Fostering the Use of Zero and Near Zero Emission Vehicles in Freight Operations

July 2020

A Research Report from the National Center for Sustainable Transportation

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16. Abstract
California is in the midst of improving its freight system. For example, the California Sustainable Freight Action Plan (CSFAP) established the goal of reaching a 25% increase in freight efficiency, the use of 100,000 zero emission vehicles and equipment (and maximize the number of near zero emission vehicles) in the system, and improving economic competitiveness. Although there are multiple strategies and approaches to help achieve these goals, this study focuses on analyzing the factors to foster the adoption of zero and near-zero emission vehicles. For example, the use of monetary and non-monetary incentives to elucidate behavioral changes (e.g., fleet purchase decisions). This study considered compressed (renewable) natural gas (CNG/RNG), hybrid electric (HE), battery electric (BE) and fuel-cell hydrogen (H2) vehicles. The research team collected information through a web-based stated preference survey sent (in two waves) to fleets and carrier companies to gather data about their economics, and their vehicle purchase preferences. However, the response rate was very small which limited the type of analyses conducted with the data. Alternatively, the study team developed a multi-criteria decision-making tool using a Spherical Fuzzy Analytical Hierarchy Process based on experts' knowledge. The approach considered the variability in the technical and operational characteristics, market readiness, and other factors related to these technologies. The model helped provides insights about the most appropriate options for different uses (e.g., last mile, long-haul distribution). Specifically, the authors evaluate the alternatives using five criteria: economic; business, incentives & market-related; environmental & regulatory; infrastructure; and safety & vehicle performance factors. The analyses also consider twenty-one sub-criteria, e.g., total cost of ownership, payback period, brand image, financial & non-financial incentives, and public/private fueling/ charging infrastructure availability.

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July 2020

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Fostering the Use of Zero and Near Zero Emission Vehicles in Freight Operations

EXECUTIVE SUMMARY

California has put forward a number of goals to improve freight efficiency through the introduction and use of zero and near-zero emission vehicles. However, the technical and operational characteristics, market readiness, and other factors related to these technologies can be very different. Therefore, the most appropriate option for different uses (e.g., last mile, long-haul distribution) and users' preferences is not necessarily clear. This study focused on analyzing the factors to foster the adoption of zero and near-zero emission vehicles. Building on previous analyses that showed that besides the intensity of use of the vehicles, purchase price, and maintenance and operational costs, different types of incentives (monetary and non-monetary) could be a determinant factor to foster their adoption and use. Therefore, it is important to understand the behaviors and attitudes of freight stakeholders to define adequate incentives programs.

This study explored different incentives programs in California and reviewed the literature to identify other potential types of incentives to foster a change. Based on the review, the team developed a stated preference survey to collect information from fleets and carrier companies about their economics, and their vehicle purchase preferences, and to test their behavioral perceptions towards those types of incentives. The team deployed the survey in two different waves targeting, first the members of the largest transportation association in California, and second, to a sample of carrier companies. However, the response rate was very small which limited the type of analyses that could be conducted with the data. Alternatively, the team developed a multi-criteria decision making (MCDM) tool using a Spherical Fuzzy Analytical Hierarchy Process based on experts' knowledge. The model provides insights about the most appropriate options for different uses (e.g., last mile, long-haul distribution). This study considered diesel, compressed (renewable) natural gas (CNG/RNG), hybrid electric (HE), battery electric (BE) and fuel-cell hydrogen (H2) vehicles. The model evaluates the alternatives using five criteria: economic; business, incentives & market-related; environmental & regulatory; infrastructure; and safety & vehicle performance factors. It also considers twenty-one sub-criteria, e.g., total cost of ownership, payback period, brand image, financial & non-financial incentives, and public/private fueling/ charging infrastructure availability.

The study highlighted a number of important considerations for study development and for the analysis of incentive programs.

Data collection. The study evidenced challenges in collecting behavioral data from businesses and fleets. More importantly, the data collection effort was conducted during a period where one of the major regulatory agencies was in the midst of developing the ACT Program, which will have tremendous implications for vehicle manufactures and fleets (small and large). Other ongoing studies in related areas during the same period experienced similar challenges. The

California Vehicle Inventory User Survey (CalVIUS) is an exception; however, this survey required very large budgets and resources (of orders of magnitude larger than the current study).

Companies perceptions towards Zero-emission vehicles. The small sample showed that companies are not necessarily interested in zero emission vehicles, and for the next vehicle purchase the preferred alternative are still diesel vehicles. The results of the MCDM based on expert judgments exhibited similar patterns, with Diesel vehicles being the key alternative.

Incentives and other vehicle purchase determinant factors. The responses showed that companies, for the most part, are not aware of the various incentives programs available to renew their fleets. Both the sample and the MCDM show that economic and financial factors are the most important factors when making purchase decisions, while environmental and regulatory having less importance. However, the results show that there is an acknowledgement that under a stricter environmental regulatory environment the preferred choices are battery electric and fuel cell vehicles. The MCDM indicated that availability of maintenance and repair shops, and depot charging/fueling infrastructure are also critical factors, even more so than fueling and charging times.

