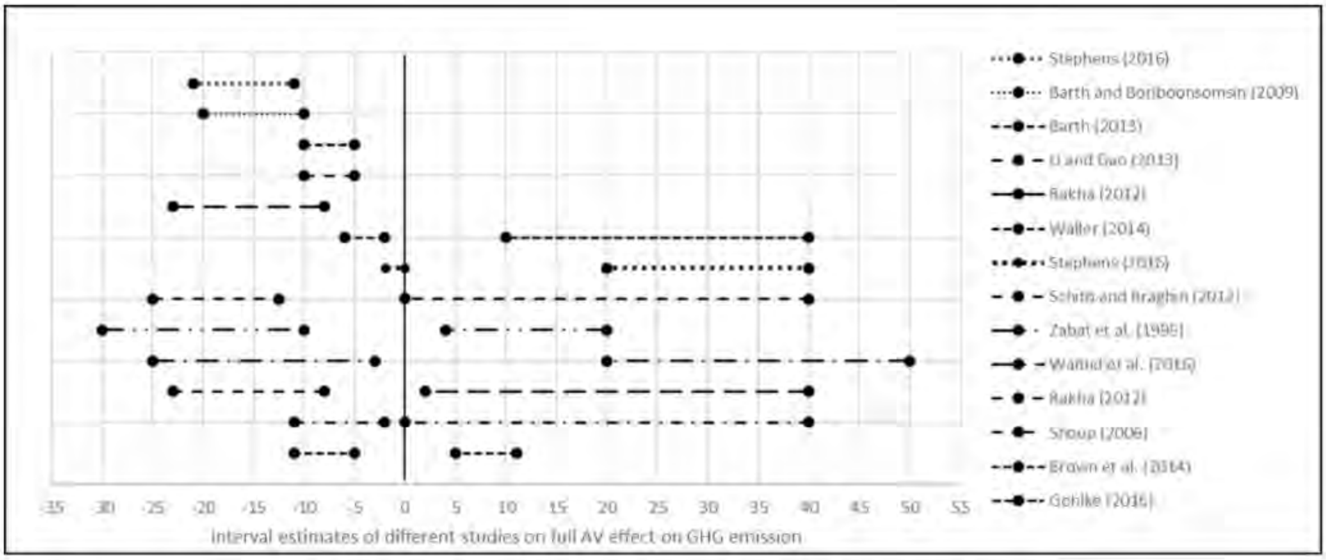


Figure 5. Interval estimates of different studies on full AV effects on GHG emission.

6.1. Causal Loop Diagram (CLD) of the AV's Effect on GHG Emission

In transport studies, system dynamics have been applied, as the feedback and connections provided by these models are useful for defining interactions of variables within the transport system. Shepherd provided a review of the different system dynamics modeling approaches used in transport systems [104]. In his study, he mentioned that the causal loop diagram (CLD) is the primary technique used to analyze the qualitative relationships between various aspects of the system within system dynamics modeling. CLD is a helpful tool to explore possible sources of dissent to strategies, synergies, and repercussions within the system. Such prospects will then help identify potential problem statements that can be addressed by quantitative modeling. A CLD illustrates how important variables of the system interrelate with each other by using text, arrows and symbols. Arrow running from the "cause" to the "effect" with a polarity represents the interaction between two variables, known as a causal connection. A positive polarity indicates that deviations in the "causal" variable would result in deviations in the "effect" variable in the same direction, assuming all other influences remain constant in the system. Similarly, a negative arrow shows that changes in one variable cause the other to change in the opposite direction, given that all other conditions are fixed.

The feedback loops created by the causal relationship are termed as balancing (B) or reinforcing (R) based on the polarity sign, which represents positive or negative feedbacks, respectively within the system [105].

A CLD is developed based on the literature to depict the interactions of different root causes and variables with the GHG emissions from AVs (Figure 6). The CLD starts with the gradual penetration or increased market share of AVs within the transportation system. This system dynamic model assumes that both the non-AVs and AVs use fossil fuel for power generation. Since the AVs are fuel-efficient, there is a substantial chance that the demand for AVs increases, with all its benefits in terms of traffic safety, operation, and management. However, since the AVs are expected to offer several benefits to the transport system, the introductory retail price of it might be some fold higher than the conventional non-AVs. A higher retail price of AV will impart a negative effect on AV's market share.

Figure 6. Causal Loop Diagram of the influence of fuel-efficient AVs on GHG emissions (inspired by [106,107]).

Nevertheless, the increase in population and social pressure to purchase AVs will positively affect the AV's penetration rate to the market. In this context, it is predicted that the number of cars in the city will increase as the population increases, causing road congestion as well. Congestion reduces the efficiency of automobile engines, contributing to increased fuel consumption and leading to higher rates of pollution [107]. An increased market share of fuel-efficient AVs will reduce the fuel demand as a whole. The reduced fuel demand initiates a balancing loop; a shortfall of demand will push the fuel price to increase and increase travel cost per mile, only to be balanced by less miles traveled. The price of gasoline is a wiggle that can play either in favor or against AVs. As observed today, gasoline prices have not prevented the ownership and use of fossil fuel vehicles (FFV) in general, but if prices go up, FFV use could fall as people move to more affordable choices, given the limited nature of petrol resources. However, an increase in the cost/miles travel will observe fuel-efficient AVs' marginal utility as people will enjoy the added benefit by buying an additional AV unit.

A reinforcing loop will also generate fuel demand. In the event of increased demand, energy consumption will also escalate, giving rise to vehicle emission or GHG emission. Implementing pollution reduction policies that cause environmental degradation should be balanced in this loop, though there is a delay in this cycle that prevents it from performing as planned. The mounting pressure on policy regulation to control the environmental degradation will possibly deter the growing AV production. More capital is expected to be invested within the automobile industry to make the AVs more fuel-efficient.

6.2. AVs Potential Impact on Reducing GHG Emission during a Global Pandemic

On 30 January 2020, the World Health Organization (WHO) announced the respiratory coronavirus disease outbreak 2019 (COVID-19) and subsequently, on 13 March, declared a global pandemic. While government policies in most countries reduced mobility, travel also declined in response to the number of local cases in the respective country. This shows how people adapted their travel behavior depending on the level of information available on the outbreak. Not only did people restrict their travel, but destinations were often avoided that had more infected cases. The automotive and transport industries are closely observing how consumer behavior changes will impact AV technologies in key aspects of the economy and daily life, given that numerous changes have been imposed upon people's daily lives due to the global COVID-19 pandemic.

COVID-19 is overhauling the consumer's perceptions towards public transit in ways that are likely to support AV technology in the longer run. As the pandemic has spread across the world, people have generally remained home, either by choice or by local directives. Hence, transit ridership has declined substantially, barring essential and emergency support workers. Major cities like New York, Washington, D.C., and San Francisco of the US have seen the ridership plummeted by a staggering 70–90% in August 2020 compared to the same time in the previous year [108]. While the decrease in ridership is attributed to home-based work, the closure of educational institutes, and local travel bans, consumers have become more interested in personal motor vehicle ownership than ever before. While the potential car customer might be putting new purchases on hold, McKinsey's recent survey reported that "20 percent of people in the United States who do not possess a vehicle under their name, now considering buying one" [108]. This group mainly includes people who live in cities and rely on public transportation for mobility. While the customer demands for new and used cars may have temporarily postponed adopting AV systems in the consumer sector, the COVID-19 pandemic per se warranted the important role of AV in day-to-day business and, most importantly, to deal with the risks posed by COVID-19.

Over the past decade, the automotive industry has had to adapt to changing attitudes to mobility, with global car ownership predicted to peak in 2034 before beginning its decline. However, with many still reluctant to use public transport due to the risk of infection, the prospect of owning a car may seem more inviting in the context of the unprecedented COVID-19 pandemic. This change in attitudes towards mobility is already evident in the adoption of micro-mobility solutions, while some have predicted that autonomous vehicles, capable of driving with some to no human input, may see an acceleration in terms of development, deployment and public interest. With industrial activity forced to slow down, flight and car journeys decreasing, greenhouse gas emissions around the world have plummeted. Consumers will get used to these changes, which is likely to see an increase in the adoption of autonomous vehicles in the future. These new vehicles are meant to be fuel-efficient, affordable, clean and green and a natural feature in smart cities and interactive communities—and will forever change the future of mobility. One of the key barriers to autonomous vehicle rollout is public perception, with a 2018 survey by OpenText revealing that 52% of consumers would not buy a driverless car. However, the COVID-19 pandemic may have contributed to changing attitudes. When weighing up the risk of COVID-19 infection presented by public transport or shared mobility, it is possible that the public will look more favorably on driverless cars. The current pandemic has had a significant impact on transport demand and mode, with a shift away from shared mobility, and in particular public transport, because of worries over public health.

7. Conclusions

Net effects of vehicle automation on emissions across a variety of illustrative examples show that automation could theoretically reduce GHG emissions and energy usage plausibly by almost half—or double-fold—depending on the implications that would come to the fore [22]. It is believed that reductions in GHG emissions through AVs' adoption will be negated to an unascertained extent, mainly due to increased car travel, facilitated by other factors such as lower perceived travel time and costs per km/trip, probable loss of public transport patronage, and possible increases in car ownership. Thus, it is quite possible that AVs could be more energy-efficient, thereby reducing the GHG by functional unit-basis as per-passenger-mile (ppm); however, the overall gain related to transportation GHG emissions could be swamped by a surge in increased vehicle miles traveled (VMT).

The effect of AV adoption on consumer travel patterns could be more pronounced from environmental aspects rather than technical attributes. While it is challenging to accurately estimate the behavioral fronts to AV adoption, a more tangible consideration of the relationship between different AV adoption models and anticipated travel behavior is vital for estimating AVs' environmental impacts. It may be argued from the discussion presented herein that if AVs are deployed within less approbatory areas or if the road transportation sector is continued to be dominated by privately owned vehicles, it is likely that AVs may escalate the transport-related GHG emissions. Hence, adoption tendencies like vehicle ownership models are also expected to largely influence whether AVs will decrease or increase the overall VMT as well as the subsequent GHG emissions. Few studies have indicated that the positive emission changes may not be realized at lower AV penetration rate, where the maximum emission reduction might take place within the 60–80% AV penetration rate.

Impacts of autonomous vehicles on GHG emission are highly dependent on continuous technological development and evolution, market reaction, and regulatory actions, making it challenging to confidently predict the overall benefits expected to deliver by AVs to the transportation systems in terms of GHG emission. With long-term land-use adjustments, the role of policy, welfare and equity yet to be explored and the potential effects of AVs remain unknown; it is unlikely that we can anticipate long-term effects on GHG emission with certainty. Moreover, the overwhelming COVID-19 global pandemic has also posed challenges to some of the well-perceived mode choice models, which may force the policymaker to adopt suitable mobility alternatives that ensure public health and safety. Therefore, it is of paramount importance to develop appropriate methodologies, tools, and techniques to better understand the impact of GHG emissions for AV adoption at different levels by harnessing an appropriate system approach.

Author Contributions: Conceptualization, M.M. and S.M.R.; methodology, M.M. and S.M.R.; writing—original draft preparation, M.M., I.R. and S.M.R.; writing—review and editing, S.M.H.A., A.J. and F.S.A.-I.; visualization, I.R., A.J. and S.M.R.; supervision, S.M.R. and F.S.A.-I.; project administration, S.M.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Not Applicable.

Acknowledgments: The authors would like to gratefully acknowledge the support of King Fahd University of Petroleum & Minerals (KFUPM) in conducting this research.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Vahidi, A.; Sciarretta, A. Energy Saving Potentials of Connected and Automated Vehicles. *Transp. Res. Part C Emerg. Technol.* **2018**, *95*, 822–843. [CrossRef]
2. Facts, E.F. *US Transportation Sector Greenhouse Gas Emissions 1990−2013*; US Environmental Protection Agency: Washington, DC, USA, 2015.

3. National Academies of Sciences, Engineering, and Medicine. *Commercial Motor Vehicle Driver Fatigue, Long-Term Health, and Highway Safety: Research Needs*; National Academies Press: Washington, DC, USA, 2016; ISBN 0-309-39252-7.
4. Metcalf, G.E. Market-Based Policy Options to Control US Greenhouse Gas Emissions. *J. Econ. Perspect.* **2009**, *23*, 5–27. [CrossRef]
5. Andrés, L.; Padilla, E. Driving Factors of GHG Emissions in the EU Transport Activity. *Transp. Policy* **2018**, *61*, 60–74. [CrossRef]
6. Liu, D.; Yang, D.; Huang, A. LEAP-Based Greenhouse Gases Emissions Peak and Low Carbon Pathways in China's Tourist Industry. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1218. [CrossRef]
7. Crayton, T.J.; Meier, B.M. Autonomous Vehicles_ Developing a Public Health Research Agenda to Frame the Future of Transportation Policy. *J. Transp. Health* **2017**, *6*, 245–252. [CrossRef]
8. Newman, P.; Kenworthy, J. *Sustainability and Cities: Overcoming Automobile Dependence*; Island Press: Washington, DC, USA, 1999.
9. Mersky, A.C.; Samaras, C. Fuel Economy Testing of Autonomous Vehicles. *Transp. Res. Part C* **2016**, *65*, 31–48. [CrossRef]
10. Moriarty, P.; Wang, S.J. Could Automated Vehicles Reduce Transport Energy? In *Energy Procedia*; Elsevier Ltd.: Amsterdam, The Netherlands, 2017; Volume 142, pp. 2109–2113.
11. Markit, I. *Autonomous Vehicle Sales Forecast to Reach 21 Mil. Globally in 2035, According to IHS Automotive*; IHS Markit: London, UK, 2016.
12. Rivera, J.; van der Meulen, R. *Gartner Says 4.9 Billion Connected 'Things' Will Be in Use in 2015*; Gartner: Barcelona, Spain, 2014.
13. Alexander-Kearns, M.; Peterson, M.; Cassady, A. The Impact of Vehicle Automation on Carbon Emissions. Center for American Progress. Available online: https://www.americanprogress.org/issues/green/reports/2016/11/18/292588/theimpact-of-vehicle-automation-on-carbon-emissions-where-uncertainty-lies (accessed on 11 November 2020).
14. Litman, T. *Safer Than You Think!: Revising the Transit Safety Narrative*; TRID: Victoria, BC, Canada, 2016.
15. Barth, M.; Boriboonsomsin, K. Energy and Emissions Impacts of a Freeway-Based Dynamic Eco-Driving System. *Res. Part D Transp.* **2009**, *14*, 400–410. [CrossRef]
16. Chen, T.; Kockelman, K.; Hanna, J.P. Operations of a Shared, Autonomous, Electric Vehicle Fleet: Implications of Vehicle & Charging Infrastructure Decisions. *Transp. Res. Part A Policy Pract.* **2016**, *94*, 243–254.
17. Stephens, T.; Gonder, J.; Chen, Y.; Lin, Z.; Liu, C.; Gohlke, D. *Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles*; National Renewable Energy Lab.(NREL): Golden, CO, USA, 2016.
18. Barkenbus, J.N. *Author's Personal Copy Eco-Driving: An Overlooked Climate Change Initiative*; Elsevier: Amsterdam, The Netherlands, 2009. [CrossRef]
19. Rakha, H.; Kamalanathsharma, R.K. *Eco-Driving at Signalized Intersections Using V2I Communication*; IEEE: Piscataway, NJ, USA, 2011; pp. 341–346.
20. Psaraki, V.; Pagoni, I.; Schafer, A. Techno-Economic Assessment of the Potential of Intelligent Transport Systems to Reduce CO2 Emissions. *IET Intell. Transp. Syst.* **2012**, *6*, 355–363. [CrossRef]
21. Pettigrew, S.; Fritschi, L.; Norman, R. The Potential Implications of Autonomous Vehicles in and around the Workplace. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1876. [CrossRef] [PubMed]
22. Wadud, Z.; MacKenzie, D.; Leiby, P. Help or Hindrance? The Travel, Energy and Carbon Impacts of Highly Automated Vehicles. *Transp. Res. Part A Policy Pract.* **2016**, *86*, 1–18. [CrossRef]
23. Greenblatt, J.B.; Shaheen, S. Automated Vehicles, On-Demand Mobility, and Environmental Impacts. *Curr. Sustain. Renew. Energy Rep.* **2015**, *2*, 74–81. [CrossRef]
24. Anderson, J.; Nidhi, K.; Stanley, K.; Sorensen, P. *Autonomous Vehicle Technology: A Guide for Policymakers*; Rand Corporation: Santa Monica, CA, USA, 2014.
25. Tomás, R.F.; Fernandes, P.; Macedo, E.; Bandeira, J.M.; Coelho, M.C. Assessing the Emission Impacts of Autonomous Vehicles on Metropolitan Freeways. *Transp. Res. Procedia* **2020**, *47*, 617–624. [CrossRef]
26. Stasinopoulos, P.; Shiwakoti, N.; Beining, M. Use-Stage Life Cycle Greenhouse Gas Emissions of the Transition to an Autonomous Vehicle Fleet: A System Dynamics Approach. *J. Clean. Prod.* **2021**, *278*, 123447. [CrossRef]
27. Wang, A.; Stogios, C.; Gai, Y.; Vaughan, J.; Ozonder, G.; Lee, S.; Posen, I.D.; Miller, E.J.; Hatzopoulou, M. Automated, Electric, or Both? Investigating the Effects of Transportation and Technology Scenarios on Metropolitan Greenhouse Gas Emissions. *Sustain. Cities Soc.* **2018**, *40*, 524–533. [CrossRef]
28. Le Hong, Z.; Zimmerman, N. Air Quality and Greenhouse Gas Implications of Autonomous Vehicles in Vancouver, Canada. *Transp. Res. Part D Transp. Environ.* **2021**, *90*, 102676. [CrossRef]
29. Liu, F.; Zhao, F.; Liu, Z.; Policy, H.H.-E. *Can Autonomous Vehicle Reduce Greenhouse Gas Emissions? A Country-Level Evaluation*; Elsevier: Amsterdam, The Netherlands, 2019.
30. de Souza Melaré, A.V.; González, S.M.; Faceli, K.; Casadei, V. Technologies and Decision Support Systems to Aid Solid-Waste Management: A Systematic Review. *Waste Manag.* **2017**, *59*, 567–584. [CrossRef] [PubMed]
31. Kitchenham, B.; Charters, S. *Guidelines for Performing Systematic Literature Reviews in Software Engineering*; Technical report, Ver. 2.3 EBSE Technical Report; EBSE: Keele, UK, 2007.
32. Guccione, L.; Holland, B. *Car & (No) Driver*; Rocky Mountain Institute (RMI): Basalt, CO, USA, 2013.
33. Wang, W.; Zhong, H.; Zeng, Y.; Liu, Y.; Chen, J. A Carbon Emission Calculation Model for Roadside Parking. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1906. [CrossRef] [PubMed]
34. Shoup, D.C. Cruising for Parking. *Transp. Policy* **2006**, *13*, 479–486. [CrossRef]

35. Brown, A.; Gonder, J.; Repac, B. *An Analysis of Possible Energy Impacts of Automated Vehicles*; Springer: Berlin/Heidelberg, Germany, 2014; pp. 137–153.
36. Torbert, R.; Herrschaft, B. *Driving Miss Hazy: Will Driverless Cars Decrease Fossil Fuel Consumption?* Rocky Mountain Institute: Basalt, CO, USA, 2016.
37. Li, J.-M.; Gao, Z. Exploring the Impact of Speed Synchronization through Connected Vehicle Technology on Fleet-Level Fuel Economy. *SAE Int. J. Passeng. Cars Electron. Electr. Syst.* **2013**, *6*, 213–221. [CrossRef]
38. Rakha, H.A.; Ahn, K.; Park, S. AERIS: Eco-Driving Application Development and Testing (No. FHWA). 2012. Available online: https://vtechworks.lib.vt.edu/handle/10919/55092 (accessed on 11 November 2020).
39. He, Y.; Rios, J.; Chowdhury, M.; Pisu, P.; Bhavsar, P. Forward Power-Train Energy Management Modeling for Assessing Benefits of Integrating Predictive Traffic Data into Plug-in-Hybrid Electric Vehicles. *Transp. Res. Part D Transp. Environ.* **2012**, *17*, 201–207. [CrossRef]
40. Rakha, H.; Kamalanathsharma, R.; Ahn, K. *AERIS: Eco-Vehicle Speed Control at Signalized Intersections Using I2V Communication Final Report*; Virginia Polytechnic Institute and State University: Blacksburg, VA, USA, 2012.
41. Al-Turki, M.; Jamal, A.; Al-Ahmadi, H.M.; Al-Sughaiyer, M.A.; Zahid, M. On the Potential Impacts of Smart Traffic Control for Delay, Fuel Energy Consumption, and Emissions: An NSGA-II-Based Optimization Case Study from Dhahran, Saudi Arabia. *Sustainability* **2020**, *12*, 7394. [CrossRef]
42. Yelchuru, B.; Waller, T. Preliminary Eco-Traffic Signal Timing Modeling Results. 2014. Available online: https://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/SummID/B2014-00912 (accessed on 11 November 2020).
43. Zimmerman, C.; Marks, J.; Jenq, J.; Cluett, C.; DeBlasio, A. *Phoenix Metropolitan Model Deployment Initiative Evaluation Report (Draft)*; TRID: Washington, DC, USA, 2000.
44. NHTSA. *Fatality Analysis Reporting System*; National Highway Traffic Safety Administration; NHTSA, US Department of Transportation: Washington, DC, USA, 2008.
45. Zahid, M.; Chen, Y.; Khan, S.; Jamal, A.; Ijaz, M.; Ahmed, T. Predicting Risky and Aggressive Driving Behavior among Taxi Drivers: Do Spatio-Temporal Attributes Matter? *Int. J. Environ. Res. Public Health* **2020**, *17*, 3937. [CrossRef] [PubMed]
46. Schrank, D. *TTI's 2012 Urban Mobility Report*; Texas A&M Transportation Institute, The Texas A&M University System: Bryan, TX, USA, 2012.
47. Najm, W.; Stearns, M.; Howarth, H.; Koopmann, J.; Hitz, J. *Evaluation of an Automotive Rear-End Collision Avoidance System*; Department of Transportation, National Highway Traffic Safety Administration: Cambridge, MA, USA, 2006.
48. Kasseris, E.P. *Comparative Analysis of Automotive Powertrain Choices for the Near to Mid-Term Future*; Massachusetts Institute of Technology: Cambridge, MA, USA, 2006.
49. Zhu, H.; Yang, Z. *Simulation of the Aerodynamic Interaction of Two Generic Sedans Moving Very Closely*; IEEE: Piscataway, NJ, USA, 2011; pp. 2595–2600.
50. Schito, P. Numerical and Experimental Investigation on Vehicles in Platoon. *SAE Int. J. Commer. Veh.* **2012**, *5*, 63–71. [CrossRef]
51. Duan, K.; Mcdaniel, C.; Muller, A.; Yokota, B.; Kleissl, J. *Effects of Highway Slipstreaming on California Gas Consumption*; University of California: San Diego, CA, USA, 2007.
52. Tsugawa, S. An Overview on an Automated Truck Platoon within the Energy ITS Project. *Ifac Proc. Vol.* **2013**, *46*, 41–46. [CrossRef]
53. Zabat, M.; Stabile, N.; Farascaroli, S. *UC Berkeley Research Reports Title the Aerodynamic Performance of Platoons*; California PATH Research Report; California PATH: Oakland, CA, USA, 1995; 8p. Available online: Https://Escholarship.Org/Uc/Item/8ph187fw (accessed on 15 December 2020). California PATH Research Report.
54. Dávila, A.; Nombela, M. *Sartre-Safe Road Trains for the Environment Reducing Fuel Consumption through Lower Aerodynamic Drag Coefficient*; SAE Technical Paper; SAE: Warrendale, PA, USA, 2011.
55. Mccarthy, J.F. *Sustainability of Self-Driving Mobility: An Analysis of Carbon Emissions Between Autonomous Vehicles and Conventional Modes of Transportation*; Harvard University: Cambridge, MA, USA, 2017.
56. Davis, S.; Diegel, S.; Boundy, R. *Transportation Energy Data Book Edition 31*; Oak Ridge National Laboratory: Oak Ridge, TN, USA, 2012.
57. Organisation for Economic Co-Operation and Development. *Urban Mobility System Upgrade: How Shared Self-Driving Cars Could Change City Traffic*; International Transport Forum (ITF): Paris, France, 2015.
58. MacKenzie, D.; Zoepf, S.; Heywood, J. Determinants of US Passenger Car Weight. *Int. J. Veh. Des.* **2014**, *65*, 73–93. [CrossRef]
59. Joost, W.J. Reducing Vehicle Weight and Improving US Energy Efficiency Using Integrated Computational Materials Engineering. *Jom* **2012**, *64*, 1032–1038. [CrossRef]
60. Bigazzi, A.Y.; Clifton, K.J. Modeling the Effects of Congestion on Fuel Economy for Advanced Power Train Vehicles. *Transp. Plan. Technol.* **2015**, *38*, 149–161. [CrossRef]
61. Dey, K.C.; Rayamajhi, A.; Chowdhury, M.; Bhavsar, P.; Martin, J. Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Communication in a Heterogeneous Wireless Network–Performance Evaluation. *Transp. Res. Part C Emerg. Technol.* **2016**, *68*, 168–184. [CrossRef]
62. Porter, C.; Brown, A.; DeFlorio, J.; McKenzie, E.; Tao, W. *Effects of Travel Reduction and Efficient Driving on Transportation: Energy Use and Greenhouse Gas Emissions*; Transportation Energy Futures Series: Washington, DC, USA, 2013; (DOE/GO-102013-3704).
63. Shaheen, S.; Cohen, A.; Bayen, A. *The Benefits of Carpooling*; University of California: San Diego, CA, USA, 2018.