Considering that the preferred alternative are diesel vehicles, incentives do not seem to affect much the ultimate choice. For these vehicles, there are no incentives. If non-financial incentives are to be used, they have a relative weight to be about 25% lower than for financial incentives.

Overall, these results show on one hand the challenges to foster the use of zero emission vehicles, where the CCR values are almost half than for the preferred alternative. On the other hand, well-structured regulatory programs that incentivize environmental metrics, promote the technologies and support industries (repair, charging infrastructure) can have a positive impact over vehicle choices.

I. Introduction

The California Sustainable Freight Action Plan (CSFAP) published in July 2016, provides a framework to address three main targets: improve 25% freight system efficiency and transition to zero emission vehicles by 2030, and increase competitiveness and economic growth. To achieve these goals, multiple components must align in both technological and operational improvements at different stages in the freight system (short- to long-haul transport). In the last mile for instance, there is increased pressure to deliver products to consumers and residences in short time windows, which has increased the flow of vehicle to urban areas. Similarly, the growth in consumption has increased the number of vehicle miles traveled by heavy-duty trucks. Although there are multiple strategies and approaches to improve the system and achieve State goals, one critical alternative is fostering the use of zero and near-zero emission vehicles. However, the technical and operational characteristics, market readiness, and other factors related to these technologies can be very different. Therefore, the most appropriate option for different uses (e.g., last mile, long-haul distribution) and users' preferences is not necessarily clear. Consequently, this study focuses on analyzing the factors to foster the adoption of zero and near-zero emission vehicles. Previous analyses have shown that besides the intensity of use of the vehicles (e.g., yearly mileage, and duty cycles), purchase price, maintenance and operational costs, different types of incentives could be a determinant factor to foster their adoption and use (Jaller et al., 2018). Specifically, monetary and non-monetary incentives to elucidate behavioral change (e.g., fleet purchase decisions). Moreover, a better understanding of the behaviors and attitudes of freight stakeholders will help define adequate incentives that can promote an operational efficiency improvement along with the deployment of ZEVs.

In California, for example, there are a number of incentives programs such as the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) (CARB and CALTRANS, 2018), the Alternative Fuel and Vehicle Incentives, Emission Reduction Grants, Natural Gas Vehicle Incentives, and Advanced Transportation Tax Exclusion to name a few. And while more than 3,500 trucks have been replaced taking advantage of HVIP, for example, they are just a small fraction of the vehicle operating in the State. With the Advanced Clear Truck (ACT) Program from the California Air Resources Board, vehicle manufactures will have to sell a significant share of zero emission vehicles. ACT will provide market ready choices and alternatives for the fleets but there are concerns about the continuation and availability of monetary incentives to fleets, when ACT is expanded to mandate fleet adoption. Therefore, exploring incentives, beyond those of a financial nature, is critical.

Consequently, this study explored different incentives programs in California and reviews the literature to identify other potential types of incentives to foster a change. Based on the review, the team developed a stated preference survey to collect information from fleets and carrier companies about their economics, and their vehicle purchase preferences. More importantly, to test their behavioral perceptions towards those types of incentives. The team deployed the survey in two different waves targeting, first the members of the largest transportation association in California, and second, to a sample of carrier companies (company contact and information purchased from a commercial data aggregator). However, the response rate was very small which limited the type of analyses that could be conducted with the data. Alternatively, the team developed a multi-criteria decision making (MCDM) tool using a Spherical Fuzzy Analytical Hierarchy Process based on experts' knowledge. MCDM tools have been extensively used in many applications and the different techniques provide a compromise with respect to the process uncertainties, the experts' expertise, and other instrumental issues.

In this work, the authors considered the variability in the technical and operational characteristics, market readiness, and other factors related to these technologies. The model provides insights about the most appropriate options for different uses (e.g., last mile, long-haul distribution). This study considered compressed (renewable) natural gas (CNG/RNG), hybrid electric (HE), battery electric (BE) and fuel-cell hydrogen (H2) vehicles. The model evaluates the alternatives using five criteria: economic; business, incentives & market-related; environmental & regulatory; infrastructure; and safety & vehicle performance factors. And consider twenty-one sub-criteria, e.g., total cost of ownership, payback period, brand image, financial & non-financial incentives, and public/private fueling/ charging infrastructure availability.

The remaining of the document is organized as follows. Section II (Background) provides a succinct review of the literature regarding the evaluation of zero emission alternatives, and reviews the types of incentives programs in California. Section III describes the overall methodology and discusses the development of the survey instruments. Section IV shows empirical results. The document ends with a conclusions and discussions section (V).

II. Technologies and Incentives

New Vehicle Technology Adoption

There are some studies in the literature that carry out an evaluation of the adoption of alternative technologies in medium (MDV) and heavy duty (HDV) vehicles but many of them provide outdated data. There is a lack of current information about operational costs and purchase decision processes of commercial fleets, mainly due to the high competitive environment of the freight trucking industry that does not provide much of this “sensitive” information. Another reason is the fact that most fleet operators are small owners that may not have advanced processes to capture all costs and lack financial opportunities.

Pelletier et al. (2014), for example, developed a survey paper to capture the international context of electric vehicles and their potential in the goods distribution. The study incorporates a market penetration analysis of such vehicles and discusses the conditions that make them cost effective compared to conventional diesel vehicles (e.g., financial and non-financial incentives). Klemick et al. (2015) also provide useful information about focus groups and interviews in the HDV sector and the energy efficiency paradox of adopting more sustainable technologies due to the high upfront costs of these technologies compared to the conventional ones. They point out relevant discrepancies among owners and drivers where incentives may have a different impact. An overall evaluation of the operations, costs, purchase process (some truck attributes are preferred), technologies information, and risk aversion of new technologies due to their reliability, among other factors.

Miller et al. (2017) use freight data and develop a truck purchase decision choice model to better understand how California’s fleets will transition to low carbon technologies and fuels, especially zero-emission technologies such as electric and fuel cell trucks. They consider vehicle/technology performance, vehicle capital and operating costs, mileage and performance requirements, and other important purchase decision factors for different types of trucks and fleets. Jaller et al. (2018), using data from the Fleet DNA Project Data from the National Renewable Energy Laboratory (NREL) conducted an extensive study of the total cost of ownership for different vehicle classes in last mile delivery vocations. Moreover, they performed sensitivity analyses to understand the impact of different cost components in the overall cost.

Overall, there are some common factors that affect the adoption of ZEVs: technology reliability concerns, range, drivers training, upfront purchase costs, lack of information about new technologies and incentives programs, lack of charging infrastructure and cost, very competitive market that reduces taking risks with new technologies, and not that many ZEVs in the market. In general, large fleets and companies are the ones trying new technology and implementing pilots but small operators are still behind.

Although the technical specifications of the vehicles could fit the requirements for specific vocations, there are still other issues related to price, infrastructure, behaviors (range anxiety), and support, among others that hamper the adoption of such vehicles (Davis and Figliozzi, 2013; Feng and Figliozzi, 2012). To mitigate some of those issues, there are several financial based incentives available, some of which target the vehicle manufacturers, while others target the fleets.

Incentives and Regulations

The Department of Energy provides an updated inventory of the various programs throughout the nation[1]. Concentrating in California, the State has implemented several laws & regulations, and programs that provide financial incentives to adopt better and cleaner vehicles. The reader is referred to Table 13 thru Table 15 in Appendix A for a list of the various incentives. Moreover, Figure 1 shows examples from various incentive programs (California Air Resource Board, 2019), and additional information is provided CARB in the Advanced Clean Truck (ACT) Program's website[2].

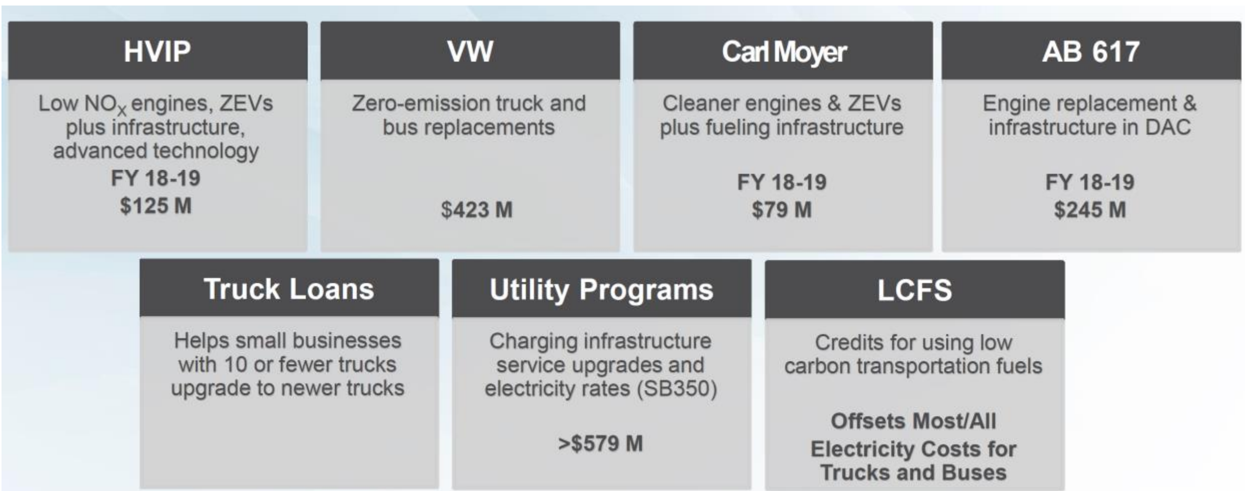

Figure 1. Incentive programs available in California (California Air Resource Board, 2019)

Among these programs, the Low Carbon Fuel Standard (LCFS)[3] is a measure to reduce GHG emissions in the California, and allows fleets that use clean low-carbon fuels in the State to sell their credits to regulated agents (fuel providers) that need them to comply with their carbon intensity target. The LCFS also provides battery electric credit values to electric vehicle supply equipment (EVSE) owners in the range of $.1/kWh to $.16/kWh depending on the vehicle classes (assuming a LCFS credit price of $125 per credit).