64. Igliński, H.; Babiak, M. Analysis of the Potential of Autonomous Vehicles in Reducing the Emissions of Greenhouse Gases in Road Transport. *Procedia Eng.* **2017**, *192*, 353–358. [CrossRef]
65. Xia, H.; Wu, G.; Boriboonsomsin, K.; Barth, M.J. Development and Evaluation of an Enhanced Eco-Approach Traffic Signal Application for Connected Vehicles. In Proceedings of the 16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013), The Hague, The Netherlands, 6–9 October 2013; pp. 296–301.
66. Burns, L. Sustainable Mobility: A Vision of Our Transport Future. *Nature* **2013**, *497*, 181. [CrossRef]
67. De Haan, P.; Peters, A.; Scholz, R.W. Reducing Energy Consumption in Road Transport through Hybrid Vehicles: Investigation of Rebound Effects, and Possible Effects of Tax Rebates. *J. Clean. Prod.* **2007**, *15*, 1076–1084. [CrossRef]
68. Childress, S.; Nichols, B.; Charlton, B.C.-T. Using an Activity-Based Model to Explore the Potential Impacts of Automated Vehicles. *Transp. Res. Rec.* **2015**, *2493*, 99–106. [CrossRef]
69. Gucwa, M. Mobility and Energy Impacts of Automated Cars. In Proceedings of the Automated Vehicles Symposium, San Francisco, CA, USA, 15–17 July 2014.
70. Harper, C.D.; Hendrickson, C.T.; Mangones, S.; Samaras, C. *Estimating Potential Increases in Travel with Autonomous Vehicles for the Non-Driving, Elderly and People with Travel-Restrictive Medical Conditions*; Elsevier: Amsterdam, The Netherlands, 2016. [CrossRef]
71. Fagnant, D.J.; Kockelman, K.M. *The Travel and Environmental Implications of Shared Autonomous Vehicles, Using Agent-Based Model Scenarios*; Elsevier: Amsterdam, The Netherlands, 2014. [CrossRef]
72. Berry, I.M. *The Effects of Driving Style and Vehicle Performance on the Real-World Fuel Consumption of U.S. Light-Duty Vehicles*; Massachusetts Institute of Technology: Cambridge, MA, USA, 2007.
73. Thomas, J.; Hwang, H.-L.; West, B.; Huff, S. Predicting Light-Duty Vehicle Fuel Economy as a Function of Highway Speed. *Sae Int. J. Passeng. Cars Mech. Syst.* **2013**, *6*, 859–875. [CrossRef]
74. Schäfer, A.; Heywood, J.; Jacoby, H.; Waitz, I. *Transportation in a Climate-Constrained World*; MIT Press: Cambridge, MA, USA, 2009.
75. Gehrke, S.; Felix, A.; Metropolitan Area Planning Council. Fare Choices: A Survey of Ride-Hailing Passengers in Metro Boston. 2018. Available online: https://pdxscholar.library.pdx.edu/trec_seminar/152/ (accessed on 15 December 2020).
76. Whitney, J. *Autonomous Vehicles: How US Cities Are Preparing*; University of Oregon: Eugene, OR, USA, 2018.
77. Ullah, I.; Jamal, A.; Subhan, F. Public Perception of Autonomous Car: A Case Study for Pakistan. *Adv. Transp. Stud.* **2019**, *49*, 145–154.
78. Cervero, R.; Murakami, J. Effects of Built Environments on Vehicle Miles Traveled: Evidence from 370 US Urbanized Areas. *Environ. Plan. A* **2010**, *42*, 400–418. [CrossRef]
79. Barrington-Leigh, C.; Millard-Ball, A. More Connected Urban Roads Reduce US GHG Emissions. *Environ. Res. Lett.* **2017**, *12*, 044008. [CrossRef]
80. Stogios, C.; Kasraian, D.; Roorda, M.J.; Hatzopoulou, M. Simulating Impacts of Automated Driving Behavior and Traffic Conditions on Vehicle Emissions. *Transp. Res. Part D Transp. Environ.* **2019**, *76*, 176–192. [CrossRef]
81. Olia, A.; Abdelgawad, H.; Abdulhai, B.; Razavi, S.N. Assessing the Potential Impacts of Connected Vehicles: Mobility, Environmental, and Safety Perspectives. *J. Intell. Transp. Syst.* **2016**, *20*, 229–243. [CrossRef]
82. Conlon, J.; Lin, J. Greenhouse Gas Emission Impact of Autonomous Vehicle Introduction in an Urban Network. *Transp. Res. Rec.* **2019**, *2673*, 142–152. [CrossRef]
83. *Bloomberg New Energy Finance*; New Energy Outlook 2018; Bloomberg New Energy Finance: New York, NY, USA, 2018; Available online: https://about.bnef.com/new-energy-outlook/ (accessed on 15 December 2020).
84. EPA. *US Transportation Sector Greenhouse Gas Emissions: 1990–2011*; Office of Transportation and Air Quality EPA-420-F-13-033a; EPA: Washington, DC, USA, 2013.
85. *Global Energy & CO_2 Status Report 2017*; IEA: Paris, France, 2018.
86. Wu, C.; Zhao, G.; Ou, B. A Fuel Economy Optimization System with Applications in Vehicles with Human Drivers and Autonomous Vehicles. *Transp. Res. Part D Transp. Environ.* **2011**, *16*, 515–524. [CrossRef]
87. Khondaker, B.; Kattan, L. Variable Speed Limit: A Microscopic Analysis in a Connected Vehicle Environment. *Transp. Res. Part C Emerg. Technol.* **2015**, *58*, 146–159. [CrossRef]
88. Li, S.E.; Peng, H.; Li, K.; Wang, J. Minimum Fuel Control Strategy in Automated Car-Following Scenarios. *IEEE Trans. Veh. Technol.* **2012**, *61*, 998–1007. [CrossRef]
89. Kamal, M.A.S.; Taguchi, S.; Yoshimura, T. Efficient Driving on Multilane Roads under a Connected Vehicle Environment. *IEEE Trans. Intell. Transp. Syst.* **2016**, *17*, 2541–2551. [CrossRef]
90. Luo, L.; Liu, H.; Li, P.; Wang, H. Model Predictive Control for Adaptive Cruise Control with Multi-Objectives: Comfort, Fuel-Economy, Safety and Car-Following. *J. Zhejiang Univ. Sci. A* **2010**, *11*, 191–201. [CrossRef]
91. Rios-Torres, J.; Malikopoulos, A.A. Automated and Cooperative Vehicle Merging at Highway On-Ramps. *IEEE Trans. Intell. Transp. Syst.* **2016**, *18*, 780–789. [CrossRef]
92. Wang, M.; Daamen, W.; Hoogendoorn, S.; Van Arem, B. Potential Impacts of Ecological Adaptive Cruise Control Systems on Traffic and Environment. *Iet Intell. Transp. Syst.* **2014**, *8*, 77–86. [CrossRef]
93. Zohdy, I.H.; Rakha, H.A. Intersection Management via Vehicle Connectivity: The Intersection Cooperative Adaptive Cruise Control System Concept. *J. Intell. Transp. Syst.* **2016**, *20*, 17–32. [CrossRef]
94. Kamalanathsharma, R.K.; Rakha, H.A. Leveraging Connected Vehicle Technology and Telematics to Enhance Vehicle Fuel Efficiency in the Vicinity of Signalized Intersections. *J. Intell. Transp. Syst.* **2016**, *20*, 33–44. [CrossRef]

95. Asadi, B.; Vahidi, A. Predictive Cruise Control: Utilizing Upcoming Traffic Signal Information for Improving Fuel Economy and Reducing Trip Time. *Ieee Trans. Control Syst. Technol.* **2010**, *19*, 707–714. [CrossRef]
96. Ala, M.V.; Yang, H.; Rakha, H. Modeling Evaluation of Eco–Cooperative Adaptive Cruise Control in Vicinity of Signalized Intersections. *Transp. Res. Rec.* **2016**, *2559*, 108–119. [CrossRef]
97. Manzie, C.; Watson, H.; Halgamuge, S. Fuel Economy Improvements for Urban Driving: Hybrid vs. Intelligent Vehicles. *Transp. Res. Part C Emerg. Technol.* **2007**, *15*, 1–16. [CrossRef]
98. Wang, Z.; Chen, X.; Ouyang, Y.; Li, M. Emission Mitigation via Longitudinal Control of Intelligent Vehicles in a Congested Platoon. *Comput. Aided Civ. Infrastruct. Eng.* **2015**, *30*, 490–506. [CrossRef]
99. Bose, A.; Ioannou, P. Evaluation of the Environmental Effects of Intelligent Cruise Control Vehicles. *Transp. Res. Rec.* **2001**, *1774*, 90–97. [CrossRef]
100. Choi, J.-E.; Bae, S.-H. Development of a Methodology to Demonstrate the Environmental Impact of Connected Vehicles under Lane-Changing Conditions. *Simulation* **2013**, *89*, 964–976. [CrossRef]
101. Greenblatt, J.B.; Saxena, S. Autonomous Taxis Could Greatly Reduce Greenhouse-Gas Emissions of US Light-Duty Vehicles. *Nat. Clim. Chang.* **2015**, *5*, 860–863. [CrossRef]
102. Taiebat, M.; Stolper, S.; Xu, M. Forecasting the Impact of Connected and Automated Vehicles on Energy Use: A Microeconomic Study of Induced Travel and Energy Rebound. *Appl. Energy* **2019**, *247*, 297–308. [CrossRef]
103. Kopelias, P.; Demiridi, E.; Vogiatzis, K.; Skabardonis, A.; Zafiropoulou, V. Connected & Autonomous Vehicles–Environmental Impacts—A Review. *Sci. Total Environ.* **2020**, *712*, 135237. [PubMed]
104. Shepherd, S.P. A Review of System Dynamics Models Applied in Transportation. *Transp. B Transp. Dyn.* **2014**, *2*, 83–105. [CrossRef]
105. Sterman, J. *System Dynamics: Systems Thinking and Modeling for a Complex World*; Massachusetts Institute of Technology: Cambridge, MA, USA, 2002.
106. Stepp, M.D.; Winebrake, J.J.; Hawker, J.S.; Skerlos, S.J. Greenhouse Gas Mitigation Policies and the Transportation Sector: The Role of Feedback Effects on Policy Effectiveness. *Energy Policy* **2009**, *37*, 2774–2787. [CrossRef]
107. Andrea, P.; Conor, H.; Veronica, P. *The Influence of Transport on GHG Emissionin BrisbaneT*; The University of Queensland: Brisbane, Australia, 2014.
108. Boll, C. The Impact of COVID-19 on Adoption of Autonomous Vehicle Technology. 2020. Available online: https://www.foley.com/en/insights/publications/2020/08/covid-19-adoption-autonomous-vehicle-technology (accessed on 11 November 2020).

BERKELEY CITY COUNCILMEMBER
TERRY TAPLIN
DISTRICT 2

CONSENT CALENDAR
May 24th, 2022

To: Honorable Mayor and Members of the City Council

From: Councilmember Terry Taplin

Subject: Regulation of Autonomous Vehicles

RECOMMENDATION
Refer to the City Attorney the assessment of the legal abilities and opportunities for the City Council to regulate the operation, sale, and testing of autonomous vehicles (AVs) within the City of Berkeley and report to the Facilities, Infrastructure, Transportation, Environment and Sustainability Committee (FITES) on all findings.

CURRENT SITUATION AND ITS EFFECTS
According to recent data provided by the California Department of Motor Vehicles, 2021 was a record-setting year for miles driven by test-autonomous vehicles (AVs) in California.[1] Despite the sudden growth in AVs on public roads in recent years, municipal governments have limited control over the regulation of AV testing and little access to basic information on the testing itself. This will pose a growing concern to local policymakers in the coming years as AV testing continues to spread. In California, AV testing oversight belongs to the DMV and the California Public Utilities Commission. This concentration of regulatory power at the state level makes it difficult to even determine the number of AV tests that have been conducted on Berkeley's streets, particularly because the DMV and CPUC do not require that AV companies report the whereabouts of their vehicles.[2] In order for the City to plan for the introduction of AVs onto public roads, use what limited regulatory abilities may be available, and lobby the state government to expand its oversight power, the Berkeley City Council must be made aware of all legal options for setting both AV testing rules and rules for functional AVs in a future where testing is complete and AVs are commercially available.

Beyond the testing of AVs that is expected to continue for many years, Berkeley must be prepared for a scenario where AVs are widely sold and threaten many of the City's transportation and climate goals. For the sake of safer streets and a reduction of fossil fuel emissions, the City of Berkeley is pursuing a growth in non-car transportation mode shares in its transportation, infrastructure, and planning policies. This pursuit may easily

[1] https://techcrunch.com/2022/02/10/fewer-autonomous-vehicle-companies-in-california-drive-millions-more-miles-in-testing/
[2] https://www.sfexaminer.com/findings/how-san-francisco-became-an-autonomous-vehicle-test-course/

be threatened by the sudden availability of self-driving cars. The option for drivers to choose a vehicle that offers the present day convenience of an automobile with an added reduction in the actual requirement to drive the vehicle carries the possibility of undoing any progress made if no preemptive regulatory policies are made. While it will be many years before self-driving cars are available or even common on Berkeley's streets, the City must proceed with transportation planning that is cautious with AVs and committed to a future where cars are not the largest mode-share.

FISCAL IMPACTS
Staff time for the referral response.

ENVIRONMENTAL SUSTAINABILITY AND CLIMATE IMPACTS
Reducing the use of automobiles on Berkeley's streets is a critical task for the reduction of the City's fossil fuel emissions, an immense share of which come from private vehicle emissions.[3]

CONTACT
Terry Taplin, Councilmember, District 2, (510) 981-7120

[3] https://www.cityofberkeley.info/Clerk/City_Council/2018/12_Dec/Documents/2018-12-06_WS_Item_01_Climate_Action_Plan_Update_pdf.aspx

Kate Harrison
Councilmember District 4

ACTION CALENDAR
November 30, 2021

To: Honorable Mayor and Members of the City Council

From: Councilmember Harrison

Subject: Adopt an Ordinance Adding a New Chapter 12.01 to the Berkeley Municipal Code Establishing Emergency Greenhouse Gas Limits, Process for Updated Climate Action Plan, Monitoring, Evaluation, Reporting and Regional Collaboration

RECOMMENDATION

1. Adopt an ordinance adding a new Chapter 12.01 to the Berkeley Municipal Code (BMC) establishing Emergency Greenhouse Gas Limits with an effective date of [ ], 2022.

2. Refer to the FY23-24 Budget Process $[ ] consistent with implementing the requirements of Sections 12.01.040, 12.01.050, 12.01.060.

CURRENT SITUATION, EFFECTS, AND RATIONALE FOR RECOMMENDATION

Scientific evidence indicates that between the industrial period of 1850 and 2021, economic systems, namely state and free-market forms of capital accumulation and economic growth have increased global atmospheric carbon dioxide levels to a staggering 418 parts per million (ppm), beyond the established planetary boundary of 350 ppm, and warmed global average temperature by approximately 1.1 degrees Celsius. Available scientific evidence indicates there is no ‘safe’ level of warming beyond 350 ppm, only gradations of risk with respect to habitability.

Berkeley is already experiencing unprecedented negative effects of warming associated with 1 degree of warming, and current global growth trends and policies could push humanity past 1.5 degrees by mid-century, leading to a devastating 2-4 degrees by the end of the century. The ‘Global North,’ which includes Berkeley, has far exceeded its fair share of the emissions comprising and exceeding the boundary, and must reduce its emissions rapidly and justly.

2180 Milvia Street, Berkeley, CA 94704 ● Tel: (510) 981-7140 ● TDD: (510) 981-6903 ● Fax: (510) 981-6903 E-Mail: KHarrison@cityofberkeley.info

The City of Berkeley has engaged with the issue of global warming for at least three decades and has unquestionably been a leader in certain climate actions. Yet, in light of the current gravity of the climate emergency, current strategies and targets are not adequate. Exceptionally risky “mitigation” strategies, namely midcentury ‘net-zero’ pledges have provided for unbridled economic and emissions growth and thus severely dwindled carbon budgets, effectively rendering Berkeley’s gradual reduction goals: 80% by 2050 (Measure G, 2005 and Resolution 64,480-N.S., 2009) and net-zero by 2045 (Resolution 69,852–N.S., 2021), untenable. The majority of risk associated with each additional ton of greenhouse gas emitted will be borne by generations who will have not consented to current reduction goals and strategies. Current policies could exacerbate or lead to exceedingly dangerous new tipping points.

This item is timely in light of ongoing reports that national “pledges” under Paris Agreement could lead to at least 3 degrees of catastrophic warming, the inability for Congress to pass meaningful domestic and international climate policies and legislation, and the failure of world leaders to reach an effective and substantive agreement at the 26th UN Climate Change Conference of the Parties (COP26) in Glasgow.

BACKGROUND

The ordinance establishes emergency greenhouse gas limits aimed at reducing sector-based greenhouse gas emissions 90% below 2000 levels and consumption-based emissions 90% below 2013 levels by 2030. These limits would bring Berkeley closer to its global ‘fair share’ and science-based reduction obligations, and could help achieve reductions at scale as part of a program of regional coordination and collaboration.

While such targets are ambitious, mitigating and minimizing global warming risk and maximizing adaptation, resilience and adherence to planetary boundaries earlier in the century rather than later will likely result in less disruption to society over the long term, and will generate opportunities for more inclusive and sound democratic decision making as compared to waiting until atmospheric carbon levels reach increasingly catastrophic levels.

These limits are consistent with the City’s 2006 “precautionary principle” established by BMC 12.29, and which states:

> “The purpose of this chapter is to promote the health, safety, and general welfare of the community by minimizing health risks, improving air quality, protecting the quality of ground and surface water, minimizing consumption of resources, and minimizing the City’ s contribution to global climate change by implementing in a phased manner, as provided in this chapter, the City’s use of a precautionary principle approach in its decisions.”

As enacted by Council, BMC 12.29 requires the City to apply the following precautionary principle tenets in the course of action and decision-making:

1. Anticipatory Action: Anticipatory action may prevent harm. Government, business, community groups, and the public share this responsibility.

2. Right to Know: The community has a right to know complete and accurate information on potential health and environmental impacts associated with the selection of products, services, operations or plans.

3. Alternatives Assessment: Examine a full range of alternatives and select the alternative with the least potential impact on health and the environment including the alternative of doing nothing.

4. Consideration of Significant Costs: Consider significant short-term and long-term costs in comparing product alternatives, when feasible. This includes evaluation of significant costs expected during the lifetime of a product, (e.g. raw materials, manufacturing and production, transportation, use, clean-up, acquisition, extended warranties, operation, supplies, maintenance, disposal costs, long and short-term environmental and health impacts); and that expected lifetime compared to other alternatives.

5. Participatory Decision Process: Decisions applying the Precautionary Principle should be transparent, participatory by including community input, and informed by the best available information.

The ordinance requires the City to develop a new Climate Action Plan and consistent with these GHG limits and precautionary principle tenets, and to establish relevant legislative and budgetary timelines to help the City reach its objectives.

In addition, the ordinance requires the City to consider post-growth climate mitigation strategies and policies as potential alternatives to the growth and market-based and other policies that created the crisis and remain a persistent obstacle to meaningful action. The City's policies and programs *must not* aim to merely increase economic growth for growth's sake, but rather to support the provision of basic human needs and happiness.

It also provides an institutional framework to build solidarity with neighboring Bay Area communities and jurisdictions to achieve collective limits that could change rate of global warming while simultaneously providing sister cities in other countries precious time to improve living standards and pursue decarbonization.

<u>ENVIRONMENTAL SUSTAINABILITY</u>
This item is consistent with the latest climate science and the precautionary principle established by BMC 12.29.

<u>ATTACHMENTS</u>

1. Proposed Ordinance adding a new Chapter 12.01.

FINANCIAL IMPLICATIONS

Staff time will be necessary to implement the new ordinance. This item refers $[ ] to the FY23-24 Budget Process consistent with implementing the requirements of Sections 12.01.040, 12.01.050, 12.01.060.

CONTACT PERSON

Councilmember Kate Harrison, Council District 4, (510) 981-7140

ORDINANCE NO. –N.S.

ADDING CHAPTER 12.01 TO THE BERKELEY MUNICIPAL CODE TO ESTABLISH EMERGENCY GREENHOUSE GAS EMISSIONS LIMITS

BE IT ORDAINED by the Council of the City of Berkeley as follows:

Section 1. That Chapter 12.01 of the Berkeley Municipal Code is added to read as follows:

Chapter 12.01

EMERGENCY GREENHOUSE GAS EMISSIONS LIMITS

Sections:

12.01.010 Findings and purpose.

The Council of the City of Berkeley finds and declares as follows:

A. Available scientific evidence indicates that between the industrial period of 1850 and 2021 economic systems, namely state and free-market forms of capital accumulation and economic growth, have increased global atmospheric carbon dioxide levels to a staggering 418 parts per million (ppm) beyond the established planetary boundary of 350 ppm, and warmed global average temperature by approximately 1.1 degrees Celsius. The 'Global North,' which includes Berkeley, has far exceeded its fair share the emissions comprising and exceeding the boundary, and must reduce its emissions rapidly and equitably.

B. Available scientific evidence indicates there is no 'safe' level of warming beyond 350 ppm, only gradations of risk with respect to habitability. Berkeley, California, the United States, and the world is already experiencing unprecedented negative effects of warming associated with 1 degree of warming, and current global growth trends and policies will push humanity past 1.5 degrees as early as the 2030s and 3 to 4 degrees by the end of the century. Global warming between 1.5 to 2 degrees Celsius is expected to further accelerate existential risks to health and safety including but not limited to, extreme weather, mass extinction, water and food shortages, violent conflict, fire, forced migration, economic collapse, disease, heat stress, and sea level rise. The majority of risk associated with each additional ton of greenhouse gas emitted will be borne by generations who will have not consented to current reduction strategies.