The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) (CARB and CALTRANS, 2018) is another program where incentives (vouchers) are directly offered by truck dealers to purchase eligible technologies: battery-electric, fuel cell, hybrid, electric power take-off (ePTO) and ultra-low NOx natural gas engines. Vouchers levels vary according to the

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[1] https://afdc.energy.gov/laws/state_summary?state=CA
[2] https://ww2.arb.ca.gov/our-work/topics/incentives
[3] https://www.arb.ca.gov/fuels/lcfs/background/basics-notes.pdf

technology, they can go from 2,500 to 100,000 USD where battery-electric trucks have the highest incentive amount. So far more than 3,500 trucks have been acquired through the HVIP and it will continue to offer these incentives. Including EVSE incentives, HVIP has provided about $300 million since 2009 (Table 1). Similarly, Table 2 shows the amount distributed for different vocations.

Usually in total cost of ownership (TCO) analyses, the highest costs of operating a vehicle are the difference in price compared to a conventional vehicle, charging infrastructure and driver wages. However, battery and fuel cell costs[4] are declining according to the California Resources Board (ARB) and some manufacturers such as BYD[5]. Under SB 350, utilities are proposing to reduce or eliminate infrastructure costs for electric fleets, which is an additional policy changing the incentives requirements for fleets.

Table 1. Total HVIP incentives provided by fiscal year and technology type (1,000s)

Tech	09-10	10-11	11-12	13-14	14-15	15-16	16-17	Other	Grand Total
ePTO								$351	$351
HV	$19,095	$10,936	$7,727	$10,810	$6,340	$3,007	$3,899	$387	$62,201
Low NOx						$1,856	$15,386	$38,387	$55,630
ZEV	$25	$10,478	$2,065	$500	$355	$675	$18,229	$130,025	$162,352
EVSE							$1,664	$17,289	$18,954
Grand Total	**$19,120**	**$21,414**	**$9,792**	**$11,310**	**$6,695**	**$5,538**	**$39,179**	**$186,440**	**$299,489**

Table 2. Total HVIP incentives provided by fiscal year and vocation (1,000s)

Vocation	09-10	10-11	11-12	13-14	14-15	15-16	16-17	Other	Grand Total
Bever. Deliv.	$10,760	$2,986	$845	$234	$161	$46	$193		$15,225
Other Truck	$5,135	$7,150	$3,577	$4,878	$2,471	$916	$25,496	$45,551	$95,174
Parcel Deliv.	$3,115	$10,956	$5,288	$5,805	$3,963	$2,697	$4,662	$103	$36,589
Refuse Truck	$110	$322	$82	$393	$100	$1,879	$8,828	$7,198	$18,913
NA								$133	$133,586
Grand Total	**$19,120**	**$21,414**	**$9,792**	**$11,310**	**$6,695**	**$5,538**	**$39,179**	**$186,440**	**$299,489**

Some issues associated with financial incentive programs include the capacity of the fleets to internalize the risk and purchase the vehicles even with the large voucher incentives; the sheer magnitude of vehicles used in last mile requires billions of dollars of incentive funds; purchasing a new vehicle technology would not address some of the operational issues such as congestion, lack of parking, loading and unloading areas, and cost savings compared to operational risks, among others. Consequently, to improve the system and foster the adoption of these

[4] https://www.arb.ca.gov/msprog/bus/battery_cost.pdf
[5] Truck STEPS workshop, 2017

technologies, an incentive program must go beyond financial incentives. Explicitly, a program most consider non-financial incentives, as well as incentives based on operational performance.

The use of non-financial incentives to foster behavioral changes is not new, as it has been evaluated in other cases. For example, there have been projects trying to generate spatial and temporal changes in freight flows in urban areas. Jaller and Holguín-Veras (2013) and Holguín-Veras et al. (2015) discuss the results of a project using financial incentives to shift freight traffic to the off-hours. Moreover, the researchers evaluated and compared the value of non-financial vs. financial incentives. The results showed that offering business support would have the same effect on their utility than a $1,078 to $3,049 one-time financial incentive. Providing public recognition is equivalent to a one-time incentive ranging from $666 to $1,885. This range is lower than the one for business support, though it is an attractive alternative because there is no need to incur in large expenses to make it possible. Having a trusted vendor offered the most surprising result with a subjective monetary value ranging between $1,741 and $36,538, which shows the importance given to this factor by some industry segments (Holguín-Veras et al., 2017).

Moreover, quantification of other non-monetary incentives has been performed by local programs related to low emission zones (LEZ), fast lanes, preferential parking, charging infrastructure, loading/unloading zones, recognition programs, and green PR, among others. For example, Bauer et al. (2018) discuss a number of monetary and non-monetary examples used to foster behavioral changes for travelers. Moreover, Salama et al. (2014) discuss how Green Loading Zones (GLZs) (curbside loading zones reserved for electric trucks), represent an innovative, low-cost policy incentive to encourage the purchase and use of ZEVs.

Non-Financial Incentives

The research team used the results from the literature review regarding the importance of factors that affect the adoption of ZEVs, and the experiences in other freight and passenger transport behavioral projects to develop a potential set of non-financial incentives. This include, parking/loading/unloading area availability and priority, parking exemptions, procurement priority, infrastructure agreements, reduced registration fees, business support, and public recognition, among others. Recent examples from London, Amsterdam, Stockholm, and other European locations provide insights about the effectiveness of such incentives for fostering zero and near-zero emission vehicles (European Union, 2016). Moreover, private discussions with freight stakeholders resulted in a suggestion to consider priority (or bonus criteria) for fleets using ZEVs when bidding for Federal or State contracts. After careful analyses, Table 3 defines the four different programs considered in the remainder of the study.

Table 3. Non-financial incentives

Incentive	Description
Permission to park, load or unload in designated areas in the city/corridor (Priority Parking Permit)	Designated areas and zones to park/load/unload goods. This permit will provide preferential access to those areas to ZEVS. This may include charging infrastructure for battery electric vehicles.
Permission to use bus lanes and high-occupancy vehicle (HOV, HOT) lanes (Special Lane Use Permit)	ZEVs allowed to use these lanes (priority infrastructure).
Public recognition program	Public agencies will develop a recognition program that advertises the companies participating in environmentally friendly initiatives such as the use of zero-emission vehicles.
Preference during official bidding/contracting	Public agencies will give preference to companies using environmentally friendly initiatives such as the use of zero-emission vehicles when selecting winning contract bids.

III. Methodology

Survey Design, Data Collection and Modeling (Stated Preference)

Survey Design

To identify the perceptions and preferences towards the adoption and use of ZEVs and effect of the incentive programs, the team expected to collected data from fleets and carrier companies. Without loss of generality, the data would include questions to address the dependent variables (e.g., preference for a specific alternative). When identifying preferences, there are two main types of surveys: revealed and stated preferences. If the participants in the experiment are asked about their past choices in real-world situations, the data collected is called Revealed Preference (RP) data. On the other hand, if the questions refer to a hypothetical situation, the experiment results in Stated Preference (SP) data. Revealed preferences represent past behaviors while stated preferences are choice preferences.

Considering that ZEVs are not widely used in the market, and some technologies are still not market ready, this study focused on a SP survey. Therefore, it is important to design the experiments in the SP survey to be able to capture the variability in alternative attributes which can reflect changes in choices. And as stated by Hensher (1994), "…*the engine of stated preference analysis is a controlled experiment, out of which comes a series of survey questions eliciting a response to alternative combinations of levels of attributes. A good experiment is one which has a sufficiently rich set of attributes and choice contexts, together with enough variation in the attribute levels necessary to produce meaningful behavioral responses in the context of the strategies under study*…" However, SP survey data, and the forecasting models using these data may not fully reflect how respondents might actually behave when faced with the real-world situations. For instance, they could feel forced to make a socially desired choice in favor of green technologies (Ben-Akiva et al., 2002).

To develop the survey instrument, the authors analyzed the population of interest, e.g., firms deploying trucks in California, and determined the choice set and the alternatives' attributes with an influence on truck technology choices. The initial technology choice set included Diesel, Plug-In Hybrid Electric Truck, Battery Electric Truck and Fuel Cell Electric Truck. However, after analyzing the regulatory environment in the California, the team concentrate on Battery Electric trucks compared to Diesel. Vehicle attributes include purchase price, operating costs, CO2 emissions, range, infrastructure and service station availability and refueling/recharging time, and the various incentives (including monetary incentives). Once defined, the authors selected the measurement unit and the number and magnitudes of attribute levels to evaluate. The authors used diesel vehicle attributes as a reference point for the definition of the levels for the other alternatives. Considering the number of attributes and the levels could result in a large number of combinations making the survey impractical and a burden for respondents. This is the case in full factorial designs, alternatively, the survey design can use a fractional factorial design reducing the number of combinations, where levels of attributes change in repeated choice experiments. Specifically, the authors use a fractional factorial orthogonal design, and create the choice experiments using a Bayesian D-efficient design, which resulted in 20 choice situations. These were split into four separate blocks, randomly assigned to the respondent (each respondent stated preferences over 5 choice situations). Table 4 shows the different attributes and levels considered in the choice experiments.