C. In the twenty-first century, Berkeley, California, and the United States have largely and irresponsibly relied on ineffective market-based mechanisms, unrealistic expectations of absolutely decoupling GDP growth from energy use, speculative mass deployment of negative emission reduction technologies and 'net-zero' practices to offset continued fossil fuel production and consumption, and underappreciation of irreversible tipping points, aerosol masking, and non-carbon greenhouse gasses. In light of the current gravity of the climate emergency, these strategies have unequivocally failed; between Measure G and 2018, each jurisdiction only reduced greenhouse gasses by a respective 10%, 12%, and 26%, while at the same time globally, nearly a third of all anthropogenic carbon dioxide was emitted. Exceptionally risky strategies pursued by the Global North, namely midcentury 'net-zero' pledges have provided for unbridled economic and emissions growth and thus severely dwindled carbon budgets, effectively rendering Berkeley's gradual reduction goals: 80% by 2050 (Measure G, 2005 and Resolution 64,480-N.S., 2009) and net-zero by 2045 (Resolution 69,852–N.S., 2021), untenable.

D. It is the intent of the Council to adopt stringent and equitable science-based greenhouse gas emissions limits and related action plans and reports, consistent with the precautionary principle approach established by Chapter 12.29, for the purpose of achieving the rapid, far-reaching, unprecedented and just changes in all aspects of society associated with mitigating and minimizing global warming risk and maximizing adaptation, resilience and adherence to planetary boundaries.

E. The Council further intends to endeavor to build solidarity with neighboring communities and jurisdictions to achieve collective limits that could change rate of global warming while simultaneously providing sister cities in other countries precious time to improve living standards and pursue decarbonization.

12.01.020 Definitions.
A. "Climate Action Plan" means the document required under Section 12.01 outlining the specific actions the City will endeavor to take to reduce Greenhouse gas emissions and to mitigation, resilience and adaptation efforts with respect to climate impacts.
B. “Consumption-Based Greenhouse Gas Emissions” means all the Greenhouse Gas emissions associated with producing, transporting, using, and disposing of products and services consumed by a particular community or entity in a given time period, including emissions generated outside the boundaries of the community or the geographic area where the entity is located.
C. “Greenhouse Gas” means any and all of the following gases: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.
D. “Sector-Based Greenhouse Gas Emissions” means all of the Greenhouse Gas emissions generated within the geographic boundaries of the City in a given time period.
E. “Responsible Production and Consumption” means improving how materials and products are extracted, manufactured, delivered, acquired, used, reused, recycled, and disposed of to ensure that the production and consumption of materials and products promote basic human needs, are distributed in a socially equitable manner, and carried out in a way that minimizes environmental impacts over the lifecycle of those materials and products while matching the carrying capacity of the earth’s resources and adding value so as not to jeopardize present and future generations. “Lifecycle” means the complete material life of a product, good, or service, including resource extraction, manufacture, assembly, construction, maintenance, transportation, operations or use, and end of life (reuse, recycling/composting, and disposal). “Carrying capacity” means the number or amount of people, plants, and other living organisms that an ecosystem can support indefinitely without causing environmental degradation.
F. “Post-Growth Emissions Mitigation” means Greenhouse Gas mitigation strategies and policies that acknowledge and support the following:
(1) rapid emissions reductions may not be compatible with economic policies that support limitless growth, especially growth in the production and consumption of commodities that do not support basic human needs,
(2) in jurisdictions with high aggregate wealth there may be a disassociation between additional capital accumulation, economic growth, and GDP, and key social outcomes, to include but not limited to, health, social wellbeing, happiness and equity,
(3) fairer distribution of income and wealth, and guaranteed access to universal public services.

12.01.030 Emergency Greenhouse Gas Emissions Limits.
A. The following Greenhouse Gas emissions limits are hereby established:
(1) By 2030, reduce Sector-Based Greenhouse Gas Emissions [90%] below 2000 levels.
(2) By 2030, reduce Consumption-Based Greenhouse Gas Emissions to [5] mtCO2e per household or less, equivalent to a [90%] reduction compared to 2013 levels.
(3) By 2026, the Council shall determine an appropriate deadline for achieving 100% zero emissions across both Sector and Consumption-Based inventories.

12.01.040 Climate Action Plan.
A. By [ ], 2022, the City Manager or designee shall prepare and submit for relevant Council policy committee and Council approval a Climate Action Plan (CAP) which shall

do all of the following:
(1) Align with the emissions limits established in Section 12.01.030.
(2) Consider equitable Post-growth Climate Mitigation strategies and policies.
(3) Incorporate an equity framework that addresses historic racial, class-based, and social inequalities; prioritizes social, economic, and environmental benefits derived from implementing the CAP; and ensures an equitable distribution of those benefits. This framework shall consider:
(a) The engagement and prioritization of those who are most impacted by climate change and have historically had the least influence in decision-making processes, including low-income communities of color, communities with disabilities, and other impacted populations;
(b) Burdens and/or unintended consequences of related actions, especially for low-income communities of color, communities with disabilities, and other vulnerable populations; and
(c) Social interventions needed to secure workers' rights and livelihoods when economies are shifting to responsible production and consumption, collectively referred to as a "just transition" framework, and other impacts on workforce and job opportunities.
(4) Include, but not be limited to, the following elements: energy supply; transportation and land use; building operations; housing; Responsible Production and Consumption; carbon sequestration and water conservation.
(5) Identify strategies and/or make recommendations to achieve emissions limits for all elements. The CAP shall recommend approaches on goals and principles. Each strategy or recommendation shall:
(a) Identify parties responsible for implementation;
(b) Incorporate an estimated cost; and
(c) Incorporate estimated legislative and budgetary timelines based consistent with Section 12.01.030; and
(d) Contain key performance indicators and explicit equity metrics to measure progress.
B. The City Manager or their designee shall update the Climate Action Plan at least every two years.

12.01.050 Monitoring, Evaluation, And Reporting.
A. The City shall demonstrate its long-term commitment to reducing Greenhouse Gas emissions and advancing racial and social equity by measuring and reporting emissions, tracking key performance indicators and equity metrics, and monitoring the City's progress on meeting its climate action goals and commitments.
B. The City Manager or their designee shall, with the assistance from relevant City agencies:
(1) Measure and monitor Sector-Based Greenhouse Gas Emissions, including municipal emissions, using best available global protocols for preparing Citywide Greenhouse Gas emission inventories.
(2) Measure production and consumption emissions using best available global methodologies for preparing consumption-based emission inventories.
(3) Evaluate Sector-Based Greenhouse Gas Emissions against set limits, document production and consumption emissions, and produce an annual Greenhouse Gas emissions report.
(4) Establish a monitoring and reporting process for the implementation of the CAP that:
(a) Tracks key performance indicators and equity metrics for strategies to help

monitor their progress and implementation;
(5) Request and receive data from City departments to support:
(a) The annual Greenhouse Gas emissions inventory. City departments may be asked to provide data on, but not limited to, the following: their energy use; types of fuels used for their operations; fuel volume; vehicle-miles travelled (if applicable) within their jurisdictions; and private sector Greenhouse Gas emission sources regulated by the department. Departments may also be requested to verify emission estimates and assumptions and review resulting reports;
(b) Monitoring and reporting of Climate Action Plan implementation. City departments may be asked to provide data on key performance indicators and equity metrics related to adopted strategies and actions; and
(6) Coordinate with other City agencies to monitor, track, and report on climate action progress to local, state, national, and global partners.
(7) Report its findings in a progress report to the Council and public every year.
(8) Report on at least a biannual basis to relevant Council policy committees and commissions to support policy and budget development consistent with reduction limits established in Section 12.01.030.

12.01.060 Regional Collaboration.
The Council and City staff, working alongside the public, shall endeavor to build solidarity and coalitions with neighboring communities, jurisdictions, and agencies to achieve equitable collective Greenhouse Gas limits and observe planetary boundaries.

11.63.070 Severability.
If any word, phrase, sentence, part, section, subsection, or other portion of this Chapter, or any application thereof to any person or circumstance is declared void, unconstitutional, or invalid for any reason, then such word, phrase, sentence, part, section, subsection, or other portion, or the prescribed application thereof, shall be severable, and the remaining provisions of this Chapter, and all applications thereof, not having been declared void, unconstitutional or invalid, shall remain in full force and effect. The City Council hereby declares that it would have passed this title, and each section, subsection, sentence, clause and phrase thereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses or phrases had been declared invalid or unconstitutional.

12.01.080 Construction.
This Chapter is intended to be a proper exercise of the City's police power, to operate only upon its own officers, agents, employees and facilities and other persons acting within its boundaries, and not to regulate inter-city or interstate commerce. It shall be construed in accordance with that intent.

12.01.090 Effective date.
The provisions in this ordinance are effective [ ], 2022.

Section 2. Copies of this Ordinance shall be posted for two days prior to adoption in the display case located near the walkway in front of the Maudelle Shirek Building, 2134 Martin Luther King Jr. Way. Within 15 days of adoption, copies of this Ordinance shall be filed at each branch of the Berkeley Public Library and the title shall be published in a newspaper of general circulation.

04

Kate Harrison
Councilmember District 4

CONSENT CALENDAR
March 9, 2021

To: Honorable Mayor and Members of the City Council

From: Councilmembers Harrison

Subject: Refer to the City Manager to Prioritize Establishment of Impact/Mitigation Fees to Address Disproportionate Private and Public Utility Impact to the Public Right of Way

RECOMMENDATION
In order to ensure equitable support of the public right of way by private and public entities that use City facilities, refer to the City Manager and City Attorney to prioritize the following in consultation with the Facilities, Infrastructure, Transportation, Environment, & Sustainability Committee:

1. establish impact and/or mitigation fees to address disproportionate private impacts to the public right of way, such as our roads and utility poles; and

2. establish transfers between sewer, waste, or other utilities as appropriate to address impacts to the public right of way.

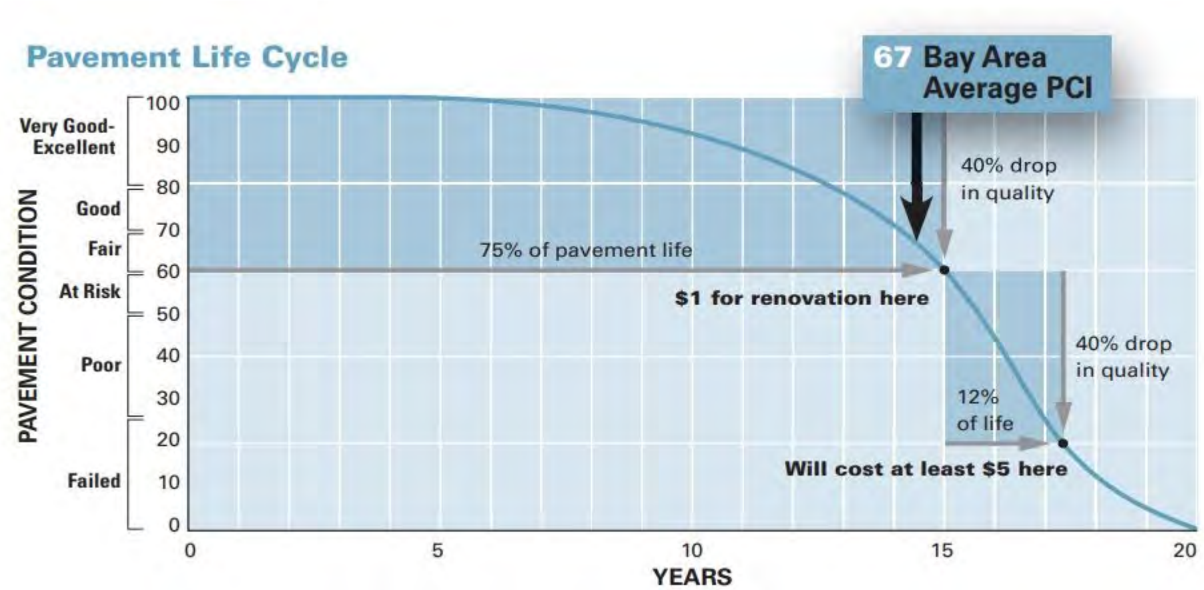
BACKGROUND
A Metropolitan Transportation Commission report warns that Berkeley's overall paving condition is "At Risk," meaning on the cusp of falling into "Failing" category.[1] The current five-year paving plan is the result of historic deferred maintenance and an underfunded, imperfect and complex balance between arterial, collector and residential streets distributed across Council districts. The City's bicycle, pedestrian and Vision Zero projects are severely underfunded. Meanwhile, neighboring cities in the Bay Area, such as Richmond, El Cerrito, San Francisco have "Excellent/Very Good" to "Fair/Good" streets conditions.

Critically, maintenance of the public right of way has been underfunded due to (1) historic lack of impact/mitigation fees levied against private corporations who

[1] "The Pothole Report: Bay Area Roads At Risk," Bay Area Metropolitan Transportation Commission, September 2018, https://mtc.ca.gov/sites/default/files/Pothole%20Report%20III_September%202018.pdf

disproportionally cause negative impacts to Berkeley's streets and (2) an absence of transfers from public utility ratepayers to the Berkeley Public Works Department to mitigate utility-related damage to the right of way. The public right of way is key part of the City's "commons," a public resource that is available to all community members and to be managed for the collective benefit. As learned during recent FITES hearings, it appears that certain private actor and public utilities have not been paying their fair share to address their disproportionate impact on the condition of Berkeley's right of way.

The Public Works Department has advised that ongoing funding under the rolling 5-Year Street Plan will not be enough to stabilize Berkeley's streets. In fact, if street investment is not increased, Public Works warns that the City could face $1 billion in future repair costs as the cost of deferred paving maintenance increases exponentially each year.

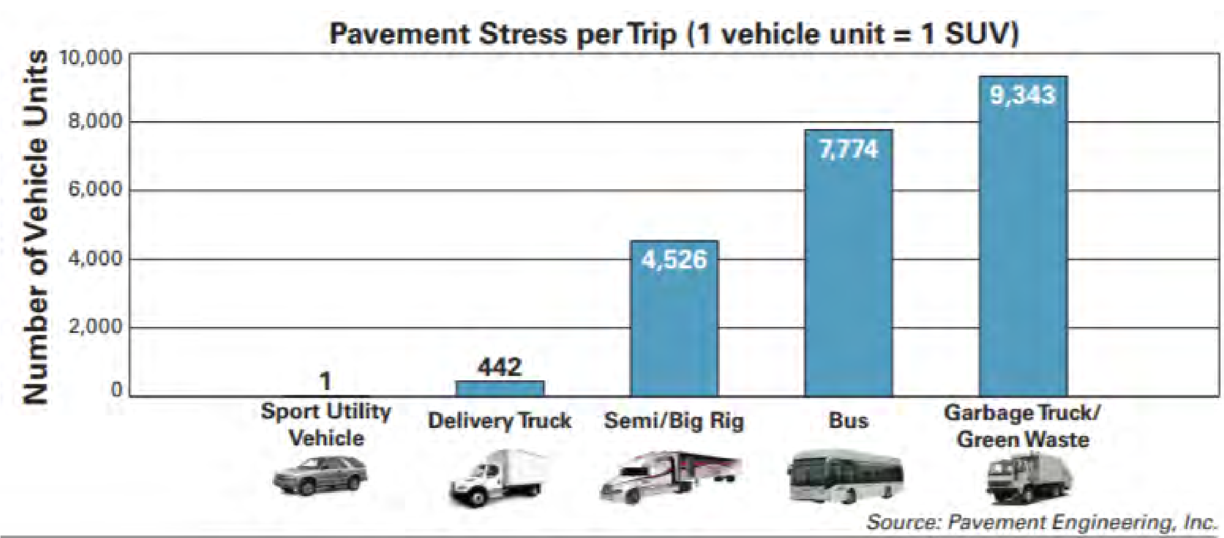


Since January 2020, the Facilities, Infrastructure, Transportation, Environment, & Sustainability (FITES) Committee has been working with the Public Works Department and Public Works Commission to explore funding opportunities to enhance the Paving Condition Index (PCI) of Berkeley's streets. In addition, it has been reviewing the City's Paving Policy, which was last updated in 2009, and has been working to develop a Paving Master Plan.

To stabilize street conditions, the City will likely need to pursue a combination of investment strategies ranging from increasing General Fund allocations, initiating transfers from waste, sewer and other utility accounts, initiating impact/mitigation fees in response to heavy private vehicle use and potentially issuing bonds. However, before going to the voters for new bonds, who already pay significant sales, property and other taxes, which contribute to paving maintenance, it is critical that the Council exhaust all equitable alternatives, including leveraging the proceeds of new fees and transfers from private corporations and public utilities who contribute disproportionately to the deterioration of Berkeley's streets and greenhouse gas emissions.

The current 2009 Paving Plan, which is being revised by the Public Works Commission. Public Works Department and the FITES Committee, explicitly specifies that "fees [may be] assessed to mitigate for excessive deterioration on and wear and tear of streets resulting from construction activities, public or private, shall be used for street rehabilitation."[2] However, the FITES Committee has not been able to identify historical evidence of such fee being levied upon private users for such excessive deterioration.

During hearings on the paving policy, the FITES Committee has learned that large private vehicles such as delivery trucks, big rigs, private buses and construction vehicles contributed heavily to excessive deterioration. The same is true for vehicles acting on behalf of public utilities, such as AC Transit, the City's Sanitary Sewer Program, Recology waste services, and gas, electric and telecommunications utilities.



[2] "City of Berkeley Street Rehabilitation and Repair Policy," Public Works Department, March 2009, https://www.cityofberkeley.info/Public_Works/Sidewalks-Streets-Utility/Street_Rehabilitation_and_Repair_Policy_updated_March_2009.aspx

Public Works staff indicate that transfers could bring in approximately $1 million per year in additional paving funding, but more research will need to be done to calculate potential revenue from impact fees.

It is in the public interest to ensure an equitable and rapid as possible assessment of such private and public actors for the purpose of providing supplemental funding to Berkeley’s Street Repair Program.

FINANCIAL IMPLICATIONS

The item would require staff time to develop potential fees and transfers, however it could potentially offset and supplemental millions of dollars in existing City paving funding.

ENVIRONMENTAL SUSTAINABILITY

Supporting low-carbon asphalt alternatives and building bicycle and alternative mobility infrastructure will compliment and accelerate Berkeley’s ongoing efforts to reduce carbon emissions at an emergency and equitable pace in line with the Climate Action Plan and Climate Emergency Declaration.

CONTACT PERSON

Councilmember Kate Harrison, Council District 4, 510-981-7140

05

Kate Harrison
Vice Mayor, District 4

REVISED AGENDA MATERIAL

Meeting Date: **May 4, 2022**

Item Description: **Adopt an Ordinance Adding a Chapter 11.62 to the Berkeley Municipal Code to Regulate Plastic Bags at Retail and Food Service Establishments**

Submitted by: **Vice Mayor Harrison**

- Updated ordinance to:
  - remove
    - references to restaurants;
    - remove reference to 100% post-consumer content paper bags;
    - remove prohibition on plastic pre-checkout bags;
  - add
    - $0.10 charge for plastic pre-checkout bags;
    - Compostable Pre-Checkout Bags definition;
    - Reusable Pre-checkout Bag definition;
    - reasonable requirement to stock and provide paper bags at no charge and reusable Pre-Checkout Bags for sale;

2180 Milvia Street, Berkeley, CA 94704 Tel: 510.981.7140 TDD: 510.981.6903
E-Mail: *kharrison@CityofBerkeley.info*

ORDINANCE NO. –N.S.

ADDING CHAPTER 11.63 TO THE BERKELEY MUNICIPAL CODE TO REGULATE THE USE OF CARRYOUT AND PRE-CHECKOUT BAGS AND PROMOTING THE USE OF REUSABLE BAGS

BE IT ORDAINED by the Council of the City of Berkeley as follows:

Section 1. That Chapter 11.63 of the Berkeley Municipal Code is added to read as follows:

Chapter 11.63

REGULATING THE USE OF CARRYOUT AND PRE-CHECKOUT BAGS AND PROMOTING THE USE OF REUSABLE BAGS

Sections:

11.63.010 Findings and purpose.
The Council of the City of Berkeley finds and declares as follows:

A. Single-use plastic bags and plastic produce bags are a significant contributor to street litter, ocean pollution, marine and other wildlife harm and their production creates greenhouse gas emissions.
B. The production, consumption and disposal of plastic based bags contribute significantly to the depletion of natural resources. Plastics in waterways and oceans break down into smaller pieces that are not biodegradable, and present a great harm to the global environment.
C. Among other hazards, plastic debris attracts and concentrates ambient pollutants in seawater and freshwater, which can transfer to fish, other seafood and salt that is eventually sold for human consumption. Certain plastic bags can also contain microplastics that present a great harm to our seawater and freshwater life, which indirectly presents a threat to human life.
D. It is in the interest of the health, safety and welfare of all who live, work and do business in the City that the amount of litter on public streets, parks and in other public places be reduced.
E. The City of Berkeley must eliminate solid waste at its source and maximize recycling and composting in accordance with its Zero Waste Goals. Reduction of plastic bag waste furthers this goal.
F. The State of California and Alameda County Waste Management Authority both regulate single-use, paper, and reusable carryout bags respectively under SB 270/Proposition 67 and Ordinance 2012-02 (as amended by Ordinance 2016-02). However, neither currently address all establishments or pre-checkout (e.g., produce) bags to carry fruits, vegetables, and other loose or bulky items while shopping before reaching the checkout area. These bags, which are often plastic, share many of the same physical qualities as single-use plastic carryout bags no longer permitted in California, and are difficult to recycle, reuse or compost.
G. The State also does not regulate the price of bags provided at the point of sale by restaurants and streets events, including farmers' markets. While the County's Ordinance 2016-02 regulates restaurant carryout bags, it allows thicker film plastic.
H. The City of Berkeley currently regulates a number of disposable plastic items through the Single-Use Foodware and Litter Reduction Ordinance (Ord. 7639-NS § 1 (part), 2019), but does not impose regulations with respect to bags. It is in the public interest to reduce plastic and paper waste in areas not preempted by the State of California.
I. This Chapter is consistent with the City of Berkeley's 2009 Climate Action Plan, the County of Alameda Integrated Waste Management Plan, as amended, and the CalRecycle recycling and waste disposal regulations contained in Titles 14 and 27 of the California Code of Regulations.

11.63.020 Definitions.
A. "Accepted Compostable Pre-Checkout Bag" means a bag that is accepted by the City's compost facility as having the requisite and appropriate physical qualities for controlled biological decomposition in conjunction with other organic solid waste.

B. "Carryout Bag" means a bag provided at the check stand, cash register, point of sale or other location for the purpose of transporting food or merchandise out of a Covered

Entity. Carryout Bags do not include Pre-checkout or Product Bags.“Accepted Compostable Pre-Checkout Bag” means a bag that is accepted by the City’s compost facility as having the requisite and appropriate physical qualities for controlled biological decomposition in conjunction with other organic solid waste.

BC. “Covered Entity” means any of the following:
(1) any restaurant, take-out food establishment or other business (including, but not limited to, food sales from vehicles or temporary facilities open to the public) that receives 90% or more of its revenue from the sale of prepared and ready-to-consume foods and/or drinks to the public and is not subject to the requirements of Public Resources Code Section 42281; and
(12) any event, or Person therein, requiring a street event permit pursuant to Berkeley Municipal Code 13.44.040 and not subject to the requirements of Public Resources Code Section 42281; and
(23) any other commercial establishment other than a restaurant, take-out food establishment (including, but not limited to, food sales from vehicles or temporary facilities open to the public) that sells perishable or nonperishable goods including, but not limited to, clothing, food and personal items directly to a customer and not subject to the requirements of Public Resources Code Section 42281.
CD. “Customer” means any Person obtaining goods from a Covered Entity or Food Product Store.
DE. “Food Product Store” means a supermarket, Food Product Store, convenience food store, foodmart, or other entity engaged in the retail sale of goods that include perishable and nonperishable food items, and with a total floor area over 2,500 square feet;.
EF. “100% Recycled Content Paper Bag” means either a Carryout Bag provided by a Covered Entity or a Pre-checkout Bag provided by a Food Product Store that contains no old growth fiber and a minimum of forty percent (40%) one hundred percent (100%) postconsumer recycled material; is one hundred percent (100%) recyclable and compostable, consistent with the timeline and specifications of the American Society of Testing and Materials (ASTM) Standard D6400; and has printed in a highly visible manner on the outside of the bag the words;
“Recyclable,” the name and location of the manufacturer, and the percentage of postconsumer recycled content.;
FG. "Reusable Carryout Bag” means a bag that is specifically designed and manufactured for multiple reuse and meets all of the following requirements:
(1) has a minimum lifetime of 125 uses, which for purposes of this subsection, means the capability of carrying a minimum of 22 pounds 125 times over a distance of at least 175 feet;
(2) has a minimum volume of 15 liters;
(3) is washable by hand or machine, or is made from a material that can otherwise be cleaned or disinfected;
(4) does not contain lead, cadmium or any other heavy metal in toxic amounts, as defined by applicable state and federal standards and regulations for packaging or reusable bags;
(5) has printed on the bag, or on a tag that is permanently affixed to the bag, the name of the manufacturer, the location (country) where the bag was manufactured, a

statement that the bag does not contain lead, cadmium, or any other heavy metal in toxic amounts, and the percentage of postconsumer recycled material used, if any; and (6) is not made of plastic film, regardless of thickness. Notwithstanding this subsection, non-plastic film bags may be comprised of recycled plastic film.

GH. "Person" means an individual, firm, public or private corporation, limited liability company, partnership, industry or any other entity whatsoever.

HI. "Pre-checkout Bag" means a 100% Recycled Content Paper Bag,, or or Accepted Compostable Pre-Checkout Bag, or plastic film bag provided or sold to a customer to carry produce, bulk food, or other food items to the point of sale inside a store.

IJ. "Reusable Pre-checkout Bag" means a bag that is specifically designed and manufactured for multiple reuse and meets all of the following requirements:

(1) is washable by hand or machine, or is made from a material that can otherwise be cleaned or disinfected;

(2) does not contain lead, cadmium or any other heavy metal in toxic amounts, as defined by applicable state and federal standards and regulations for packaging or reusable bags;

(3) has printed on the bag, or on a tag that is permanently affixed to the bag, the name of the manufacturer, the location (country) where the bag was manufactured, a statement that the bag does not contain lead, cadmium, or any other heavy metal in toxic amounts, and the percentage of postconsumer recycled material used, if any; and

(4) is not made of plastic film, regardless of thickness. Notwithstanding this subsection, non-plastic film bags may be comprised of recycled plastic film.

IK. "Product Bags" are bags that are integral to the packaging of a product such as film or other bags used to fully encapsulate liquid or semi-liquid takeout food items (e.g., soup containers) to prevent spillage; or bags designed to be placed over articles of clothing on a hanger at dry cleaning or laundry facility.

11.63.030 Carryout Bag restrictions for Covered Entities.

A. No Covered Entity shall provide or sell a Carryout Bag other than 100% Recycled Content Paper Bags or Reusable Carryout Bags at the check stand, cash register, point of sale or other location to a Customer for the purpose of transporting food or merchandise out of such Covered Entity.

B. A Covered Entity may provide or make available for sale to a Customer a 100% Recycled Content Paper Bags for a minimum price of ten cents ($0.10).

11.63.040 Pre-checkout Bag restrictions and requirements for Food Product Stores and Covered Entities.

A. A Food Product Store providing or Covered Entity may make available for sale to a Customer with plastic film Pre-checkout Bags shall charge a minimum price of ten cents ($0.10) per bag. Food Product Stores should consider providing appropriate signage detailing procedures for acquiring and purchasing such bags. ,No Food Product Store or Covered Entity shall provide Pre-checkout Bags other than 100% Recycled Content Paper Bags.

B. Notwithstanding subsection A, Covered Entities and Food Product Stores may provide plastic film bags as Pre-checkout Bags to Customers free of charge for the sole purpose of separating meats and seafood only upon the specific request of a Customer. Covered Entities shall not solicit Customers with respect to this exception.

Formatted: Font: (Default) Arial, Font color: Black

C. Food Product Stores may provide Recycled Content Paper or Accepted Compostable Pre-checkout Bags free of charge in produce and other aisles.
D. Food Product Stores shall make reasonable efforts to stock and make Reusable Pre-checkout Bags available or for sale. B. A Food Product Store or Covered Entity may make available for sale to a Customer Pre-checkout Bags for a minimum price of ten cents ($0.10).

11.63.050 Unreasonable denial of customer bags or containers.
Any establishment regulated by Public Resources Code Section 42281, Alameda County Waste Management Authority Ordinance 2016-02, or this Chapter, shall not unreasonably deny a customer from using bags or containers of any type that they bring themselves, including in lieu of using bags or containers provided by the establishment. However, establishments may refuse, at their sole discretion, any customer-provided bag or container that is cracked, chipped or corroded, appears inappropriate in size, material, or condition for the intended food item, or that appears to be excessively soiled or unsanitary. If the customer accepts a store-provided bags or containers in lieu, any charge required pursuant to this ordinance, other applicable law, or the establishment's policy will apply.

11.63.060 General exemptions.
A. Bags exempt from the Chapter include Product Bags, or bags sold in packages containing multiple bags such as those intended for use as garbage, pet waste or yard waste bags, or which are integral to the use of other objects.
B. Nothing in this Chapter prohibits customers from using bags of any type that they bring to the establishment themselves or from carrying away merchandise or materials that are not placed in a bag at point of sale, in lieu of using bags provided by the establishment.
C. Notwithstanding the requirements of Sections 11.63.30 and 11.63.40, Covered Entities and Food Product Stores, except as subject to the requirements of Public Resources Code Section 42281, providing 100% Recycled Content Paper Bags as Carryout Bags at the point of sale or Pre-Checkout Bags before the point of sale, shall provide such bags at no cost to a Customer participating in the California Special Supplemental Food Program for Women, Infants, and Children pursuant to Article 2 (commencing with Section 123275) of Chapter 1 of Part 2 of Division 106 of the California Health and Safety Code; a Customer participating in Calfresh pursuant to Chapter 1 commencing with Section 18900) of Part 6 of Division 9 of the California Welfare and Institutions Code; and a Customer participating in the Supplemental Food Program pursuant to Chapter 10 (commencing with Section 15500) of Part 3 of Division 9 of the California Welfare and Institutions Code.

11.63.070 Waivers—applicability and process to obtain.
A. The City Manager shall prescribe and adopt rules, regulations and forms for Covered Entities or Food Product Stores to obtain a partial waiver from any requirement of this ordinance upon sufficient evidence by the applicant that the provisions of this Chapter would cause undue hardship. The phrase "undue hardship" may include, but is not limited to situations where compliance with the requirements of this Chapter would deprive a person of a legally protected right.

B. Waivers may be granted by the City Manager or their designees, based upon documentation provided by the applicant and, at the City Manager's discretion, independent verification, including site visits.
C. The City Manager or their designees shall act on a waiver application no later than 90 days after receipt of such application, including mailing written notification of the City Manager's decision to the address supplied by the applicant.
Food Product Store

11.63.080 City of Berkeley—purchases prohibited.
The City of Berkeley and any City-sponsored event shall only provide or sell to a Customer ~~100%~~ Recycled Content Paper Bags or Reusable Carry-out Bags for the purpose of carrying away goods or other materials from the point of sale or event.

11.63.090 Duties, responsibilities and authority of the City of Berkeley.
The City Manager or their designee shall prescribe, adopt, and enforce rules and regulations relating to the administration and enforcement of this Chapter and is hereby authorized to take any and all actions reasonable and necessary to enforce this Chapter including, but not limited to, inspecting any Covered Entity or Food Product Store's premises to verify compliance.

11.63.100 Liability and enforcement.
A. Anyone violating or failing to comply with any requirement of this Chapter may be subject to an Administrative Citation pursuant to Chapter 1.28 or charged with an infraction as set forth in Chapter 1.20 of the Berkeley Municipal Code; however, no administrative citation may be issued or infraction charged for violation of a requirement of this Chapter until one year after the effective date of such requirement.
B. Enforcement shall include written notice of noncompliance and a reasonable opportunity to correct or to demonstrate initiation of a request for a waiver or waivers pursuant to Section 11.63.060.
C. The City Attorney may seek legal, injunctive, or other equitable relief to enforce this Chapter.
D. The remedies and penalties provided in this section are cumulative and not exclusive.

11.63.110 Severability.
If any word, phrase, sentence, part, section, subsection, or other portion of this Chapter, or any application thereof to any person or circumstance is declared void, unconstitutional, or invalid for any reason, then such word, phrase, sentence, part, section, subsection, or other portion, or the prescribed application thereof, shall be severable, and the remaining provisions of this Chapter, and all applications thereof, not having been declared void, unconstitutional or invalid, shall remain in full force and effect. The City Council hereby declares that it would have passed this title, and each section, subsection, sentence, clause and phrase thereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses or phrases had been declared invalid or unconstitutional.

11.63.120 Construction.

This Chapter is intended to be a proper exercise of the City's police power, to operate only upon its own officers, agents, employees and facilities and other persons acting within its boundaries, and not to regulate inter-city or interstate commerce. It shall be construed in accordance with that intent.

11.63.130 Effective date.
The provisions in this ordinance are effective [ ], 2022.

Section 2. Copies of this Ordinance shall be posted for two days prior to adoption in the display case located near the walkway in front of the Maudelle Shirek Building, 2134 Martin Luther King Jr. Way. Within 15 days of adoption, copies of this Ordinance shall be filed at each branch of the Berkeley Public Library and the title shall be published in a newspaper of general circulation.

Dear Honorable Members of the Facilities, Infrastructure, Transportation, Environment & Sustainability Policy Committee,

CALPIRG Students is a statewide student-run and student-funded nonprofit organization. We work to organize students on some of the most pressing issues of our generation - from protecting the environment, to making college more affordable, to promoting civic engagement.

So much of our plastic waste comes from plastic "stuff" we could easily live without. It can take hundreds of years to degrade. Every single piece of plastic waste invented is still out there, clogging landfills, littering our streets, polluting our oceans and beaches, and harming marine life and the public's health. But we have lots of alternatives that would prevent needless harm to the environment and to our public health.

That's why we want our city of Berkeley to serve as the green model for the rest of our state and issue a complete ban on all plastic bags! And it's also why We want to see Berkeley lead our state to a greener, healthier, and more meaningful future. This ordinance has our full support, and support from the Berkeley community which is attached on the following pages.

Please find attached 2158 signatures and 87 photo petitions collected from students and community members, as well as sign ons from 42 small businesses in support of the Better Berkeley Bag Ban. Along with this, this semester, we signed up 800 new UC Berkeley student members who donate $10/semester to CALPIRG Students in direct support of our work on the Better Berkeley Bag Ban.
Thank you for your consideration and service to Berkeley. We look forward to you moving the ordinance forward to the full council with a positive recommendation.

Sincerely,
Jose Luongo, Chapter Chair
Amy Johnson-Rodas, Vice Chair
Erin Redding, Grassroots Coordinator
Paige Lieblich, External Outreach Coordinator
Derick Lietzow, Media Coordinator
Marisol Morales, Visibility Coordinator
CALPIRG Students @ UC Berkeley

CALPIRG Students
ACTION FOR A CHANGE

Berkeley Businesses
42 Businesses signed on in support

Dear Berkeley City Council,

Every year, Californians throw away 16 billion plastic bags. All of this waste not only clogs our landfills, trashes our parks, and litters our streets, but it also washes into our rivers and oceans, where it can harm wildlife.

Individuals repurposing these bags can help mitigate the problem, but unfortunately, these billions of bags still ultimately enter our ecosystems annually. Additionally, we produce vastly more waste than our waste management infrastructure can handle. As a society, we need to stop creating enormous quantities of unnecessary waste in the first place, rather than focus only on recycling and reusing waste after the fact.

As small business owners, we encourage you to take action with campus, city, and statewide bans on all plastic bags. We encourage Berkeley City Council to enforce a bag ban that only permits reusable, recyclable, or compostable bags. We support a Better Berkeley Bag Ban to protect our environment and public health.

Thank you for taking action,

Aisha Bell | Manager | Indigo Vintage Co-Op

Williams | Sales Manager | Bows and Arrow

Maryam Guandalini | General Manager | Mezzo/Raleigh's

Anawin Juntanamulaya | Owner | The Ink Stone

Subhash Arora | Owner | Delhi Diner

Joseph Ryan | Head Barista/Manager | Musical Offering

Tan | Manager | Dumpling Kitchen

Yejih | Manager | Kimchi Garden

Tenzin | Employee | King Pin Donut

CALPIRG Students
ACTION FOR A CHANGE

Jason Mai | Manager | Boba Time

Vikram | Owner | Punjabi Dhaba

Doris Moskomte | Owner | Moe's Books

Ernest Ip | Owner | Take Eat Easy

Tom Chondu | Manager | Multiple Businesses: Rasputin Music, Bear Basics, Anastasias Vintage Clothing

Israel | Manager | Taco & Co.

Tempe Mangn Tevec | General Manager | Angeline's Louisiana Kitchen

Noeh Lynes | Half Price Books

Ammie Young | General Manager | Berkeley Social Club

Bharat Tekham | Manager | Friendly Market

Ali Fayazi | Owner | Coffee Hut

Harvey Dons | Owner | East Wind Books

Tash Pour | Fast Imaging Ctr

Chracken | Manager | Ko Stop

Judy Sona | Manager | Friends of the Public Library

Jo Call | Manager | Marcs Mercantile

Jeff Koren | Owner | Sleepy Cat Books

Jolie Trujillo | Manager | Indigo Vintage

J. Li | Manager | Crafts and Grapes

Venicat R.Y. | Manager | Namaste

CALPIRG Students
ACTION FOR A CHANGE

Efreu Avalos | Owner | Avalos Farms

Emiley Rodriguez | Kalei Farms

Matthew | Owner | Good Faith Farms

Roberto Ghato | Owner | Golden Rule Organic

Katy Pomelo | Owner | Lifefood Garden

Leo Haertling | Achadinha Farms

Eduardo Morell | Owner | Morell's Bread

Sara Morill | Big Little Bowl Soup

Harpreet | Phoenix

Nawang | Owner | Cafe Zaubalu

Elizabeth Prescot | Riverdog Farm

Daniel Korson | Owner | Coracao Confections

Fasika Merhrat | Owner | Sika Ethiophia

CALPIRG Students
ACTION FOR A CHANGE

UC Berkeley and Berkeley Residents

2158 Grassroots Petitions

Dear Berkeley City Council,

So much of our plastic waste comes from plastic "stuff" we could easily live without. It can take hundreds of years to degrade, so all of that plastic waste is still out there, clogging landfills, littering our streets, polluting our oceans and beaches, and harming marine life and the public's health.

That's why we want our city of Berkeley to serve as the green model for the rest of our state and issue a complete ban on all plastic bags! We have lots of alternatives that would prevent needless harm to the environment. We would like to see Berkeley lead the way to a greener, healthier, and more meaningful future.

Signed,

UC Berkeley Students and Residents

Noor	A	Ishaq	Aden-Ali
Charity	Abanes	Cho	Adolfo
Hanifah	Abatcha	Thea	Adumitroaie
Mohammed Ali	Abed	Marwa	Afghani
Alex	Abillar	Max	Afifi
Caitlyn	Abragan	Vedant	Agarwal
Amjad	Abukeer	Arhaan	Aggarwal
Nonachi	Achara	Nick	Agor
Natalia	Acuesta	Shipransh	Agrawal
Lauren	Adams	Vaibhav	Agrawal

Jordan	Agresti	Sajad	Alani
Brisa	Aguayo Ramirez	Sara	Alanis
Yelinne	Aguiar	Seiham	Alansary
Gabriel	Aguilar	Mia	Albano
Alondra	Aguilar	Samiyah	Alberto
Isaac	Aguilar	Sedrick	Alcantara
Alejandra	Aguilar Arce	Jacqueline	Aldrete
Sarah	Ahazie	Dania	Alfakoos
Sharon	Ahazie	Zayd	Ali
Maria	Ahmed	Maryem	Ali
Ellie	Ai	Abigail	Allen
Tom	Aiba	marie	allouche
Yezzen	Airawi	Isabella	Aloocer
Havah	Aisha Isray	Khaled	Alqahtani
Yusuf	Akbas	Auden	Alsop
Carley	Akohoshi	Chloe	Altura
Lukas	Aksena	Fátima	Alvarado
Mohammed	Al Rashid	Pamela	Alvarado
Mohammad	Alam	Giovanni	Alvarez
Mariam	Alami	Ahmed	Alzubaidi

CALPIRG Students
ACTION FOR A CHANGE

Alejandra	Amador	Matilda	Antwi
Ishan	Amin	Alexa	Apodaca
Nicole	Ammari	Brenda	Aquilar
Ken	Amornnopawong	Paelo	Aquino
Ella	Amparo	Sergio Alejandro	Araiza Robles
Joel	An	Christina	Arakelian
Stella	An	Carol	Areta
Ellie	Andersen	Jesus	Arias
Evan	Anderson	Samuel	Arias
Riley	Anderson	Erik	Armas
Leeannie	Anderson	Vijay	Arora
Michelle	Anderson	Juliana	Arrona
Mike	Andrade	Verina	Atallah
Amarra	Andresen	Riya	Athwal
Jordan	Anichini	John	Atoche
Roma	Ankolekar	Sid	Attam
Sarah	Ansell	Samikshaya	Auanthakrisknan
Sophie	Anslinger	Tyler	Auton-Smith
Kate	Anstett	Heidi	Avalos
Zoe	Antonoff	Danielle	Avelino

CALPIRG Students
ACTION FOR A CHANGE

Nathalie	Avila	Akcan	Balkir
Ivonne	Avila	JiHo	Bang
Natalie	Aviles	Sidney	Banks
Shanzay	Awan	Nilo	Banos
guadalupe	ayala	Alexa	Banuelos
Kennya	Ayala	Christie	Bao
Katem	Ayat	Hannah	Barahona
Anant	Ayyar	Osvaldo	Barba
A	B	Niko	Bardin
Fariha	Babar	Dhoha	Bareche
Rebecca	Baek	Tahmina	Barkzai
Aaron	Baeza Cerriteno	Olivia	Barman
Ipshita	Bag	lily	Barnett
Martin	Bagadion	giselle	barough
Amanjot	Bains	Laura	Barragan
Ramanjot	Bains	Ian	Barragan
Rosa	Baiza	Matias	Barraza
Kimberly	Bajarias	Felipe	Barreto
Kimberly	Baker	Brianna	Barrett
Patrick	Bales	Maayan	Barsade

CALPIRG Students
ACTION FOR A CHANGE

Mariana	Barsotti	Helen	Berg
Sarah	Barton	Emely	Bermudez
Elizabeth	Barton-Mattos	Sofia	Bernal Ramirez
Sanah	Basrai	Estefany	Berrios
safa	basravi	Riki	Bertoldi
Osmend	Bates	matthew	betti
Catherine	Bauer	Sara	Betts
Kelsey	Bautista	Anitej	Bharaduaj
Jared	Bautista	Lavanya	Bhardwaj
Constance	Beckford	Manan	Bhargava
Paige	Begley	Ella	Bhat
Nicolas	Beguin	Aditi	Bhat
Evan	Belk	Savit	Bhat
Ron	Belman	Miranjan	Bhatia
Riley	Benedict	Sarthak	Bhatnagar
Jaden	Benitez	Mark	Biedlingmaier
Victor	Benitez	Nur Marsya	Binti Zuhari
Kevin	Benitez	Vivien	Black
james	Bennett	Lucia	Boadas
Bridget	Bentley	Carlos	Bocanegra

CALPIRG Students
ACTION FOR A CHANGE

martina	boga	William	Bradford
Llesi	Bogaard	kaitlyn	brady
Sushil	Bohara	Olivia	Branan
Mateo	Bohigian	Andy	Brandt
Edgar	Bojorquez	Malia	Brazil
Kiely	Bok	Madison	Brenner
Sarah	Bollinger	Nathan	Brenner
Nathalie	Bombase	Skylar	Briggs
Gaia Maria	Bonanno	Hector	Briseno
Jay	Bond	Sullivan	Brock
Sri	Bondada	Abigail	Brooks
Pace	Bongiovanni	Hannah	Brooks
Jatearoon	Boondicharern	Haley	Brower
Abby	Borchers	Kendall	Brown
Alex	Boren	Jordan	Brown
Isabella	Borkovic	Olivia	Buchbinder
Michael	Borrello	Megan	Bui
Chloe	Boss	Erin	Burke
Kimi	Boureston	Mina	Burns
alex	bovenzi	Thora	Butler

Lindsey	Butner	Sabi	Can Russo
Michid	Byambajav	Rayne	Cantero
Elizabeth	Byington	Diana	Cantoran-Perez
Devon	Byrne	Azzurra	Cappuccini
Doy	C	Helena	Cardiel-Stevens
Isabelle	C. Ribeiro Minosso	Alexis	Caretti
Isabel	Cabrera	Sonoma	Carlos
Frank	Cai	Caelyn	Carlson
Caitlyn	Cai	Raafat	Caroline
Joshua	Calangian	Nina	Caron
Lauren	Calcagno	dylan	Carpenter
Paige	Callaghan	Clarisse	Carpio
Jared	Calvo	Daisy	Carranza
Frida	Calvo Huerra	Giselle	Carreno
Abigail Grace	Camacho	Kleigh	Carroll
Stephanie	Camarillo	Tyler	Cary
Trinity	Campbell	John	Cary
Mia	Campbell	Andrew	Caslow
Elena	Campell	John	Cassell
Zoe	Campion	Maria	Castaneda

Fatima	Castillo	Jessica	Chan
Alma	Castillo	Shirlynn	Chan
Dayelynn	Castillo Delgado	Adelyn	Chan
Marius	Castro	Jayda	Chan
Emma	Caufield	Hsi-min	chan
Mike	Ceas	Yunling	Chan
Lester	Cedeno	Liliani	Chandranata
Katarina	Ceguerra	Lucia	Chang
Samantha	Ceja	Katie	Chang
Samantha Mae	Ceralde	Stephen	Chang
Yareli	Cervantes	Tzuyi	Chang
Calista	Cesewski	Bella	Chang
callie	cesewski	Shannon	Chang
Meyra	Ceylan	Ginger	Chang
Molly	Cha	Joey	Chao
Darshan	Chahal	Marco	Chapa
Elen	Chakhoyan	Jacqueline	Chapman
Ying	Chan	Grenier	Charlotte
Cherry	Chan	Dylan	Chau
Angelica	Chan	Anirudh	Chaudhary

CALPIRG Students
ACTION FOR A CHANGE

Grisel	Chavez
Ananya	Chawla
Ronit	Chawla
Shachi	Chemburkar
Justin	Chen
Jessica	Chen
Yu Jun	Chen
Lei	Chen
Cynthia	Chen
Kurtis	Chen
Tavis	Chen
Yaozong	Chen
Calculus	Chen
Bruce	Chen
Jenna	Cheng
Ming	Cheng
Natalie	Cheng
Chantal	Chew
Sachin	Chhabria
Yuriko	Chiaki-Robb
Sanjay	Chintapally
KAITLYN	CHIOK
Xiaowen	Chn
Deborah	Cho
Ara	Cho
Shay	Choen
Audrey	Choi
Mina	Choi
Won Jung	Choi
Alina	Choi
Kaden	Chou
Tzu Chieh	Chou
Zach	Christiansen
Catherine	Chu
Elma	Chuang
Vivian	Chung
Manuel	Cisneros
Logan	Citroen
Nicholas	Clark
Lucas	Clark