Table 4. Attribute levels in stated choice experiment

Attribute	Description	Levels
Purchase voucher incentive (discount)	Value of incentive you receive based on a percentage of the price of the battery electric vehicle.	0%, 15%, 30%, and 50%
Change in fuel efficiency compared to diesel vehicle	Percent change (increase or decrease) of fuel efficiency equivalent compared to the comparable diesel vehicle.	0%, 60%, and 80%
Change in maintenance and repair costs compared to diesel vehicle	Percent change (increase or decrease) of maintenance and repair costs compared to the comparable diesel vehicle.	-30%, -10%, and 0%
Driving range (miles)	Miles until the battery is depleted.	150, 300, and 500
Incentive Package A	Priority Parking Permit and/or Special Land Use Permit	None, Priority Parking Permit and/or Special, Special Land Use Permit, and both incentives
Incentive Package B	Public recognition program and/or Preference during official bidding/contracting	None, Public recognition program, Preference bidding, and both incentives
Market share of battery electric vehicles	Market share (percentage) of battery electric vehicles in your area.	Successful Pilot Testing [1%] Early Adopters [5%] Mass Production [15%]

The levels for these attributes resulted from an extensive review of the literature. For example, the voucher incentive levels correspond to the magnitude of incentives over different programs for different vehicles classes. For the changes in fuel efficiency, the team analyzed fuel costs and the energy efficiency ratios (EER) of electric trucks. Transport companies in California face greater expenses in transportation fuels, as the diesel fuel price is one of the highest throughout the United States due to higher tax, production costs, and fees related to environmental regulations The diesel price in California followed a rising trend since 2003 and showed a cyclical pattern after 2008, but remained on a relatively high level since 2010. The average retail price of diesel per gallon was $3.067 in 2017. According to the forecasts in the EIA Energy Outlook 2018 (US Energy Information Administration, 2018), the diesel price in the United States will rise constantly until 2050. In contrast to the diesel price, the electricity price stayed nearly constant and is on a much lower level than the diesel retail price. Regarding electricity prices, it has to be distinguished between residential, commercial, industrial and transportation applications, which can differ considerably. The average retail electricity price for the transportation sector in 2017 was $0.10 per kWh. It is important to stress that managers can switch to time-of-use rate plans and ensure that the vehicles are charged at times, when the electricity rates are lower, which further increases the fuel cost gap between diesel and electric trucks. Based on these factors, the team identified the potential improvements in fuel efficiency of 60-80%. Although there is a high uncertainty regarding the true value for maintenance and repair costs of electric trucks due to a lack of experience, it is common believe that they are lower for electric trucks than for diesel trucks, which have more moving parts and wear items. According to AFLEET (Argonne National Laboratory, 2017), maintenance and repair costs per mile for diesel trucks are $0.201 whereas they are $0.139 for electric trucks. Using these values as reference and considering the uncertainty, the team defined reductions in the order of 10% and 30% compared to diesel vehicles.

The driving range is expressed in miles that can be driven until the battery is depleted or the diesel tank is emptied. The electric driving range of a battery electric truck depends on the battery capacity and energy efficiency. A higher driving range of electric trucks can be achieved with an increase in battery capacity or a decrease in electricity consumption. The team selected three levels, 150 miles to be considered the minimum level for most applications, and then 300 and 500 miles for applications requiring longer distances. During the design of the survey, a vehicle manufacturer claimed those distances as feasible.

The team considered other attributes but they were not ultimately included in the experiments. For example, emission levels as a percent relative to the standard diesel truck's CO_2 emissions output. Although the battery electric truck is operated emission-free, the electricity production releases CO_2 into the atmosphere. Therefore, the attribute levels for the electric truck's CO_2 emissions output could have values different from zero. A truck with lower CO_2 emissions could help truck customers build up a greener image, circumvent city congestion charges and enable night-time deliveries in noise-sensitive areas. The refueling time for the diesel truck and the recharging time for the electric truck were also considered to account for the fact that some operators might be dependent on opportunity charging while loading and unloading the goods or the existence of public fast charging infrastructure due to financial or depot space restrictions. And, refueling and charging infrastructure availability to express infrastructure densities.

The team designed the survey including 6 different sections. In Section 1, participants are asked questions about the operational environment and characteristics of their fleet, and duty cycles. Section 2 concentrates on the vehicle acquisition preferences and vehicle technology knowledge. Section 3 seeks to understand the respondent's preferences through the randomly assigned (block) set of questions. Section 4 asks information about the company and facilities, while Sections 5 and 6, requested information about daily operations (e.g., trip generation, and vehicle operations). The respondents were offered the chance to participate in a raffle for several monetary prizes to compensate for their time. The team requested IRB approval and was granted approval under Exempt 2 Determination by the UC Davis IRB Administration. Appendix B includes the cover letter used during the electronic deployment of the survey, and Appendix C contains the survey questionnaire.

Data Collection

The team implemented the survey in Qualtrics Survey Software, and distributed the survey online. The team executed two different waves of survey deployment through two different channels. In the first wave, during the first trimester of 2019, the team deployed the survey to the membership of the California Trucking Association (CTA), and through contacts of the vehicle manufacturers sponsoring the Sustainable Freight Research Center at the Institute of Transportation Studies (ITS), Davis. The members of the CTA range from motor carriers to other businesses that provide services to the trucking industry. CTA has been an advocate for comprehensive policies that support the goods movement system in an efficient, environmentally responsible and safe way. For the second wave, the team purchased a sample database of carrier companies in the State of California (with available contact email address), from data aggregator InfoUSA. The sample contained information for 2,468 businesses (see Table 5 for the description of the different sub-industry categories and the spatial distribution of the sample). The team electronically deployed the second wave during the summer of 2020. For the second wave, the team also reduced the number of Questions included (from the original first wave deployment). Most of the reduction were in Sections 4 and 5 of the survey instrument.