CALPIRG Students ACTION FOR A CHANGE

Florante	Claudio	Quinn	Corcoran
Wyatt	Clay	Taylor	Cordoba
Caitlin	Clift	John	Cornejo
Rena	Co	Gabriela	Cornejo
Taleen	Cochran	Victor	Cornejo
Jevon	Cochran	Jairo	Corral Chavez
Shay	Cohen	larissa	corry
Francesca	Cohen	Liliana	Cortes
Simon	Colburn	Viviane	Cortes
malcolm	collins	Ana	Cortez
Claudia	compas	Kristel	cosio
Raphael	Condor	Katheryn	Cota
James	Conklin	Ridge	Coughlin
Brandon	Contreras	Ainslie	Coughran
Daniel	Conway	Maxwell	Coy
John	Cook	Elizabeth	crass
Angela	Cooley	Emily	Crofoot
Isobel	Cooper	Richard	Crorch
Mahlet	Copeland	Jessica	Croysdill
Abigail	Corcio	Pedro	Cruz

CALPIRG Students
ACTION FOR A CHANGE

Luis	Cruz	Aashna	Dalal
Ricardo	Cruz	Aiden	Damirez
James	Cruz	Valdezti	Dandekar
Juana	Cruz Sampedro	Marcus	DAngelo
Emerson	Cruz-Ramirez	Claire	DaQuino
Kennedy	Cuello	Katie	DaQuino
Dixun	Cui	Carlo	Daquioag
Tingyue	Cui	Raj	Dasani
Austin	Culp	Nishita	Dashpute
Nick	Currie	Isabella	Daste
Ava	Currie	Kat	Davenport
Eugeniu	Cuznetov	Derek	Davis
Sehr	Dada	Mohammad	Dawood
diksha	dahal	Kiki	de Bruijne
Sanaya	Dahanukar	Arissa	De La Cerda
Chen	Dai	Cassandra	De La Pena
Gracie	Dai	Jack or Jace	De La Riona
Jason	Dai	Sophia	De la Rocha
Aditya	Daita	Tatiana	De La Sancha
Daisy	Dal	Natalia	De La Torre

CALPIRG Students
ACTION FOR A CHANGE

Niko	De La Torre	Ella	Diamond
Gavin	de Leon	Rachel	Diao
Xavier	De Leon	Shaylan	Dias
Samantha	DeCosta	Jackelyn	Diaz
Salaah	Deen	Gilberto	Diaz
Morgan	Dehdashti	Emily	Diaz
Monica	Deherrera	William	Diaz
Karleigh	Dehlsen	Luis	Diego Riojas
Aidan	del real	Xintong	Ding
Gianna	Delgado	Ella	Dittmann
Sofia	Delpriore	Michaia	Dixon
Jon	Dena	Caleb A.	Dixon
Bruce	Deng	Megchiani	Diya
Boyuan	Deng	Nam	Doan
Daniel	Deng	Donn	Dolorito
Pallavi	Desai	Maria	Dominguez
Elise	Deshazer	Jacqueline	Dominguez
rahul	deshmane	Ericka	Dominguez
Asrith	Devalaraju	Ariana	Dominick
Shivreet	Dhillon	Saghen	Dommes

CALPIRG Students ACTION FOR A CHANGE

Zhen	Dong	Armaan	Dwivedi
Kalea	Doryon	Val	E Machedo
Samantha	Doyle-Jacobson	Maxine	E.
Justice	Drake	Violet	Edwards
Savannah	Dryden	Benjamin	Eisley
Kau	Du	Rachel	Eizner
Lianna	Duag	Kaleb	Elarms-Orr
XUANYU	DUAN	Emmanuel	Elizalde-Ocampo
Siddarth	Dukkipati	Maria	Elizarraras
Lindsey	Duncan	Ryan	Elkhouri
Alida	Dunleavy	Mahiya	Ellis
Kalani	Dunn	Kevin	en
Alexa	Dunn	Cooper	Endicott
Sabrina	Dunn	Gigi	engalla
Liam	Dupeyron	Saum	Entezasi
Lanah	Duque	Payamullah	Erfan
Chris	Duran	Jesnine	Erillo
Samantha	Duran	Sara	Ertac
Damian	Duran	Sara	Ertae
Brian	Durnell	Ariel	Esagoff

CALPIRG Students ACTION FOR A CHANGE

Deanna	Escarieses	He	Fang
Maxine	Eschger	Charlie	Faramarzi
Nathan	Escobar	Vice	Farley
Steve	Escobar	Naasie	Farooqi
Nora	Espinoza	Alina	Fatima
Ethel	Espinoza	Greyson	feather
Gabriela	Espinoza Alfaro	Karla	Feldmann
Emeli	Esquivias	Ronan	Felton-Priestner
Nathan	Essman	Carly	Feng
Jonathan	Estrada	Tulsi	Fernandez
Paulina	Estrada	Vanessa	Fernandez
Melvin	Estrada	isabella	ferrucci
Mark	Eusterman	Maximo	Fierro
Garrett	Evans	Aubrey	Fife
Jordan	Evans-Polockow	Brianna	Figueroa
Sophie	Everett	Martin	Figueroa
Francesca	Ezra	Lucas	Fink
Mona	Faham	Kayleen	Fiscal
Lorianne	Fan	Jessie	Fisher
Jeffrey	Fan	Colin	FitzGerald

CALPIRG Students
ACTION FOR A CHANGE

Rayna	Fitzgerald	Alia	Franczyk
David	Fitzoerald	Thalissa Malagoli	Frazon
isabel	flanders	Misie	French
Zoe	Flemate	kyle	friend
Nick	Fleming	Angelo	Frisina
alfie	fletcher	Vivian	Frisk
Crizel	Flores	Julia	Fu
Fernando	Flores	Guanhua	Fu
Naomi	Flores	Zaman	Fualmooh
Roberto	Flores Blancas	Zaira	Fuentes
Lia	Flores Palacios	Filson	Fugfugosh
Alfredo	Florez	Kenzo	Fukuda
Ari	Fomalont	Kathryn	Funderburg
Chrissa	Foscolos	Madeline	Furey Peters
Ava	Foster	Constance	Gaard Storvestre
Rachel	Fox	Emily	Gabion
Valerie	Fraga	Natalie	Gaffney
Marisol	Franco	Kate	Gaffney
Emmanuel	Franco	Graeson	Gajewski
Tomas	Francois	Arly	Galindo

CALPIRG Students
ACTION FOR A CHANGE

Samantha	Galindo	Armando	Garcia
Emily	Gallardo	Miguel	Garcia
Joshua	Gallo	Grecia	Garcia
Lindsay	Galperson	JP	Garcia
Jocelyn	Galvan	Robert	Garcia
Jocelyn	Gama	Debbie	Garcia
Hannah	Gammon	Josselin	Garcia Sereno
Genna	Gams	Kimberly	Garcia-Aguilar
Rustam	Gandhi	Martin	Garcia-Angel
Mehul	Gandhi	Preshtha	Garg
Liam	Ganion	Khislenn	Garino
Cynthia	Gao	Adamaris	Gasca
Shihan	Gao	Aaron	Gaspar
Annie	Gao	Sara	Gastelum
Tiffany	Gao	Bryanna	Gavino
Kush	Gara	Olivier	Gennart
Gianna	Garcia	Renuka	Gentela
Kaylee	Garcia	Declan	Gessel
Jessica	Garcia	Nare	Gharibi
Julian	Garcia	Allie	Giang

Carla	Gil	Ronny	Gonzales
Manraj	Gill	Ari	Gonzalez
Jaadé	Gillespie	Sebastian	Gonzalez
lucas	gilmour	Moncerrath	Gonzalez
Mateo	Giovannini	Eitalia	Gonzalez
Vikash	Giritharan	Katherine	Gonzalez
Asiah	Giuntoni	Jose	Gonzalez
Jordan	Gleaton	David	Gonzalez
Madeline	Godbey	Tomas	Gonzalez
Emerson	Goebels	Mayra	Gonzalez-Gomez
Tyler	Goldstein	Sophia	Gorlato
Kevin	Gomes	Priyanka	Goswami
Julieta	Gomez	Ryan	Gottschalk
Carlos	Gomez	rohan	goyal
Stefany	Gomez	Jack	Grable
Angel	Gómez	Ian	Grace
Ana Alice	Goncalves	Eva	Grace
Sreya	Gonugunta	Amy	Granados
D'Angelo	Gonzales	Brooklyn	Grant
Ana	Gonzales	Maurice	Grayson

Thomas	Green	Aayush	Gupta
Moss	Gridley	Raghav	Gupta
Alexander	Griffin	Anish	Gupta
Olivia	Grimes	Sitara	Gupta
Natalie	Grover	Sonya	Guralnyk
Carter	Gruebel	Camila	Gutierrez
Zeze	Gu	Heriberto	Gutierrez
Grace	Guan	Jonathan	Gutierrez
Maggie	Guan	Guz	Guzman Gomez
Akhil	Gudapati	Ann-Marie	Ha
Alexia	Guerra	Aliya	Haas Blinman
Melanie	Guerrola	Grace	Haase
Adalma	Gueuara	Denna	Hadipour
Jacqueline	Guevara	Sierra	Hahn
Aishi	Gulati	Rebecca	Haile
David	Guo	Jonathan	Hale
Arinna	Guo	Crystal	Halk
Ishrita	Gupta	Andrew	Hall
Agam	Gupta	Helen	Halliwell
Rijul	Gupta	Charles	Halstead

Andrea	Halsted	Matthew	Haynam
Fumiko	Halteman	jada	hays
Isabela	Hamasaki	Shadow	Hayward
Tehreem	Hamid	Yiwei	He
Samuel	Han	Qing Qing	He
Michelle	Han	Shuyao	He
Zikang	Han	Qiting	He
Tatum	Handel	Madison	Heath
Tommy	Hang	Madeline	Heller
Cornelius	Hant	Benjamin	Henriquez
Asaad	Haroun	Na Lee	Her
Chad	Harper	Rosa	Heraldez
Samuel	Harris	Dionne	Herbold
Cyndi	Harris	Ross	Herling
Katelyn	Harter	Sofia	Hernandez
Lauren	Harvey	Francis	Hernandez
Said	Hashmat	Yvette	Hernandez
Seemal	Hassan	Abigail	Hernandez
William	Hayes	Angelica	Hernandez
Nathaniel	Haynam	Brisa	Hernandez

Enmanuel	Hernandez	Anthony	Hoang
Julie	Hernandez	Tawny	Hoang
Daniela	Hernández	Emma	Hoehn
Diego	Hernandez Callejas	Claudia	Holland
Yamilekx	Hernandez Guzman	Imani	Holmer
Ana	Hernandez Vega	Tara	Hong
Richard	Herrera	Andrew	Hong
Luis	Herrera-Silva	Xochitl	Hood
Kelsey	Hetherington	Geneva	Hopwood
Joshua	Hickel	Maya	Horenstein
Sansan	Hien	Samantha	Horne
Heather	Highland	Anders	Hosek
Amaya	Hill	Jerry	Hou
Corwin	Hill	Elena	Hsieh
Nina	Hill	Claire	Hsu
Heidi	Hirsohn	Zin	Htet
Bailee	Ho	Sherry	Hu
Stanley	Ho	Nancy	Hu
Austin	Ho	Summer	Hua
davian	Ho	Chun	Huang

CALPIRG Students
ACTION FOR A CHANGE

Cynthia	Huang	Ji soo	Hwang
Weiping	Huang	Olinna	Ian
Junting	Huang	Carolina	Ibanez
Jeremy	Huang	Madison	Idso
Ellie	Huang	Kaitlyn	Iglesias
Vienna	Huang	Kyle	Igo
Zhiyuan	Huang	Omar	Imam-Darling
Clement	Hudson	Irmak	Incedayi
Ana	Huerta	Stefanie	Iojica
Vivienne	Huerta Guimont	Mehrazin	Iranbakhsh
Rocky	Hughes	Jade	Isaacs
Alexander	Huizar	Cyrhil	Ishi Soriente
yuri	humrich	Laila	Ismail
Dylan	Hungate	Pranav	Iyer
Ines	Huret	Amanda	Jackson
kilty	huskisson	kathryn	jackson
Lindzi	Hutchinson	Clarissa	Jacobo Hernandez
Nhi	Huynh	Manish	Jaganath
Andy	Huynh	Taya	jain
Yoon	Hwang	Jasmine	Jalloh

CALPIRG Students
ACTION FOR A CHANGE

Emme	James	Naia	johnson
Aimen	Jamshed	Meghan	Johnson
Kishan	Jani	Amy	Johnson
kendall	jensen	Auxiliadora	Johnson
Emma	Jensen	Ahmi	Johnston-Ponell
Kristen	Jeong	Braeden	Jones
Charlie Cheng-Jie	Ji	Jacqlyn	Jones
Skyler	Ji	Bennie	Jordan
Jerry	Ji	Edwin	Jorge-Benitez
Xiangli	Jia	Hector	Juarez-Vargas
Jacob	Jiang	Ari	Jujin
Nick	Jiang	Anna	Julian
Anais	Jimenez	Amalia	Junco
fatima	jimenez	Jacoby	Junes
Lina	Jimenez	Ayeon	Jung
Mathew	Jimenez	Terry	Jung
Yoon	Jin Loom	Hailey	Jung
Abhinar	Jin-joo Veduti	Micheal	Jungh
Leah	Jizelle	Raina	Jupay
Jordan	Johl	Aldo	Jusso Ramirez

CALPIRG Students
ACTION FOR A CHANGE

Elizaveta	K	mahek	kaur
Abd	Kahhaleh	Maho	Kawai
Meher	Kajaria	Ashley	Kaya
Anastasia	Kaloshina	Lia	Keener
Marina	Kamezawa	Sai	Keerthana Puvvuls
Emma	Kang	Allison	Kelley
Woojung	Kang	Zoe	Kelly
Liang	Kang	Robert	Kelly
Yoga	Kanneboina	Angelique	Kelly-Patino
Austin	Kao	John	Kenny
Michael	Kao	Jessica	Keszey
Selin	Kaptana	Benjamin	Key-Rodriguez
Charitha	Kari	Sundus	Khan
Arjun	Karnik	sana	khan
Sheer	Karny	Maria	Khan
Swetha	Karthikeyan	Tina	Khangtintsang
Jayanth	Karuturi	Shivani	Kharbanda
Anvi	Kasargod	Kirsten	Kho
Sage	Kasick	Jana	Kikhia
Amar	Kaul	sueji	Kim

CALPIRG Students
ACTION FOR A CHANGE

Dani	Kim	ruby	king
Erica	Kim	Emmett	King
Jaremy	Kim	Kayla	Kirkorian
Tommy	Kim	Savannah	Klein
Allison	Kim	Rowen	Kliethermes
Katie	Kim	Peyton	Kn
Gamin	Kim	Anna	Knall
Hyun Ho	Kim	Isabella	Knott
Madeline	Kim	David	Ko
Kailin	Kim	Rosa	Kobusch
Amy	Kim	J. Michael	Kochera
Karis	Kim	Priscilla	Koetting
Rachel	Kim	Adeola	Kofo-Abayomi
Vivian	Kim	Katelyn	Kolberg
seungyeon	kim	Pranathi	Kolla
Christina	Kim	Xiang	Kong
Minji	Kim	Federico	Kong-Gonzalez
Min	Kim	Samuel	Kooset
Youngjin	Kim	Satoshi	Kori
tristan	kimball	Zara	Koroma

CALPIRG Students
ACTION FOR A CHANGE

Akhil	Korupolu	Roshni	Kumar
Deepika	Korupolu	Hamza	Kundi
Samantha	Kotta	Raquel	Kunugi
Po-ou	Kouch	Olivia	Kurtz
Gursimar	Kouli	Aleen	Kuyumjian
Emma	Kraft	Abraham	Kwok
Maxim	Kraft	Jack	Kwon
Emma	Kraus	Andrew	Kwon
linda	Krellner	Ryan	Kwong
Ariana	Kretz	Mallika	L
Markus	Kreutzer	Marco	L.
Sejal	Krishnan	Sean	La
Uma	Krishnaswamy	Tuong	La
Arjun	Kshirsagar	Maximus	Lacey
Yiming	Kuang	Sophia	Ladyzhensky
Kylie	Kubota	Angel	lagunas
Jacob	Kuczynski	Susan	Lai
Zoe	Kuebrich	Connor	Lam
Pranesh	Kumar	Oscar	Lam
Akshat	Kumar	Janice	Lam

Annabelle	Lampson	Francis	Ledesum
Lucia	Landeros	Dylan	Lee
Lukas	Lane	Jana	Lee
Arianna	Laolagi	Kristen	Lee
Luz	Lara	Hellas	Lee
henry	Larkin	Colette	Lee
Amanda	Larsen	Kevin	Lee
Ho Yin	Lat	Megan	Lee
Tilema	Latu	Shanon	Lee
Sam	Laur	Seul Ah	Lee
Danielle	Lavitt	Kaylin	Lee
Catherine	Lawrence	sydney	lee
Garrett	Layton	Jean	Lee
Khoi	Le	Viola	lee
Han	Le	Cyrus	Lee
Trang	Le	Tyler	Lee
Megan	Le	Tommy	Lee
Vi	Le	Sophia	Lee
Vanessa	Lechuga	Jenny	Lee
Natalie	Leclerc	Joshua	Lee

CALPIRG Students
ACTION FOR A CHANGE

Aisan	Lee	Chunyuan	Li
Jaclyn	Lee	Mona	Li
Yechan	Lee	Andrew	Li
Mengziang	Lei	Grace	Li
Karina	Lei	Beike	Li
Casey	Lei	Sophie	Li
Constantina	Leibe	Jerry	Li
Lukas	Leitzgen	Chenyi	Li
Jocelyn	Lemos	Tongdan	Li
Kiana	Leong	Crystal	Li
Aidan	Leung	Bowen	li
Lauren	Leung	Esther	Li-Chen
Jenna	Levin	Katie	Liang
Alexander	Levy	natalie	liang
Benjamin	Lewis	Kathy	Liang
Jeremy	Lewis	Jason	Liao-zeng
Shawntrell	Lewis	Henry	Libermann
Abigail	Lewis	Paige	Lieblich
Ben	Lewis	Kennedy	Liem
Xiangyang	Li	Robert	Lietzow

CALPIRG Students
ACTION FOR A CHANGE

Sehee	Lim	Brandon	Liu
Evan	Lim	Fang	Liu
Kylie	Lim	Yingpian	Liu
Joshua	Lim	Doris	Liu
Maria	Lima	Tingyu	Liu
Andrea	Limon	Lianna	Liu
Isaac	Lin	Youxun	Liu
Jinjian	Lin	Wenjin	Liu
Yati	Lin	Aaron	Liu
Maggie	Lin	Ryder	Liulin
Charlotte	Lin	Jessica	Llanos-Gamboa
Branden	Lin	Laura	Llerena
James	Lin	Hayden	Loarie
Yihan	Lin	Sonam	Lobras
William	Lindstrom	Kaori	Lock
Yunjun	Ling	Anuja	Lohia
Camille	Linh	Priyanka	Lohia
Yanlin	Liu	Kathryn	Look
Ricky	Liu	Claire	Loos
Ambrose	Liu	Melany	Lopez

CALPIRG Students ACTION FOR A CHANGE

iris	lopez	Xinyin	Lu
Bella	Lopez	David	Lu
Francisco	Lopez	Lauren	Lu
Andrew	Lopez	CJ	Lu Sing
Frankie	Lopez	Diana	Lucas
Jocelyne	Lopez	Anaely	Lugo
Allen	Lopez	Raul	Luis
Vanessa	Lopez	Jana	Lukas
Rin	Lopez	David	Luna Cruz
Imalay	Lopez-Corona	Cecilia	Lunaparra
David	Lopez-Larios	Matthew	Luo
Hannah	Lothrop	James L	Luo
Nicole	Louie	Tatum	Luoma
Thomas	Louther	Maya	Luong
Asthon	Love	Joaquin	Luongo
Juliette	Lovell	Madeline	Ly
Emma	Lowe	Alexander	Ly
Camila	Lozano	Caylee	Lyman
Nick	Lu	Grace	Lytle
Ducheng	Lu	Tong	Lyu

CALPIRG Students
ACTION FOR A CHANGE

Bingbing	Ma	Marcelo	Makhlovf
Celina	Mac	Marc	Makornwattana
Andrea	Macairan	Abigail	Malakun
Emmanuel	Macedo	Andrea	Maldonado
Inigo	Macey	Emiliano	Maldonado
Thais	Macias	Michelle	Maldonado
Nhaovaleth	Macias	Arika	Malik
Laishaa	Maciel	Iskita	Malik
Carlyle	Mackenzie	Tanaya	Malik
Aaron	Mackenzie	Star	Mallamo
Aditya	Madaraju	Giselle	Malveda
Raghava	Madireddy	Samuel	Mankoff
David	Madriz	Meher	Mann
Julio	Magana	Justin	Marc Alvarez
Declan	Mahaffey-Dowd	Selian	Marie Grogan
Niamh	Maher	Kaleo	Mark
Sara	Mahjoobi	David	Marquez
Haania	Mahmood	Ella	Marsh
Duong	Mai	Caleb	Marsh
Sinan	Makdisi	Adrian	Martinez

CALPIRG Students
ACTION FOR A CHANGE

Judith	Martinez	Emily	McCabe
Claudia	Martinez	Bridget	McCabe
Christian	Martinez	Olivia	McCauley
Allyson	Martinez	Floyd	McCluhan
Frank	Martinez	Jake	McCullough
Jenna	Martinez	Annabelle	McCutcheon
Joan	Martinez	Claire	Mcdonald
Lavanya	Maruthapandian	Jessie	Mcginley
Ali	Marvin	Liam	McHugh
Alex	Masci	John	McKay
Jiroum	Masoudi	Jameson	McKenna
Jordan	Masterson	Maggie	McLean
Elaina	Matos	Asha	McLyn
Alisa	Matsoyan	Kevin	McNally
Sylvia	Mau	Tyler	McNierney
Milo	Maurer	Raina	McRae
Jay	Maytorena	Maureen	McSweeney
Armina	Mayya	Hilary	Medel
Maddie	Mc Elheney	Hillary	Medel
Allie	McAndrews	Elizabeth	Megaw

CALPIRG Students
ACTION FOR A CHANGE

Alexander	Mehregan	Luis	Meza
Yingyan	Mei	Yutorey	Mi
Monise	Mejia	Mariatereza	Michael Lidou
Jaye	Mejia-Duwan	Leonard	Milea
Mehaa	Mekala	Anna	Miller
Kayra	Mendez	Ellie	Miller
Melissa	Mendieta	Lia	Mimun
Ashley	Mendiola	Yeirell	Minder
Janet	Mendoza	Arlet	Miranda
Ulyses	Mendoza	Sara	Mirza
Bella	Mendoza	Ashi	Mishra
Therese	Mendoza	Tilak	Misner
Nadav	Mendoza	Maya	Mitchell
Juana	Mendoza Cruz	Margot	Mitchell
Maya	Mendrxa	Ian	Mitchell
Ines	Menendez	Adi	Mittal
Miguel	Mercado	Kanav	Mittal
Aminah	Merchant	Megan Moe	Moe
cooper	mervin	Saahit	Mogan
James	Meyer	Niki Sanieenia	Moghaddam