Modeling

Based on the experiences evaluating similar types of incentives (Holguín-Veras et al., 2017) the team expected to model the dependent variable through the joint estimate of a score function and a set of parameters, μ, (thresholds) that split the domain of the score function in such a way that they replicate the original choice probabilities. The efficiency of the ordered discrete model is measured by maximizing the log-likelihood function. This type of models belongs to Random Utility Models that consider utility maximizing individuals (Domencich and McFadden, 1975). Mathematically, the choice (*y*) is estimated by defining a utility (*U*) that depends on the attributes of the individuals and the alternatives. *U* is specified using a linear function:

$$\boldsymbol{U} = \boldsymbol{\beta X} + \boldsymbol{\varepsilon} \qquad (1)$$

Where, X: Vector of variables or attributes proper to the observation

β: Vector of estimable parameters

ε: Random disturbance (assumed to follow a Gumble distribution)

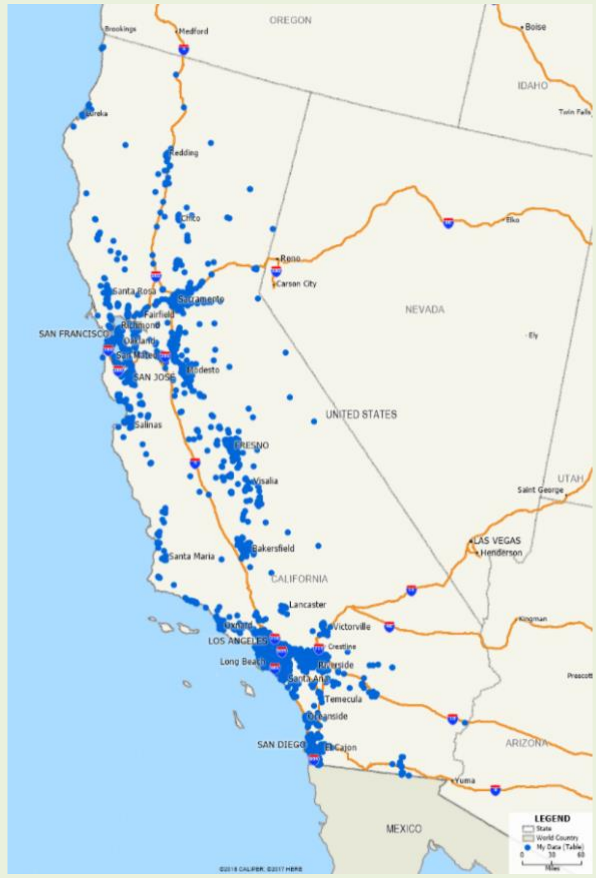
Moreover, the process would derive the threshold parameters, $\mu(i)$, along with the dependent variable. The thresholds provide a numerical range that indicates the level of willingness, *j.* The model estimates the associated probabilities to each willingness level, $P_n(j)$, for the individuals. One important component of the modeling process is estimating the elasticities. Direct elasticities are estimated using the following equation:

$$\eta_{x_{nk}}^{P_n(j)} = \frac{\partial P_n(j)}{P_n(j)} \Big/ \frac{\partial x_{nk}}{x_{nk}} = \frac{\partial P_n(j)}{x_{nk}} * \frac{x_{nk}}{P_n(j)} \quad \forall j \in W, n \in N, k \in K \qquad (2)$$

Table 5. Sub-industry categories and the spatial distribution of sample carrier companies

SIC - Description	No.
421201 - Trucking-contract Hauling	44
421203 - Livestock Hauling	1
421204 - Lumber Carriers	1
421205 - Delivery Service	161
421206 - Cartage	1
421209 - Truck-loading & Unloading	1
421210 - Trucking-dump	3
421211 - Sand & Gravel Hauling	1
421212 - Trucking-local Cartage	19
421213 - Grain Hauling	28
421214 - Truck-transporting	1
421219 - Fill Dirt	2
421221 - Recyclables-pick Up Service	1
421222 - Hauling & Debris Removal	7
421227 - Hay Hauling	1
421228 - Tank Truck Service	5
421229 - Petroleum Products-transporting	1
421230 - Hazardous Materials-transporting	2
421304 - Trucking	931
421306 - Trucking-liquid & Dry Bulk	6
421307 - Trucking-heavy Hauling	6
421308 - Trucking-refrigerated	4
421309 - Trucking-motor Freight	150
421310 - Express & Transfer Svc	3
421401 - Movers	308
421403 - Transfer Companies	1
421501 - Courier Services	59
421502 - Parcel Delivery	2
422101 - Grain Elevators	3
422105 - Warehouses-commodity & Merchandise	3
422106 - Tobacco Warehouses	1
422201 - Locker Plants	1
422202 - Warehouses-cold Storage	47
422501 - Storage	31
422502 - Warehousing-field	3
422503 - Storage-household & Commercial	313
422505 - Warehouses-merchandise & Self Storage	67
422506 - Warehouses-private & Public	33
422507 - Warehouses-self Storage	9
422508 - Warehouses-mini & Self Storage	147
422509 - Warehouses	57
423101 - Truck Terminals	1
423102 - Dispatch Service-trucking	2
Total	2,468