Shreya	Mohanty	Julia	Moreno
Madison	Mohblea	Alisson	Moreno
Madeline	Molina	Miguel	Moreno
Andrea	Molina	Nadia	Morenore
Molly	Monahan	Mimi	Morgan
Ishan	Monie	Marietta	Morgan
Richel	Monis	Sky	Morgen
Nate	Monocchio	Evelyne	Morisseau
Ruth	Montes Avila	Caden	Moskowitz
Ryan	Montevo	Sarah	Moss
Pascale	Montgomery	Farouk	Mostafa
Jacqueline	Montoya	Dylan	Motley
Rohith	Moolakatt	Ava	Moubi
Gun	Moon	Abram	Moudi
Avalon	Moore	Max	Mueller
Jocelyn	Moore	Ahmad	Muhammad
Kristie	Moore	Valmic	Mukund
Gracy	Mora	Christiane	Munda
Nazly	Moran	Jennifer	Mundo
Julissa	Moreno	Michelle	Munera

Maureen	Munoz	Lara	Nahcivan
Melissa	Munoz	Varun	Nair
Quintin	Munoz	Ria	Nakahara
Jesica	Muñoz	Miku	Nakamura
Orlando	Muñoz	Sevina	Nanda
Ashwini	Murali	Cecilia	Naranjo
Alexus	Murchison	Nainika	Narayanan
Daniel	Murphy	Patricia	Narro
Sheila	Murthy	Japinder	Narula
Riteka	Murugesh	Miles	Nash
Karina	Murugesu	Shabnam	Nasiri
Yuuki	Mutsumoto	Rania	Nasser
Prachitesh	Mysorekar	Layla	Nasseri
Emeline	Myung	Shruti	Natarajan
Iris	Myung	Krithika	Nathamuni
armando	na	Vanessa	Nauarro
Ramona	Naddaff	Christopher	Naughton
Anup	Nadesan	Deisi	Nava
imaan	nadir	Natalia	Nava-Urbina
Samhita	Nagubandi	Ayanna	Navarro

Saloni	Nayak	Alyssa	Nguyen
Ryan	Nayebi	Andzin	Ngwa
Ryan	Nayeli	Katerina	Nierotka
Eman	Nazir	Melody	Ning
Heather	Nelson	Jennifer	Nnoli
Samantha	Nelson	Kenichiro	Nojiri
Miguel	Nepomuceno	Jazmin	Nolasco
Rachel	Ng	Mia	Norris
Raissa	Ngoma	Tania	Norzagaray
Brigitta	Nguyen	Emily	Nowak
Minh	Nguyen	Benjamin	Nunez
Thuy	Nguyen	Ryan	Nuqui
Jackie	Nguyen	Angel	Nwosu
Shelby	Nguyen	Dylan	O'Doyer
Catherine	Nguyen	Colin	O'Malley
Jazmine	Nguyen	Doah	Obaid
Juliana	Nguyen	Jack	Oberdorfer
Truong	Nguyen	Emmariel	Obero
Christina	Nguyen	Alex	Ocampo Espinoza
Giang	Nguyen	Alejandra	Oceguera

CALPIRG Students
ACTION FOR A CHANGE

Cristina	Ochoa	Alejandro	Orozco
Jose	Ochoa	Antonio	Orozco
Michael	Ofengenden	Paolo	Orozco
Hanser	Oh	Julianna	Ortega
Andie	Oh	Angelica	Ortega
jackee	ohara	Daniel	Ortega-Mendez
Emily	Ohman	Marilyn	Ortez-Bonilla
Arnold	Olguin	Cristina	Ortiz
Jaqueline	Olivares	Katrina	Osborn
Tyler	Onderdonk	Julianne	Oshiro
Nicholas	Ong	Harrison	Oswald
Noel	Onuoha	Carli	Oxenham
Thin Rati	Oo	Taishi	Oyamada
Angelica	Oram	Sanni	Oyinkansola
Justine	Oribello	Merve	Ozdemir
Charles	Orlando	Nate	Pacheco Lopez
Jakeline	Orollo	Daniel	Pack
Anaruby	Oropeza	Kirk	Paderes
Rosa	Oropeza	Esperanza	Padilla
Mary	Orozco	Kaitlyn	Pak

Victor	Pak	Erin	Park
Hayley	Palilla	Pritish	Parmar
Rasmus	Pallisgaard	Sofia	Parsons
Joel	Palma	Diya	Patel
Mike	Palmer	Akshay	Patel
Uriel	Palmos	muhammad	patel
Yiwen	Pan	Valdehi	Patel
Yu Han	Pang	Khushi	patel
Anoohya	Panidapv	Nidhi	Patel
Anuj	Panta	Joshua	Paul
Ayush	Panta	Pancham	Pawan
Kalea	Papandrew	Ozan	Paydak
Kim	Pape	Danielle	payopay
Khushi	Parashar	Ariana	Pemberton
Lily	Parcells	Natalie	Pena Serafin
keya	pardasani	Jialiang	Peng
Krishna	Parekh	Daria	Peppler
Su Min	Park	Dasha	Peppler
Hailey	Park	Cassandra	Peralta
Eric	Park	Natalie	Peret

CALPIRG Students
ACTION FOR A CHANGE

Alad	Peretz
Diana	Perez
Marcela	Perez
Rachel	Perez
Lakshman	Peri
Claudia	Peri
Kevin	Peter
Margaret	Peterson
Michael	Petrides
Charlotte	Petty
Rebecca	Peyriere
Beatrice	Pham
Danh	Pham
Wendy	Pham
Ava	Phillips
Myet Chael	Phone
Jade	Phrty
Phoebe	Pierce
Molly	Pigot
Gyasi	Pigott
Chiara	Pilato
Jennifer	Pineda
Alberto	Pineda
Izayah	Pineda
Daniela	Plascencia Delgado
William	Pleasant
Xavier	Plourde
Emily	Poland
Caleb	Pollack
Neel	Polle
Pranav	Ponam
Graciela	Ponce
Lauren	Pong
Isabella	Porras
Letnel	Portillo
Samuel	Potter
Ethan	Preston
Georgiana	Prevost
Jemma	Prichard
Makayla	Propst

Elizabeth	Pugh	Aditya	Rajavelu
Ruben	Pulido	Shivani	Rajkumar
Vishal	Pulugurtha	Shriya	Ramdas
Kartik	Punia	Eduardo	Ramirez
Sapna	Puri	Isabella	Ramirez
Yash	Purohit	Jocelyn	Ramirez
Shane	Puthuparambil	Adam	Ramirez
Yushu	Qiu	Carlos	Ramirez
Patrici	Quaye	Juliana	Ramirez
Arella	Queirolo	Ashley	Ramirez
Martha	Quezada	Mayra	Ramirez
Nick	Quinlan	Galilea	Ramirez
Ariana	Quintana	Rodrigo	Ramirez-Perez
angela	Quintero	Jessica	Ramos
Cristina	Quintero	Varun	Rao
Francisco	Quiroga	Kenda	Rauscher
Jaymie	R	Julie	Ray
Shanmukh	Rachakunta	Presley	Rayon
Lea	Raha	Fizza	Raza
Abrar	Rahman	Safiyan	Razzak

Ryan	Read	Gavin	Richard
Edwardo	Realegen	Brazil	Richards
Kailey	Reardon	River	Richart
Stella	Recht	Joaquin	Richmond
Niahl	Reddy	Chloe	Richmond
Isabella	Reeves	alicia	rifkin
Allie	Rehm Kashaka	Priya	Riley
Ashley	Reilly	Thea	Rime
Trinity	Reimer	Stephanie	Rios
Vitto	Remick	Adolfo	Rios
Yixing	Ren	Ashly	Rivas
Xingying	Ren	Ryan	Rivas
Jake	Rengifo	Paris	Rivera
Mia	Revelle	Benjamin	Rivero
Lucy	Revina	Gerald	Roberts
Joely	Reyes	Sara	Robertson
Cristobal	Reyes	Chyna	Robeson
Maia	Reyes	Jonah	Robinson
Anali	Reyes Reyes	Phoenix	Robledo
Sarah	Ricci	Annabell	Robles

William	Roddy	Anshu	Rudraraju
Jennifer	Rodriguez	Kybeth	Ruiz
Sally	Rodriguez	Savanah	Ruiz
Alondra	Rodriguez	Jordan	Ruiz
Victoria	Rodriguez	Francis	Ruiz-marenco
Haley	Rodriguez	whitley	rummel
Arleen	Rodriguez	Preksha	Rungta
James	Rogers	Julien Michael	Ruppert
Lilia	Rohmann	Tristan	Ruppert
Maria	Rojas	Meena	Ruqaiya
Ilse	Rojo	Mahathi	Ryali
Nelitsa	Roman	Jewook	Ryu
Kristal	Roman	Jeongmin	Ryu
Rebecca	Romero	Misbah	S
Mariano	romero ochoa	Anthony	S
Romeo	Rong	Anchit	Sadana
Mayra	Rosales	Mekayla	Saechao
Cerys	Rotondo	Anna	Saez
Oliver	Rowe	Jacob	Saffarian
Wendy	Ruan	Najja	Saheli

CALPIRG Students
ACTION FOR A CHANGE

Teqhpreet	Sahni	Agnese	Sanavio
Hannah	Saib	Tatiana	Sanchez
Zara	Saif	Natalie	Sanchez
Samara	Saigal	Emily	Sanchez
Jackie	Sala	Lucero	Sanchez
Sabahun	Salam	Oscar	Sanchez
Cynthia	Salazar	Ryan	Sandan
Miguel	Salazar-Rivera	Mukt	Sandhu
Tania	Salceda	Michelle	Santiago
maricela	salcido	Rebeca	Santiago
ana	saldana	Angel	Santiago
Hayden	Salfen	Sofia	Santiago
Anthony	Salinas Suarez	Jacqueline	Santizo
Shantal	Saloma	Magaly	Santos
Michael	Salon	Tanya	Santos
Imaan	Saltan	Carolina	Santos-Paez
Michael	Samaha	Milla	Sapienza
Avik	Samanta	Amy	Saravia
melack	Samson	Sofia	Sarmiento
camilla	San Juan	Madeline	Sarvey

CALPIRG Students
ACTION FOR A CHANGE

Neha	Sathishkumar	Anish	Seshadri
Adhya	Satish	Shira	Shabtian
Cassidy	Saunar	Zaiyana	Shafqut
Alison	Savage Brooks	Afreen	Shah
Ichchitaa	Sawrika	Mira	Shah
Ichchitaa	Sawrikar	Atiya	Shah
Savannah	Sawyer	Anya	Shah
Aishani	Saxena	Adit	Shah
brianna	Schafheitle	Ishan	Shah
Zane	Schemmer	Noor	Shahkarami
Otto	Schmidt	Irah	Shaikh
Aanya	Schoetz	Sukniti	Sharma
Deleree	Schornack	Neha	Sharma
Shane	Schulte	Sukriti	Sharma
Isaac	Schultz	Satuik	Sharma
Antonia	Schwartz	Sankalp	Sharna
Lorenzo	Scotto Di Carlo	Devan	Shauber
Anna	Senjem	Jenny	Shaw
Sam	Seo	Michaela	Shaw
Tijmen	Sep	Ryan	Sheehan

Rohan	Shelke	Leila	Shook
Jordan	Shellow	debora	Shosh
Ty	Shelton	Khushi	Shrivastava
Connie	Shen	Sakshi	Shrivastava
Chenkun	Sheng	Samyurta	Shrivatsa
Kevin	sheny	Kelly	Shu
Arjun	Sheoran	Kexin	Shu
Annie	Sheoran	Millie	Shukla
Sunsaara	Shergill	Lincoln	Si Bansai
Anant	Sherwal	Odilia	Sianto
Viva	Sheth	Andres	Sibrian
Althea	Shi	Katie	Sie
Sotonyas	Shibre	Alison	Siebert
rhody	Shiel	Delaney	Siegmund
Ella	Shih	Amanpreet	Sihra
Joanne	Shin	Alisia	Silva
Parth	Shisode	Ricardo	Silva
Abi	Shiva	Jorge	Silva
Marissa	Shoji	Catalina	Silvestre
Maya	Sholia	Serah	Sim

CALPIRG Students ACTION FOR A CHANGE

Adaya	Simanian	Milla	Skowron
Safak	Simsek	Cal	Slatten
Arpine	Sinani	Merbel	Slothouwer
Jack	Singer	Megan	Slovatizki
stella	singer	John	Smif
Samiha	Singh	Anastasiaijh	Smirnova
Anindita	Singh	Alexander	Smith
Karm	Singh	Rachelle	Smith
sukhveer	singh	Alyssa	Smith
Harsimran	Singh	Deverin	Smith
Sahana	Singh	Aaron	Smith
Indianjit	Singh	Clio	Smith
Shreya	Singh	Mark	Smith
Triesha	Singh	Clara	So
Dilsher	singh	Klaire	Sobrepena
Patrick	Skat	Kristen	Sobschak
Talia	Skeen	tania	sodhi
Kelci	Skinner	Jairo	Sohwartz
Ronald	Skocypec	Vyalice	Sok
Annika	Skov	Jozelle	Solatorio

CALPIRG
Students
ACTION FOR A CHANGE

Adam	solorlaao	Amna	Steinberg
Dennis	Song	Christina	Steinmeier
Vivian	Song	Mateus	Stellet
Stephen	Song	Kayla Ann	Stephens
Shuxuan	Song	Kira	sterling
Ko	Songin	Milena	Stern
Isha	Soni	Brynne	Stevens
Noora	Soroushnejad	Adam	Stickney
Andrea	Soto	Jaden	Stillman
Christian	Sotomayor	Katelynn	Stinson
Matthew	Spankowski	Eva	Stolarz
Betina	Spiegal	Lucas	Stremba
Sara	Spinner	Ruby	Strickland
Domenico	Squillaro	Canon	Stringer
Katherine	Squire	Fe	Su
Tatteera	Srethbhakdi	Andrew	Su
Ramya	Sridhar	Berenisse	Suarez
Sarabaesh	Srikumar	Chloe	Suarez
Bryant	Srioudom	Shelsea	Suazo
ViviAnne	Steer	Natalie	Suboc

CALPIRG Students
ACTION FOR A CHANGE

Misha	suink	Karen	Tahuite
Romelio	Suliva III	Helvia	Taina
cassidy	sullivan	Alex	Tam
Manaal	Sultan	Olinha	Tan
Tiffany	Sun	Teddy	Tan
Yue	Sun	Hanze	Tan
Youjia	Sun	Cindy	Tang
Kavin	Suresh	Michelle	Tang
Sara	Susanto	Christa	Tang
Ayana	Sutton	Kalynna	Tang
William	Sutton	Keefe	Tankeh
Sitara	Swaroop	Vibha	Tantry
Hafsah	Syed	Michael	Tao
Nicholas	syphera	Emily	Tapia-Delgado
Jenny	Szu	Naomi	Tatarsky-Bridges
Ellena	Tabbal	Keri	Tate
Jessica	Tablante	Clara	Tawadrous
Maha	Tabrez	Alice	Taylor
Juliette	Tafoya	Reyna	Taylor
alvina	tahir	David	Teasue

CALPIRG Students ACTION FOR A CHANGE

Sundiata Chaka	Tellem	Ava	Ting
Myriam	Tellez	Artem	Tkachuk
Maria	Tello	Danial	Toktarbayev
Sophia	Teng	Maria	Toldi
Christian	Tepper	Kirsten	Tomas
Kaitlin	Thach	Beck	Tompkins
Muadh	Thaika	Ellen	Tong
Carrie	Thang	Grace	Toolsie
Mai Te	Thao	Crystal	Torres
Tavisha	Thapar	Leandro	Torres Mantilla
Saanvi	Thapliyal	Sienna	Totah
Jackie	Thibault	Michelle	Toyooka
Blake	Thomas	Isaac	Tragarz
Roy	Thommas	Man	Tran
Maya	Thompson	Triet	Tran
Tanvi	Thummala	mila	tran
Ananya	Thyagarajan	Bryan	Tran
Christian	Tibernard	Danny	Tran
Lola	Tieslau	Danielle	Tran
Chun Him	Tin	Albert	Tran

CALPIRG Students
ACTION FOR A CHANGE

Andrew	Tran	Anyssa	Underdue
Alice	Tran	Annette	Ungermann
Quan	Tran	Sinai	Urbano
Benjamin	Trefry	Eve	Uriarte
ELLA	TREINEN	salvador	uribe
Mariah	Trinity	Camryn	Uyesato
Citlali	Troncoso	Gladys	Valadez
Chayan	Tronson	Matthew	Valderrama
David	Truumees	Isabelle	Valdes
Amanda	Tsang	cynthia	valdez
Da Chien	Tsui	ysabelle clarice	valdez
Niko	Tsukino	Angel	Valdivia
Clara	Tu	Arely	Valencia
Brandon	Tu	Diana	Valenzuela
Emily	Tu	Katarina	Vallero
Alexander	Tung	Anahi	Valverde
Reese	Turner	Mara	Van Tussel
Aditya	Udgaonkar	Katie	Vanegas
Jordan	Ullman	Amanda	Vang
Lance	Ultsch	Andrew	Vang

CALPIRG Students ACTION FOR A CHANGE

daniela	vargas	Cinthia	Villalobos
Yuridia	Vargas Perez	Paola	Villanueva
Julian	Vargo	Amrita	Vinjamury
Marcus	Varni	Alex	Vitara
Erica	Varon	Samantha	Vitela
Ansh	Vashisth	Jocelyn	Vivaldo
Mercedes	Vasquez	Evelyn	Vo
Emelliah	Vaught	Ahana	Vora
Eric	Vazquez	Jean-Luc	Votichenko
Brandon	Vecchio	Michelle	Vuong
Justin	Vecchio	Kendall	Wade
Noemi	Vega	Tushita	Wadhawan
Aaron	Velasquez	luke	wagner
Kat	Velazquez	Hazel	Walia
Damaris	Velazquez	Arria	Walsh
Erick	Vergara	Natalie	Walzer
Sabreena	Verma	Madeleine	Wang
Shambhavi	Verma	Jace	Wang
Vamsi	Vetsa	James	Wang
Rafael	Villagomez	Shushan	Wang

CALPIRG Students
ACTION FOR A CHANGE

Fiona	Wang	Benjamin	Weinberger
Caitlin	Wang	elizabeth	weinstein
Ashley	Wang	Satyamuny	Weir
Perri	Wang	Bella	Weksler
Anderson	Wang	Miguel	Wences
Connie	Wang	Romina	Weng
Qin	Wang	Megan	Wesche
Mary	Wang	Amber	White
Chuck	Wang	Lauren	White
Alicia	Wang	Tai	White
Winnie	Wang	Doole	Wiener
Patrick	Wang	Sydney	Wiernicki
Yijnn	Wang	Charlie	Wigul
Taylor	Washington	Chelsea	Wijaya
Asbah	Wasim	Anna	Wilcox
Mia	Watanabe	Zofia	Wilk
Hannah	Weaver	Fella	Williams
Nimangie	Weerakoon	Maddie	Williams
Valevra	wehzwy	Chanel	Williams
Zixiao	Wei	Nyla	Williams

CALPIRG Students
ACTION FOR A CHANGE

Hayden	Willy	Luke	Wonzen
Malia	Wilson	Ruby	Woo
piper	wilson	Kimberly	Woo
Logan	Wilson	Emma	Wood
Imani	Wilson	Theodora	Worledge
Dylan	Wilson	Saman	Wright
Gia	Wirjawan	Wai Shuen	Wu
Karina	Wisen	Jessie	Wu
Yushao	Wo	Aaron	Wu
Camille	Woicekowski	Megan	Wu
Mathilde	Wokeveer	Aileen	Wu
William	Wolfe	Yiwen	Wu
Christina	Wong	Emma	Wu
Charlie	Wong	Emily	Wu
Katherine	Wong	Edward	Wu
Candace	Wong	Catherine	Wwang
Ana	Wong	Erin	Wynden
Anson	Wong	Theodore	Wyss-Flamm
Jade	Wong	Sophia	Xiau
napassorn	wongakkarakhun	Shiqi	Xie

Junyi	Xu	Jack	Yang
Kexin	Xu	Lanyi	Yang
Bradley	Xu	Vivian	Yang
Terry	Xu	Aldrich	Yanga
Scarlett	Xu	Olivia	Yanover
Mo	Xu	Jiahao	Yao
Xiaokang	Xue	Murtaza	Yar Hiraj
Yuning	Xue	Su	Yardimci
Emma	Yakutis	Sara	Yavas
catherine	yamasaki	Parker	Yazzie-Umberger
Akira	Yamashita	Yingshan	Ye
Roo	Yan	Yaoxing	Yi
Becks	Yang	Geena	Yin
Lily	Yang	Michael	Yin
Bryan	Yang	Nick	Ying
Joyce	Yang	Robin	Ying
Rachel	Yang	Eunice	Yoon
qi	yang	Andrea	Yoon
Shuran	Yang	Eva	You
Yifan	Yang	Audrey	Young

CALPIRG Students
ACTION FOR A CHANGE

Jason	Yu	Yongshi	Zhan
Michael	Yu	Haolin	Zhang
Gily	Yu	Katherine	Zhang
Zlyan	Yu	Maureen	Zhang
Xiaowen	Yuan	Zhiming	Zhang
Geraldine	Yue	Trista	Zhang
Natalie	Yun	Yumeng	Zhang
Ivan	Yun	Silin	Zhang
Berlin	Z	Alicin	Zhang
Felicia	Z	Xue Jie	Zhang
shauna	Zahabi	Sarah	Zhang
Griffin	Zajac	Elaine	Zhang
Lucia	Zamora Gonzalez	Pufan	Zhang
Eliana	Zapata	Hanzhe	Zhang
Addison	Zaring	Chibin	Zhang
Diego	Zavala	Cindy	Zhang
Mille	Zavala	Gefei	Zhang
diego	zevallos valdizan	Helen	Zhao
Kelly	Zhan	selena	Zhao
Wengi	Zhan	Alan	Zhao

CALPIRG Students
ACTION FOR A CHANGE

Anna	Zhao	Cosette	Zhou
Zihan	Zhao	Angela	Zhou
Micaal	Zhaque	David	Zhu
Ashley	Zheng	Leo	Zhuang
Athena	Zhong	Kristina	Zlatinova
Fenmiao	Zhong	Brianna	Zobler
Anthony	Zhou	Melinda	Zou
Elizabeth	Zhou	Owen	Zuidema
Melissa	Zhou	Wildfredo	Zuloaga

CALPIRG Students
ACTION FOR A CHANGE

87 Individuals in Photo Petitions

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG
Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students
ACTION FOR A CHANGE

CALPIRG Students

ACTION FOR A CHANGE

ORDINANCE NO. –N.S.

ADDING CHAPTER 11.62 TO THE BERKELEY MUNICIPAL CODE TO REGULATE PLASTICTHE USE OF CARRYOUT AND PRODUCE BAGS AT RETAIL AND FOOD SERVICE ESTABLISHMENTSAND PROMOTING THE USE OF REUSABLE BAGS

BE IT ORDAINED by the Council of the City of Berkeley as follows:

Section 1. That Chapter 11.62 of the Berkeley Municipal Code is added to read as follows:

Chapter 11.62

PLASTIC BAGS - RETAIL AND FOOD SERVICE ESTABLISHMENTSREGULATING THE USE OF CARRYOUT AND PRODUCE BAGS AND PROMOTING THE USE OF REUSABLE BAGS

Sections:

11.62.010 Findings and ~~Purpose~~purpose.

The Council of the City of Berkeley finds and declares as follows:

A. Single-use plastic bags~~, plastic produce bags,~~ and plastic ~~product~~produce bags are a ~~major~~significant contributor to street litter, ocean pollution, marine and other wildlife harm and greenhouse gas emissions.

B. The production, consumption and disposal of plastic based bags contribute significantly to the depletion of natural resources. Plastics in waterways and oceans break down into smaller pieces that are not biodegradable, and present a great harm to global environment.

C. Among other hazards, plastic debris attracts and concentrates ambient pollutants in seawater and freshwater, which can transfer to fish, other seafood and salt that is eventually sold for human consumption. Certain plastic bags can also contain microplastics that present a great harm to our seawater and freshwater life, which ~~implicitly~~indirectly presents a threat to human life.

D. It is in the interest of the health, safety and welfare of all who live, work and do business in the City that the amount of litter on public streets, parks and in other public places be reduced.

E. The City of Berkeley must eliminate solid waste at its source and maximize recycling and composting in accordance with its Zero Waste Goals. Reduction of plastic bag waste furthers this goal.

~~F.~~ The State of California ~~regulates~~and Alameda County Waste Management Authority both regulate single-use, paper, and reusable carryout bags ~~as directed~~respectively under ~~Senate Bill~~SB 270~~, but numerous local governments, including San Francisco and Palo Alto, have imposed more stringent regulations~~/Proposition 67 and Ordinance 2012-02 (as amended by Ordinance 2016-02). However, neither currently address problems related to ~~reduce the toll plastic bags inflict upon the environment.~~

~~G.~~F. ~~Stores often provide customers with plastic~~ pre-checkout bags to ~~package~~carry fruits, vegetables, and other loose or bulky items while shopping~~,~~ before reaching the checkout area. ~~They~~These bags, which are often plastic, share many of the same physical qualities as single-use plastic carryout bags no longer permitted in California, and are difficult to recycle ~~or~~, reuse or compost.

~~H.~~G. SB 270 ~~permits local governments to increase~~also does not regulate the price of bags provided at the point of sale by restaurants and ~~leaves open any regulation on pre-checkout~~streets events, including farmers' markets. While the County's Ordinance 2016-02 regulates restaurant carryout bags, ~~such as at meat or vegetable stands within grocery stores.~~it falls short of completely phasing out single-use film bags, and does not impose a meaningful point of sale charges for reusable and paper bags.

~~I.~~H. The City of Berkeley currently regulates a number of disposable plastic items through the Single-Use Foodware and Litter Reduction Ordinance (Ord. 7639-NS § 1 (part), 2019), but does not currently impose regulations ~~on~~with respect to bags. It is in the public interest to reduce plastic and paper waste in areas not preempted by the State of California.

~~J.~~I. This Chapter is consistent with the City of Berkeley's 2009 Climate Action Plan, the County of Alameda Integrated Waste Management Plan, as amended, and the

CalRecycle recycling and waste disposal regulations contained in Titles 14 and 27 of the California Code of Regulations.

11.62.20 Definitions.

~~"Checkout~~A. "Carryout Bag" means a bag provided ~~by a Retail Service Establishment~~ at the ~~checkstand~~check stand, cash register, point of sale or other ~~point of departure~~ location for the purpose of transporting food or merchandise out of ~~the establishment. Checkout~~a Covered Entity. Carryout Bags do not include Produce ~~Bags~~ or Product Bags.

~~"Recyclable Paper Checkout Bag"~~B. "Covered Entity" means ~~a paper bag that meets~~ any of the following ~~criteria:~~:

~~1. Contains no old growth fiber;~~
~~2. Is 100% recyclable overall and contains a minimum of 40% post-consumer recycled content;~~

~~Displays the word "Recyclable"~~(1) any restaurant, take-out food establishment or other business (including, but not limited to, food sales from vehicles or temporary facilities open to the public) that receives 90% or more of its revenue from the sale of prepared and ready-to-consume foods and/or drinks to the public and is not subject to the requirements of Public Resources Code Section 42281; and

(2) any event, or Person therein, requiring a street event permit pursuant to Berkeley Municipal Code 13.44.040 and not subject to the requirements of Public Resources Code Section 42281.

C. "Customer" means any Person obtaining goods from a Covered Entity or Grocery Store.

"Grocery Store" means a supermarket, grocery store, convenience food store, foodmart, or other entity engaged in the retail sale of goods that include perishable or nonperishable food items;

"Recycled Content Paper Bag" means either a Carryout Bag provided by a covered Entity or a Produce Bag provided by a Grocery Store that contains no old growth fiber and a minimum of one hundred percent (100%) postconsumer recycled material; is one hundred percent (100%) recyclable and compostable, consistent with the timeline and specifications of the American Society of Testing and Materials (ASTM) Standard D6400; and has printed in a highly visible manner on the outside of the bag ~~along with the~~ the words "Recyclable," the name and location of the manufacturer, and the percentage of postconsumer recycled content.

"Reusable Bag" means a bag with handles that is specifically designed and manufactured for multiple reuse and meets all of the following requirements:

(1) has a minimum lifetime of 125 uses, which for purposes of this subsection, means the capability of carrying a minimum of 22 pounds 125 times over a distance of at least 175 feet;

(2) has a minimum volume of 15 liters;

(3) is machine washable or is made from a material that can be cleaned or disinfected;

(4) does not contain lead, cadmium or any other heavy metal in toxic amounts, as defined by applicable state and federal standards and regulations for packaging or reusable bags;

3. (5) has printed on the bag, or on a tag that is permanently affixed to the bag, the name of the manufacturer, the location (country) where the bag was manufactured, a statement that the bag does not contain lead, cadmium, or any other heavy metal in toxic amounts, and the percentage of post-consumerpostconsumer recycled content in an easy-to-read size font;material used, if any; and

4. Or is made from alternative material or meets alternative standards approved by the City Manager or their designee.

“Reusable Checkout Bag” means all Checkout Bags defined as reusable under Cal. PRC §42280-42288, such as cloth or other washable woven bags, but do not include film bags considered reusable under Cal. PRC §42280-42288.

(6) is not primarily made of plastic film, regardless of thickness.
“Person” means an individual, firm, public or private corporation, limited liability company, partnership, industry or any other entity whatsoever.
"Produce Bag" means a bag provided to a customer to carry produce, meats, bulk food, or other food items to the point of sale inside a store and protects food or merchandise from being damaged or contaminated by other food or merchandise when items are placed together in a Reusable Checkout Bag or Recyclable Paper Checkout Bag.

"Compostable Produce Bags" means paper bags and bags made of plastic-like material if the material meets the ASTM Standard Specifications for compostability D6400 or D6868, or the product is Biodegradable Products Institute (BPI) certified, or is considered acceptable within the City’s compost collection program.

"Product Bag” means a bag provided to a customer to protect merchandise from being damaged or contaminated by other merchandise when items are placed together in a Reusable Checkout Bag or Recyclable Paper Checkout Bag; a bag"Product Bag” are bags that are integral to the packaging of the product; a bag provided to the Customer to hold prescription medication dispensed from a pharmacy; or a bag without handles that is designed to be placed over articles of clothing on a hanger.

“Retail Food Establishment” means any establishment, located or providing food within the City, which provides prepared and ready-to-consume food or beverages, for public consumption including but not limited to any Retail Service Establishment, eating and drinking service, takeout service, supermarket, delicatessen, restaurant, food vendor, sales outlet, shop, cafeteria, catering truck or vehicle, cart or other sidewalk or outdoor vendor or caterer which provides prepared and ready-to-consume food or beverages, for public consumption, whether open to the general public or limited to certain members of the public (e.g., company cafeteria for employees).

“Retail Service Establishment” means a for-profit or not-for-profit business that where goods, wares or merchandise or services are sold for any purpose other than resale in the regular course of business (BMC Chapter 9.04.135).

11.62.030 Types of Checkout Bags permitted at Retail Service and Food Service Establishments.

11.62.30 Retail Service Establishments and Food Service Establishments**Carryout Bag restrictions for Covered Entities.**

A. No Covered Entity shall provide or sell a Carryout Bag other than Recycled Content Paper Bags or Reusable Bags at the check stand, cash register, point of sale or other location to a Customer for the purpose of transporting food or merchandise out of such establishment or event.

B. A Covered Entity may provide or make available for sale to a customer onlyCustomer:

(1) Recycled Content Paper Bags at no charge;

(2) Reusable Bags for a minimum price of twenty-five cents ($0.25).

11.62.Checkout Bags, Compostable040 Produce Bags, or Recyclable Paper Checkout Bags for the purpose of carrying away goods orBag restrictions for Grocery Stores.

A. No Grocery Store or Covered Entity shall provide Produce Bags other materials from the point of sale, subject to the terms of this Chapter.

than Recycled Content Paper Bags and Reusable Bags.

Exception: Single-use plastic bags

11.62.050 General exemptions

1. A. Bags exempt from the Chapter include those integral to the packaging of the product, Product Bags, or bags sold in packages containing multiple bags intended for use as garbage, pet waste or yard waste bags.

B. Effective [ ], 2020, farmers markets shall only provide Compostable Produce Bags to hold produce, meats, bulk food or other food items. Single-use Plastic Checkout Bags, Produce Bags or Product Bags shall not be provided by farmers markets for produce or meat.

C. B. Nothing in this Chapter prohibits customers from using bags of any type that they bring to the establishment themselves or from carrying away goodsmerchandise or materials that are not placed in a bag at point of sale, in lieu of using bags provided by the establishment.

11.62.040 Checkout Bag charge for paper or Reusable Checkout Bags at Retail Service Establishments.

A. Effective [ ], 2020, no Retail Service Establishment shall provide a Compostable Produce Bag, Recyclable Paper Checkout Bag or Reusable Checkout Bag to a customer at the point of sale, unless the store charges the customer a Checkout Bag charge of at least twenty-five cents ($0.25) per bag to cover the costs of compliance with the Chapter, the actual costs of providing Recyclable Paper Checkout Bags, educational materials or other costs of promoting the use of Reusable Checkout Bags.

B. Retail Service Establishments shall establish a system for informing the customer of the charge required under this section prior to completing the transaction. This system can include store clerks inquiring whether customers who do not present their own Reusable Checkout Bag at point of checkout want to purchase a Checkout Bag.

C. The Checkout Bag charge shall be separately stated on the receipt provided to the customer at the time of sale and shall be identified as the Checkout Bag charge. Any other transaction fee charged by the Retail Service Establishment in relation to providing a Checkout Bag shall be identified separately from the checkout bag charge. The Checkout Bag charge may be completely retained by the Retail Service Establishment and used for public education and administrative enforcement costs.

D. Retail services establishments shall keep complete and accurate records of the number and dollar amount collected from Recyclable Paper Checkout Bags and Reusable Checkout Bags sold each month and provide specifications demonstrating that paper and reusable bags meet the standards set forth in Section 11.62.030 using either the electronic or paper reporting format required by the city. This information is required to be made available to city staff upon request up to three times annually and must be provided within seven days of request. Reporting false information, including information derived from incomplete or inaccurate records or documents, shall be a violation of the Chapter. Records submitted to the city must be signed by a responsible agent or officer of the establishment attesting that the information provided on the form is accurate and complete.

11.62.050 Use of Compostable Produce Bags at Retail Service Establishments.
Effective [ ], 2020, Retail Service Establishments shall only provide Compostable Produce Bags to carry produce, meats, bulk food, or other food items to point of sale within the store.

11.62.060 Hardship Exemption.
Undue hardship. exemption.

A. The City Manager, or their designee, may exempt a retail service or food service establishmentCovered Entity or Grocery Store from the requirements of this Chapter for a period of up to one year,[x months], upon sufficient evidence by the applicant that the provisions of this Chapter would cause undue hardship. An undue hardship exemption request must be submitted in writing to the cityCity. The phrase "undue hardship" may include, but is not limited to, the following:

   1. Situations where there are no acceptable alternatives to single-use plastic Checkout Bags for reasons which are unique to the Retail Service Establishment or Food Service Establishment.

2. (1) Situations where compliance with the requirements of this Chapter would deprive a person of a legally protected right.

B. Retail Service Establishments shall not enforce the ten cent ($0.25) store charge for customers participating in the California Special Supplemental Food Program for Women, Infants, and Children, or in CalFresh, or in the Supplemental Nutrition Assistance Program (SNAP).

11.62.070 11.62.070 City of Berkeley—purchases prohibited.
The City of Berkeley and any City-sponsored event shall only provide or make available to a Customer Recycled Content Paper Bags or Reusable Bags for the purpose of carrying away goods or other materials from the point of sale or event.

11.62.080 Duties, responsibilities and authority of the City of Berkeley.
The City Manager or their designee shall prescribe, adopt, and enforce rules and regulations relating to the administration and enforcement of this Chapter and is hereby authorized to take any and all actions reasonable and necessary to enforce this Chapter including, but not limited to, inspecting any Retail Service Establishment'sCovered Entity or Grocery Store's premises to verify compliance.

~~**11.62.080 City of Berkeley—purchases prohibited.**~~
~~The City of Berkeley shall not purchase any Foodware or Bag that is not Compostable, Recyclable or Reusable under Disposable Foodware and Bag Standards in Section 11.64.080, nor shall any City-sponsored event utilize non-compliant Disposable Foodware and Bag.~~

11.62.090 Liability and ~~Enforcement~~enforcement.

A. Anyone violating or failing to comply with any requirement of this Chapter may be subject to an Administrative Citation pursuant to Chapter 1.28 or charged with an infraction as set forth in Chapter 1.20 of the Berkeley Municipal Code; however, no administrative citation may be issued or infraction charged for violation of a requirement of this Chapter until one year after the effective date of such requirement.
B. Enforcement shall include written notice of noncompliance and a reasonable opportunity to correct or to demonstrate initiation of a request for a waiver or waivers pursuant to Section 11.~~64.090~~62.060.
C. The City Attorney may seek legal, injunctive, or other equitable relief to enforce this Chapter.
D. The remedies and penalties provided in this section are cumulative and not exclusive.

11.62.100 Severability.
If any word, phrase, sentence, part, section, subsection, or other portion of this Chapter, or any application thereof to any person or circumstance is declared void, unconstitutional, or invalid for any reason, then such word, phrase, sentence, part, section, subsection, or other portion, or the prescribed application thereof, shall be severable, and the remaining provisions of this Chapter, and all applications thereof, not having been declared void, unconstitutional or invalid, shall remain in full force and effect. The City Council hereby declares that it would have passed this title, and each section, subsection, sentence, clause and phrase thereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses or phrases had been declared invalid or unconstitutional.

11.62.110 Construction.
This Chapter is intended to be a proper exercise of the City's police power, to operate only upon its own officers, agents, employees and facilities and other persons acting within its boundaries, and not to regulate inter-city or interstate commerce. It shall be construed in accordance with that intent.

11.62.120 ~~Chapter supersedes existing laws and regulations~~Effective date.
~~The provisions of this Chapter shall supersede any conflicting law or regulations.~~

~~**11.62.130 Effective Date.**~~
The provisions in this ordinance are effective [ ], ~~2020~~2022.

Section 2. Copies of this Ordinance shall be posted for two days prior to adoption in the display case located near the walkway in front of the Maudelle Shirek Building, 2134 Martin Luther King Jr. Way. Within 15 days of adoption, copies of this Ordinance shall be filed at each branch of the Berkeley Public Library and the title shall be published in a newspaper of general circulation.

ORDINANCE NO. –N.S.

ADDING CHAPTER 11.62 TO THE BERKELEY MUNICIPAL CODE TO REGULATE THE USE OF CARRYOUT AND PRODUCE BAGS AND PROMOTING THE USE OF REUSABLE BAGS

BE IT ORDAINED by the Council of the City of Berkeley as follows:

Section 1. That Chapter 11.62 of the Berkeley Municipal Code is added to read as follows:

Chapter 11.62

REGULATING THE USE OF CARRYOUT AND PRODUCE BAGS AND PROMOTING THE USE OF REUSABLE BAGS

Sections:

11.62.010 Findings and purpose.
The Council of the City of Berkeley finds and declares as follows:

A. Single-use plastic bags and plastic produce bags are a significant contributor to street litter, ocean pollution, marine and other wildlife harm and greenhouse gas emissions.
B. The production, consumption and disposal of plastic based bags contribute significantly to the depletion of natural resources. Plastics in waterways and oceans break down into smaller pieces that are not biodegradable, and present a great harm to global environment.
C. Among other hazards, plastic debris attracts and concentrates ambient pollutants in seawater and freshwater, which can transfer to fish, other seafood and salt that is eventually sold for human consumption. Certain plastic bags can also contain microplastics that present a great harm to our seawater and freshwater life, which indirectly presents a threat to human life.
D. It is in the interest of the health, safety and welfare of all who live, work and do business in the City that the amount of litter on public streets, parks and in other public places be reduced.
E. The City of Berkeley must eliminate solid waste at its source and maximize recycling and composting in accordance with its Zero Waste Goals. Reduction of plastic bag waste furthers this goal.
F. The State of California and Alameda County Waste Management Authority both regulate single-use, paper, and reusable carryout bags respectively under SB 270/Proposition 67 and Ordinance 2012-02 (as amended by Ordinance 2016-02). However, neither currently address problems related to pre-checkout bags to carry fruits, vegetables, and other loose or bulky items while shopping before reaching the checkout area. These bags, which are often plastic, share many of the same physical qualities as single-use plastic carryout bags no longer permitted in California, and are difficult to recycle, reuse or compost.
G. SB 270 also does not regulate the price of bags provided at the point of sale by restaurants and streets events, including farmers' markets. While the County's Ordinance 2016-02 regulates restaurant carryout bags, it falls short of completely phasing out single-use film bags, and does not impose a meaningful point of sale charges for reusable and paper bags.
H. The City of Berkeley currently regulates a number of disposable plastic items through the Single-Use Foodware and Litter Reduction Ordinance (Ord. 7639-NS § 1 (part), 2019), but does not currently impose regulations with respect to bags. It is in the public interest to reduce plastic and paper waste in areas not preempted by the State of California.
I. This Chapter is consistent with the City of Berkeley's 2009 Climate Action Plan, the County of Alameda Integrated Waste Management Plan, as amended, and the CalRecycle recycling and waste disposal regulations contained in Titles 14 and 27 of the California Code of Regulations.

11.62.20 Definitions.
A. "Carryout Bag" means a bag provided at the check stand, cash register, point of sale or other location for the purpose of transporting food or merchandise out of a Covered Entity. Carryout Bags do not include Produce or Product Bags.
B. "Covered Entity" means any of the following:

(1) any restaurant, take-out food establishment or other business (including, but not limited to, food sales from vehicles or temporary facilities open to the public) that receives 90% or more of its revenue from the sale of prepared and ready-to-consume foods and/or drinks to the public and is not subject to the requirements of Public Resources Code Section 42281; and
(2) any event, or Person therein, requiring a street event permit pursuant to Berkeley Municipal Code 13.44.040 and not subject to the requirements of Public Resources Code Section 42281.
C. “Customer” means any Person obtaining goods from a Covered Entity or Grocery Store.
“Grocery Store” means a supermarket, grocery store, convenience food store, foodmart, or other entity engaged in the retail sale of goods that include perishable or nonperishable food items;
“Recycled Content Paper Bag” means either a Carryout Bag provided by a covered Entity or a Produce Bag provided by a Grocery Store that contains no old growth fiber and a minimum of one hundred percent (100%) postconsumer recycled material; is one hundred percent (100%) recyclable and compostable, consistent with the timeline and specifications of the American Society of Testing and Materials (ASTM) Standard D6400; and has printed in a highly visible manner on the outside of the bag the words “Recyclable,” the name and location of the manufacturer, and the percentage of postconsumer recycled content.
"Reusable Bag” means a bag with handles that is specifically designed and manufactured for multiple reuse and meets all of the following requirements:
(1) has a minimum lifetime of 125 uses, which for purposes of this subsection, means the capability of carrying a minimum of 22 pounds 125 times over a distance of at least 175 feet;
(2) has a minimum volume of 15 liters;
(3) is machine washable or is made from a material that can be cleaned or disinfected;
(4) does not contain lead, cadmium or any other heavy metal in toxic amounts, as defined by applicable state and federal standards and regulations for packaging or reusable bags;
(5) has printed on the bag, or on a tag that is permanently affixed to the bag, the name of the manufacturer, the location (country) where the bag was manufactured, a statement that the bag does not contain lead, cadmium, or any other heavy metal in toxic amounts, and the percentage of postconsumer recycled material used, if any; and
(6) is not primarily made of plastic film, regardless of thickness.
“Person” means an individual, firm, public or private corporation, limited liability company, partnership, industry or any other entity whatsoever.
"Produce Bag" means a bag provided to a customer to carry produce, meats, bulk food, or other food items to the point of sale inside a store and protects food or merchandise from being damaged or contaminated by other food or merchandise.
"Product Bag” are bags that are integral to the packaging of the product; a bag provided to the Customer to hold prescription medication dispensed from a pharmacy; or a bag without handles that is designed to be placed over articles of clothing on a hanger.

11.62.30 Carryout Bag restrictions for Covered Entities.

A. No Covered Entity shall provide or sell a Carryout Bag other than Recycled Content Paper Bags or Reusable Bags at the check stand, cash register, point of sale or other location to a Customer for the purpose of transporting food or merchandise out of such establishment or event.

B. A Covered Entity may provide or make available for sale to a Customer:
(1) Recycled Content Paper Bags at no charge;
(2) Reusable Bags for a minimum price of twenty-five cents ($0.25).

11.62.040 Produce Bag restrictions for Grocery Stores.
No Grocery Store or Covered Entity shall provide Produce Bags other than Recycled Content Paper Bags and Reusable Bags.

11.62.050 General exemptions
A. Bags exempt from the Chapter include Product Bags, or bags sold in packages containing multiple bags intended for use as garbage, pet waste or yard waste bags.
B. Nothing in this Chapter prohibits customers from using bags of any type that they bring to the establishment themselves or from carrying away merchandise or materials that are not placed in a bag at point of sale, in lieu of using bags provided by the establishment.

11.62.060 Undue hardship exemption.
A. The City Manager, or their designee, may exempt a Covered Entity or Grocery Store from the requirements of this Chapter for a period of up to [x months], upon sufficient evidence by the applicant that the provisions of this Chapter would cause undue hardship. An undue hardship exemption request must be submitted in writing to the City. The phrase "undue hardship" may include, but is not limited to, the following:
(1) Situations where compliance with the requirements of this Chapter would deprive a person of a legally protected right.

11.62.070 City of Berkeley—purchases prohibited.
The City of Berkeley and any City-sponsored event shall only provide or make available to a Customer Recycled Content Paper Bags or Reusable Bags for the purpose of carrying away goods or other materials from the point of sale or event.

11.62.080 Duties, responsibilities and authority of the City of Berkeley.
The City Manager or their designee shall prescribe, adopt, and enforce rules and regulations relating to the administration and enforcement of this Chapter and is hereby authorized to take any and all actions reasonable and necessary to enforce this Chapter including, but not limited to, inspecting any Covered Entity or Grocery Store's premises to verify compliance.

11.62.090 Liability and enforcement.
A. Anyone violating or failing to comply with any requirement of this Chapter may be subject to an Administrative Citation pursuant to Chapter 1.28 or charged with an infraction as set forth in Chapter 1.20 of the Berkeley Municipal Code; however, no administrative citation may be issued or infraction charged for violation of a requirement of this Chapter until one year after the effective date of such requirement.

B. Enforcement shall include written notice of noncompliance and a reasonable opportunity to correct or to demonstrate initiation of a request for a waiver or waivers pursuant to Section 11.62.060.
C. The City Attorney may seek legal, injunctive, or other equitable relief to enforce this Chapter.
D. The remedies and penalties provided in this section are cumulative and not exclusive.

11.62.100 Severability.
If any word, phrase, sentence, part, section, subsection, or other portion of this Chapter, or any application thereof to any person or circumstance is declared void, unconstitutional, or invalid for any reason, then such word, phrase, sentence, part, section, subsection, or other portion, or the prescribed application thereof, shall be severable, and the remaining provisions of this Chapter, and all applications thereof, not having been declared void, unconstitutional or invalid, shall remain in full force and effect. The City Council hereby declares that it would have passed this title, and each section, subsection, sentence, clause and phrase thereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses or phrases had been declared invalid or unconstitutional.

11.62.110 Construction.
This Chapter is intended to be a proper exercise of the City's police power, to operate only upon its own officers, agents, employees and facilities and other persons acting within its boundaries, and not to regulate inter-city or interstate commerce. It shall be construed in accordance with that intent.

11.62.120 Effective date.
The provisions in this ordinance are effective [ ], 2022.

Section 2. Copies of this Ordinance shall be posted for two days prior to adoption in the display case located near the walkway in front of the Maudelle Shirek Building, 2134 Martin Luther King Jr. Way. Within 15 days of adoption, copies of this Ordinance shall be filed at each branch of the Berkeley Public Library and the title shall be published in a newspaper of general circulation.

Kate Harrison
Councilmember District 4

ACTION CALENDAR
December 10, 2019

To: Honorable Mayor and Members of the City Council

From: Councilmembers Harrison and Hahn

Subject: Adopt an Ordinance Adding a Chapter 11.62 to the Berkeley Municipal Code to Regulate Plastic Bags at Retail and Food Service Establishments

RECOMMENDATION

Adopt an ordinance adding a Chapter 11.62 to the Berkeley Municipal Code to regulate plastic bags at retail and food service establishments.

BACKGROUND

Californians throw away 123,000 tons of plastic bags each year, and much of it finds its way into regional and international waterways.[1] The situation is only getting worse with 18 billion more pounds of plastic added to the already colossal amount in our seas.[2] Today, there are 100 million tons of trash in the North Pacific Subtropical Gyre;[3] in some parts, plastic outweighs plankton 6 to 1.[4]

Legislative action at the state level has been successful in achieving reductions in plastic bag pollution. According to the 2018 Change the Tide report, restrictions on plastic bags such as that in effect in California have resulted in a "steady drop" in plastic grocery bags found on California beaches. Berkeley has also recently made substantial progress on its restriction of plastic litter in the city through the Single Use Foodware and Litter Reduction ordinance (BMC Chapter 11.64).[5] The ordinance restricts food providers from offering take-out and dine-in food in single-use disposable ware. These items include "containers, bowls, plates, trays, cartons, boxes, pizza boxes, cups, utensils, straws, lids, sleeves, condiment containers, spill plugs, paper or foil wrappers, liners and any

---

[1] Environment California, "Keep Plastic Out of the Pacific," https://environmentcalifornia.org/programs/cae/keep-plastic-out-pacific.
[2] Division of Boating and Waterways, "The Changing Tide," http://dbw.parks.ca.gov/pages/28702/files/Changing%20Tide%20Summer%202018%20HQ%20(1).pdf.
[3] The North Pacific Gyre, also known as the North Pacific Subtropical Gyre, is a system of ocean currents that covers much of the northern Pacific Ocean. It stretches from California to Japan and contains the Great Pacific Trash Patch, or Pacific trash vortex. National Geographic, "Great Pacific Garbage Patch," https://www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/.
[4] Environment California, "Keep Plastic Out of the Pacific," https://environmentcalifornia.org/programs/cae/keep-plastic-out-pacific.
[5] Berkeley Municipal Code, Chapter 11.64 Single Use Foodware and Litter Reduction.

2180 Milvia Street, Berkeley, CA 94704 ● Tel: (510) 981-7140 ● TDD: (510) 981-6903 ● Fax: (510) 981-6903 E-Mail: KHarrison@cityofberkeley.info

other items used to hold, serve, eat, or drink Prepared Food."[6] Notably, plastic bags do not fall within the purview of the Single Use Foodware and Litter Reduction ordinance.

In order to take a further step in protecting the environment and reaching our zero waste goal, Berkeley must consider more aggressive action to close critical loopholes in state law with regard to plastic bags.

California currently prohibits the sale of plastic bags that fall into several categories, based on composition, intended use and business size and type. The statewide Single-Use Carryout Bag Ban prevents the sale of single-use plastic carryout bags in most large grocery stores, retail stores with a pharmacy, convenience stores, food marts, and liquor stores. Affected stores may offer reusable or recycled paper bags to a customer at the point of sale. Despite these restrictions, the law provides for the sale of plastic bags that are more than 2.25 mils thick in these stores, and exempts a number of key commercial establishments such as restaurants, general retailers, farmers markets, and other smaller businesses. State law also fully exempts plastic bags in grocery stores used for carrying produce from the shelf to the check stand.[7]

This proposed ordinance intends to expand the scope of existing regulation to further reduce plastic waste across these exempt categories, avoiding further destruction of the local, regional and global environment.

State Restrictions on Plastic Bags

California's legislature decided in 2014 to take a step to limit single-use plastic bag waste. Senate Bill 270 mandates that stores of a certain size and type offer only reusable bags at checkout and sets a minimum price of at least $0.10.[8] As a result, thin film bags, known as t-shirt bags, are no longer available at larger retail and grocery stores.

The scope of state regulation includes minimum percentage of post-consumer recycled plastics the bag most include and banning plastic bags deemed adequate for only one use. The state defines single-use plastic bags as thin film bags—bags made out of flexible sheets of plastic usually of polyethylene resin. Legislation often distinguishes between single-use film bags and reusable ones based on their thickness, measured in mils—1 thousandth of an inch.

The ban however does not apply to other types of plastic bags deemed reusable or to smaller retailers and restaurants. Many plastic film bags, in particular, are still permitted under SB 270. They are permitted for sale as long as: the bags contain more than 20%

---

[6] Berkeley Municipal Code Section 11.64.020D.

[7] Ban on Single-Use Carryout Bags (SB 270 / Proposition 67) Frequently Asked Questions, Office of the Attorney General and CalRecycle, April 2017, https://www.calrecycle.ca.gov/Plastics/CarryOutBags/FAQ/.

[8] California Legislature, Senate Bill 270, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201320140SB270

2180 Milvia Street, Berkeley, CA 94704 ● Tel: (510) 981-7140 ● TDD: (510) 981-6903 ● Fax: (510) 981-6903 E-Mail: KHarrison@cityofberkeley.info

post-consumer recycled material[9]; are recyclable in the state of California; are properly labeled as containing post-consumer recycled material; can carry over 22lb for a minimum of 175ft for at least 125 uses; and are at least 2.25 mils thick.

Despite the assumption of reusability, there is limited evidence to suggest that plastic bags are being repurposed to the degree accounted for by SB 270. Some studies suggest that fewer than 1% of people actually reuse the thicker and thus technically-reusable film bags.[10] This erroneous legislative assumption can be addressed at the local level.

Aside from SB 270, the only other legislation governing plastic bag usage in Berkeley is an Alameda County ordinance implementing SB 270 and local ordinances regulating the type of plastic allowed in food packaging.[11] By not addressing plastic produce bags and defining reusable bags as any film bag exceeding 2.25 mils, current regional and local law shares many of the shortcomings of state legislation.[12][13]

Local Restrictions on Plastic Bags

Contested but upheld in a 2016 ballot measure,[14] SB 270 set a statewide code that has been built upon by numerous local governments, including many in the Bay Area.

Palo Alto is one of the most recent cities to amend its municipal code and take the extra step in limiting the distribution of film bags. By splitting plastic bags into three categories by use—produce bags, checkout bags, and product bags—the city is able to differentiate regulation for each purpose. Its ordinance[15] bans grocery stores and farmers markets from packaging food in film bags, requiring instead the use of compostable plastics. For checkout, Palo Alto mandates that all stores only offer their customers recycled paper bags or reusable bags, a term it defines in accordance with California law as a bag thicker than 2.25 mils.

---

[9] In 2020, the percentage required will increase to 40% post-consumer recycled material.
[10] Save Our Shores, "Help Ban Plastic Bags," https://saveourshores.org/help-ban-plastic-bags/
[11] Alameda County Waste Management Authority, "Ordinance Regulating the use of carryout bags and promoting the use of reusable bags," http://reusablebagsac.org/acwma-ordinance-2012-2-amended-ordinance-2016-2.
[12] Berkeley Municipal Code Chapter 11.58 Prohibition of Chlorofluorocarbon-Processed Food Packaging, https://www.codepublishing.com/CA/Berkeley/cgi/NewSmartCompile.pl?path=Berkeley11/Berkeley1158/Berkeley1158.html.
[13] Berkeley Municipal Code Chapter 11.60 Polystyrene Foam, Degradable and Recyclable Food Packaging, https://www.codepublishing.com/CA/Berkeley/cgi/NewSmartCompile.pl?path=Berkeley11/Berkeley1160/Berkeley1160.html.
[14] Ballotpedia, "California Proposition 67, Plastic Bag Ban Veto Referendum (2016)," https://ballotpedia.org/California_Proposition_67,_Plastic_Bag_Ban_Veto_Referendum_(2016)
[15] Palo Alto Municipal Code, "Chapter 5.35 Retail and Food Service Establishment Checkout Bag Requirements," https://www.cityofpaloalto.org/civicax/filebank/documents/63550.

San Francisco has similar provisions.[16] It decided in July 2019[17] to both increase the amount of money charged for checkout bags from $0.10 to $0.25 and ban what it calls "pre-checkout bags"—defined as a "bag provided to a customer before the customer reaches the point of sale," nearly identical in definition to Palo Alto's produce bag language. San Francisco drew inspiration from Monterey, Pacifica, Santa Cruz and Los Altos, all of which charge more than SB270 requires for plastic bags.[18] The ordinance also specifically referenced an Irish law, which increased the price of plastic checkout bags from 15 cents to 22 cents, reducing plastic checkout usage by more than 95 percent, as precedent.[19]

Yet there are some cities that have gone even farther in their restriction of single-use plastics. Although Capitola does not ban produce/pre-checkout bags, it notably redefined the thickness of a reusable bag as equal or exceeding 4 mils, instead of 2.25 mils.[20] This means that any carryout bag provided by a retailer in the city is more durable than those considered multi-use by the state of California.

New York State recently introduced a plastic bag reduction ordinance that provides a number of precedents for a potential Berkeley ordinance. It bans "the provision of plastic carryout bags at any point of sale."[21] It exempts compostable bag and *non*-film plastic bags and does away with any distinction between reusable and non-reusable film bags based on their thickness. Where the New York ban falls short is in its regulation of non-checkout bags: bags for produce, meat, newspapers, take-out food and garments remain legal.

Given the progress many cities and states have made in regulating plastic bags, Berkeley has many examples to emulate.

Past Efforts in Berkeley

---

[16] San Francisco Municipal Code Chapter 17: Plastic Bag Reduction Ordinance, http://library.amlegal.com/nxt/gateway.dll/California/environment/chapter17plasticbagreductionordinance?f=templates$fn=default.htm$3.0$vid=amlegal:sanfrancisco_ca.

[17] San Francisco Municipal Code, "Ordinance amending the Environment Code," https://sfbos.org/sites/default/files/o0172-19.pdf.

[18] Isabela Agnus, "San Francisco bumps bag fee up to 25 cents," https://www.sfgate.com/news/article/SF-bumps-bag-fee-25-cents-plastic-produce-ban-14102908.php.

[19] Republic of Ireland Department of Communications, Climate Action & Environment, "Plastic Bags," https://www.dccae.gov.ie/en-ie/environment/topics/waste/litter/plastic-bags/Pages/default.aspx.

[20] Capitola Municipal Code Chapter 8.07: Single-use Plastic and Paper Carryout Bag Reduction, https://www.codepublishing.com/CA/Capitola/#!/Capitola08/Capitola0807.html#8.07.

[21] New York State Governor's Office, "An act to amend the environmental conservation law, in relation to prohibiting plastic carryout bags," https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/PlasticBagBan.pdf.

Berkeley attempted to pass its own plastic bag ban in 2010.[22] In the years following councilmembers have pushed for reform, calling for an ordinance to improve upon county and state legislation.[23] Yet the threat of lawsuits[24] and movement on the state and county level appear to have delayed local reform.

The Proposed Ordinance

This proposed ordinance picks up where prior attempts failed, bringing Berkeley on par with many of its neighbors in tightening restrictions on plastic bag sales. On some points, this ordinance ensures that the City again becomes a leader in environmental regulation. The following details the key changes that close loopholes in state and local law:

- Plastic bag regulations would now apply to a number of retail service establishments previously omitted from the state ban. Restaurants and food vendors would no longer be able to distribute single-use plastic carryout bags. Grocery stores and other retailers selling prepared food would be required to move away from single-use plastic produce bags.

- Retail service establishments of all sizes would be included, closing exemptions for smaller stores.

- Reusable plastic bags would be redefined as non-film plastic bags, adjusting the criteria to more accurately reflect common perceptions of reusability and the tendency for consumers treat all film bags as disposable, regardless of thickness.

- The price per non-plastic bag increases from $0.10 to $.25, to avoid a substitution effect.

The most common concern in reducing plastic bag waste is that the alternatives are even less sustainable. Substituting paper bags for plastic could be equally, if not more, hazardous for the environment because of the energy, transport and disposal processes required.[25] Cloth bags are also imperfect options, because of the large amount of energy and water necessary to produce them.[26] The California ban on bags thinner than 2.25

---

[22] Berkeley City Council, "Berkeley Bag Reduction Ordinance," https://www.cityofberkeley.info/uploadedFiles/Public_Works/Level_3_-_Solid_Waste/BagReductionDraftOrdinance.100316.pdf.

[23] Kriss Worthington, "Adopt Expanded Single Use Plastic Bag Ban/Paper Bag Fee Ordinance," https://www.cityofberkeley.info/uploadedFiles/Clerk/Level_3_-_City_Council/2012/01Jan/2012-01-31_Item_25_Adopt_Expanded_Single_Use_Plastic_Bag.pdf.

[24] Doug Oakley, "Berkeley's plan for plastic bag ban part of larger movement," https://www.mercurynews.com/2009/12/23/berkeleys-plan-for-plastic-bag-ban-part-of-larger-movement/.

[25] The Environmental Literacy Council, "Paper or Plastic?" https://enviroliteracy.org/environment-society/life-cycle-analysis/paper-or-plastic/.

[26] Patrick Barkham, "Paper bags or plastic bags: which are best?" https://www.theguardian.com/environment/shortcuts/2011/dec/20/paper-plastic-bags-which-best.

mils may also have resulted in a substitution toward thicker and less sustainable film bags.[27] Moreover, international studies confirm that even single-use bags are reused to a limited degree for other household functions, such as garbage disposal or to pick up dog feces.[28] A University of Sydney economist found that garbage bag consumption increased when California placed restrictions on single-use plastic bags, likely because consumers no longer had as many free single-use film bags at hand in which to dispose their waste. Yet that same study also concluded that the benefits of the ban were still significant: Californians consumed 28 million pounds fewer plastic than they did before.[29]

Still, eliminating plastic bags cannot be the only approach to combat the cycle of consumer waste. It must come, as this ordinance would ensure, in combination with higher prices and greater requirements for the percentage of recycled content in paper bags. Any paper bags sold in Berkeley must per this resolution contain no old growth fiber, be 100% recyclable overall and contain a minimum of 40% post-consumer recycled content.

Data from Alameda County as a whole seems to indicate that when the cost of single-use paper bags was set at $0.10, consumption *decreased* by approximately 40% within three years.[30] The same report revealed that "plastic bags found in storm drains decreased by 44 percent, indicating that the ordinance has been successful in reducing single use plastic bag litter." Further price increases have been shown to realize even larger benefits.

FISCAL IMPLICATIONS

Staff or contractor costs for the launch, for outreach and education, enforcement, administration and analysis.

ENVIRONMENTAL SUSTAINABILITY

Reducing the amount of discarded plastic bags—previously classified as multi-use—in the city of Berkeley will result in less over all waste and fewer plastic that makes it into local and regional waterways.

---

[27] Christian Britschgi, "California Plastic Bag Bans Spur 120 Percent Increase in Sales of Thicker Plastic Garbage Bags," https://reason.com/2019/04/11/california-plastic-bag-bans-spur-120-per/.

[28] NPR Planet Money, "Are Plastic Bag Bans Garbage?" https://www.npr.org/sections/money/2019/04/09/711181385/are-plastic-bag-bans-garbage.

[29] Rebecca L.C. Taylor, "Bag leakage: The effect of disposable carryout bag regulations on unregulated bags," https://www.sciencedirect.com/science/article/pii/S0095069618305291.

[30] Alamda County Waste Management Authority, "Addendum to the Final Environmental Impact Report Mandatory Recycling and Single Use Bag Reduction Ordinances," http://reusablebagsac.org/resources/addendum-final-environmental-impact-report-2016.

Furthermore, a switch toward bags made from polyester or plastics like polypropylene, which are more sustainable than film bags and sold at many grocery stores will lead to greater environmental sustainability.[31]

CONTACT PERSON

Councilmember Kate Harrison, Council District 4, (510) 981-7140

[31] Claire Thompson, "Paper, Plastic or Reusable?" https://stanfordmag.org/contents/paper-plastic-or-reusable?utm_source=npr_newsletter&utm_medium=email&utm_content=20190408&utm_campaign=money&utm_term=nprnews.

06

Energy Commission

CONSENT CALENDAR
April 12, 2022

To: Honorable Mayor and Members of the City Council

From: Berkeley Energy Commission

Submitted by: Bentham Paulos, Chairperson, Energy Commission

Subject: Referral Response: Community Outreach and Education Events on Proposed Regulations for the Use of Carryout and Pre-checkout Bags

RECOMMENDATION
The Energy Commission recommends that the City Council refer this matter to the forthcoming Commission on Climate and the Environment Commission, once it is established. The Energy Commission also recommends that the City Council first allocate and appropriate funding for City staff and local community partners to conduct due diligence and analysis regarding the proposed ordinance, and consider funding a pilot project with a large grocery venue.

SUMMARY
The Energy Commission discussed and considered Council's referral to conduct community outreach and education events regarding the proposed ordinance regulating the use of plastic carryout and pre-checkout bags. We support the City of Berkeley's zero waste and fossil fuel free goals, and recommend that Council consider referring this matter to the forthcoming Commission on Climate and the Environment Commission, once it is established. Due to the imminent disbanding of the Energy Commission, it is not able to administer a robust public consultation process at this time regarding this important proposed ordinance on reducing plastic pollution stemming from single-use plastic bags. The Energy Commission also recommends that Berkeley City Council first allocate and appropriate funding for City staff and local community partners to conduct due diligence and analysis regarding the proposed ordinance, and consider funding a pilot project with a large grocery venue.

FISCAL IMPACTS OF RECOMMENDATION
There are no fiscal impacts to this recommendation. If a robust public consultation process is eventually pursued, there could be costs for the staff time, consultants, stakeholder engagement, and/or public events associated with implementing such a consultation process.

CURRENT SITUATION AND ITS EFFECTS

The Energy Commission recognizes that the negative environmental and health impacts from the extraction of fossil fuels for the production, use, and disposal of plastic bags are substantial. We also applaud the City of Berkeley, its residents and local businesses, and our innovative community organizations, for the collective leadership that has been demonstrated over decades on pioneering zero waste initiatives, from banning Styrofoam to curbside recycling and composting and the 2019 ban on single-use disposable plastic foodware and packaging.[1] We also recognize that there are gaps in existing regulations governing plastic carryout and pre-checkout bags, which the proposed ordinance strives to address.

Our understanding of the current context for achieving waste reduction goals in the City of Berkeley are that the priorities are: (1) implementing and complying with SB 1383, the State of California's law to reduce short-lived climate pollutants that requires substantial reductions and diversions of organic waste going to the landfill with regulations going into effect in January 2022; (2) compliance with existing State diversion laws AB 341 and AB 1826; and (3) implementing and complying with the existing ordinance on single-use foodware and litter reduction.

In addition, the Energy Commission's discussion of this Referral at the October 27, 2021 Commission meeting was in the context of our Commission's proposed consolidation with other City Commissions and a requested completion date of said public process by December 31, 2021. While the deadline was later clarified as a target, not a requirement, the Energy Commission still faced consolidation resulting in uncertainty in our membership, expertise, and timeframe for taking on significant new responsibilities.

At its meeting of February 23, 2022, the Energy Commission voted to send this recommendation to the City Council by a vote of 5-0-1-1 [Moved (Paulos), Second (Guliasi), Ayes (Paulos, Wolf, Moore, Guliasi, Zuckerman), Nays (none), Abstain (Tahara), Recused (de Tournay Birkhahn)].

BACKGROUND

In 2018, the Zero Waste Commission led community outreach, education, and input-gathering events for the proposed single-use disposable foodware ordinance. The ZWC designed a robust public process, holding three extended comment periods at Commission meetings, three public physical informational presentation sessions, and collected comments from over 60 restaurateurs, environmental advocates, members of the people with disabilities communities, and other community members. The process was supported by City staff, outside consultants and The Ecology Center. There was substantial due diligence and a timeline of approximately eight months. The ordinance

1 https://www.cityofberkeley.info/Public_Works/Zero_Waste/Berkeley_Single_Use_Foodware_and_Litter_Reduction_Ordinance.aspx

was complex and touched numerous types of stakeholders, as the process was designed to get input from the full range of affected stakeholders and the general Berkeley public.

On September 14, 2021, City Council approved a referral to the Zero Waste and Energy Commission (or Successor Commission) to Hold Joint Meetings to Conduct Community Outreach and Education Events with Regard to the Proposed Ordinance Regulating the Use of Carryout and Pre-checkout Bags and to Make Recommendations to the Facilities, Infrastructure, Transportation, Environment & Sustainability (FITES) Committee. The proposed ordinance to regulate the use of carryout and pre-checkout bags and promote the use of reusable bags is similarly complex. The Energy Commission does not believe that we have the necessary expertise, resources, or initial due diligence and analysis to design a public consultation process as robust as necessary in the time left before the Energy Commission disbands and consolidates into the new Commission on Climate and the Environment.

The Energy Commission recommends that Berkeley City Council allocate and appropriate funding for City staff and local community partners like the Ecology Center to conduct due diligence and analysis regarding the proposed ordinance on issues including: jurisdiction and administration of the ordinance (which City departments have jurisdiction, and how does this relate to Alameda County bag ordinances); the number of type of stakeholders that would be affected by this ordinance and need to be included in the consultation process; City staff enforcement needs for the new ordinance; progress to-date on implementation and compliance with existing laws and ordinances like SB 1383, AB 341, AB 1826 and the SUDS ordinance; and how the new ordinance fits with other Zero Waste goals, priorities, and diversion rates, among other issues. A pilot demonstration project with a large grocery venue is a potential option.

ENVIRONMENTAL SUSTAINABILITY

The Energy Commission recognizes that plastic pollution from plastic bags will definitely need to be addressed for Berkeley to meet its Zero Waste and Fossil Fuel Free city goals.

RATIONALE FOR RECOMMENDATION

At the time the Referral was considered – in the face of the City's proposal to merge the Zero Waste, Energy, Community Environmental Advisory and Animal Care Commissions – the Energy Commission concluded that our Commission could not responsibly commit to undertaking a robust public outreach process because the Commission did not have the time, the staff or financial resources, the zero waste expertise on the Commission, or the preliminary due diligence and analysis of affected stakeholders and City department jurisdictions.

ALTERNATIVE ACTIONS CONSIDERED

The Energy Commission considered doing a minimal virtual and online public consultation process. We decided it was not feasible to conduct such a process before the December 2021 winter holidays and get any reasonable level of engagement from affected businesses. In addition, we did not think that a minimal or rushed process was advisable given the complexity of the issues involving a wide range of stakeholders and businesses in Berkeley.

CITY MANAGER
The City Manager takes no position the content and recommendations of the Commission's Report.

CONTACT PERSON
Billi Romain, Manager, Office of Energy & Sustainable Development – Planning Department, 510-981-9732