Geopgraphic Location



Where:

- X_{nk}: variable *k* for the individual *n* and alternative *j*
- $\eta_{x_{jnk}}^{P_n(j)}$: individual direct elasticity of choosing *j* with respect to variable *k*
- *W, N, K* are the set of willingness levels, individuals, and attributes/variables.
- $P_n(j)$: probability that an individual *n* presents a willingness level *j*

The market elasticity is then assessed based on the estimates for each individual. The market elasticity indicates the overall effects of the incentives considered on the willingness to procure and use zero emission and near zero emission vehicles.

The monetary value of each incentive would then be the marginal rate of substitution of the incentive with respect to the financial incentive:

$$MV_{I,j} = \left(\frac{\partial U}{\partial I} \Big/ \frac{\partial U}{\partial OTI}\right) \quad (3)$$

Where:

- $MV_{I,j}$: monetary value of incentive *I* for *j*
- *U:* utility function specified in the model
- I: incentive
- OTI: one time incentive offered (US$)

Survey Design, Data Collection and Modeling (Expert Assessment)

During the course of the study, and the data collection efforts, the Air Resources Board initiated discussions about their Advance Clean Truck (ACT) Program. The team believes that uncertainties surrounding ACT, the fact that ARB also deployed their Advanced Clean Local Trucks Survey[6], and that the team survey could have been perceived as part of ARB's effort hampered the success of the survey deployment, resulting in a minimal response rate over the two survey deployments. The methodology described in the previous section requires a significant number of observations to estimate the choice models. Consequently, the team decided to use a different approach and study preferences based on expert opinions and assessments. Specifically, the authors proposed the use of multi-expert multi-criteria decision-making (MCDM) approaches. In general, MCDM problems evaluate different criteria and sub-criteria (such as in the case of this project, where companies need to select the vehicle technology based on a set of different criteria). Some of these criteria may be quantitative or qualitative and could conflict with each other. When using expert assessments as decision makers, there could be uncertainties because of imprecise data and lack of information in real life applications, which can limit the ability to use exact numbers (exact answers) as preferences (Zadeh, 1965a; Zadeh, 1965b), and individuals may prefer to make linguistic evaluations. To overcome these limitations, researchers introduced fuzzy set theory to deal with uncertainty, lack of information in human judgements, and vagueness. Fuzzy set theory has improved over

[6] https://www.arb.ca.gov/msprog/actruck/mtg/170425draftacltsurvey.pdf

the years to include assessments related to membership functions of the linguistic assessments and to deal with uncertainty.

Traditional MCDM methods include Analytic Hierarchy Process (AHP), fuzzy Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), interval-valued intuitionistic fuzzy sets (IFSs) with Cross-entropy, Simple Additive Weighting (SAW), and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) methods, among other techniques. MCDM methods have many applications in different fields. For example, the team recently analyzed disaster risk management and response capabilities in developing countries (Otay and Jaller, 2020) using an intuitionistic fuzzy Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method, and evaluated potential locations for wind power generation (wind farms) using a Pythagorean Fuzzy Analytic Hierarchy Process (AHP) (Otay and Jaller, 2019). The AHP based methods identify hierarchical levels and weights for the various criteria, attributes and characteristics to evaluate the alternatives. The viability of this approach lies in its ability to address complex decision-making processes. Moreover, MCDM methods have been used to evaluate different vehicles technologies in public and freight transport. For example, Aydın and Kahraman (2014) evaluated vehicle selection choices for public transport, and Yavuz et al. (2015) developed a Hierarchical Hesitant Fuzzy Linguistic model to evaluate alternative fuel heavy duty vehicles. Overall, considering the data limitations and the requirements to conduct discrete choice models, the selected MCDM method is a viable and appropriate alternative to identify the determinant factors for the selection of vehicle and fuel technologies.

In this study, the authors selected a Fuzzy Analytic Hierarchy Process (AHP) based on a Spherical Fuzzy sets method to evaluate the various vehicle alternatives over multiple criteria. Spherical Fuzzy sets have been receiving increasing attention because of their ability to better consider uncertainty by defining membership functions on a spherical surface and covering a larger domain. Specifically, the authors evaluate the alternatives using five main criteria: economic; business, incentives & market-related; environmental & regulatory; infrastructure; and safety & vehicle performance factors. The analyses also consider twenty-one sub-criteria, e.g., total cost of ownership, payback period, brand image, financial & non-financial incentives, and public/private fueling/ charging infrastructure availability. Table 6 shows the criteria and sub-criteria considered during the evaluation process.

The team designed the survey instrument and administered to three experts. Using the linguistic terms in Table 7, the experts had to 1) conduct pairwise comparisons among the criteria and rank the criteria; 2) pairwise comparisons within the sub-criteria and ranking of sub-criteria; and 3) independent linguistic assessment of sub-criteria for each vehicle technology (diesel, hybrid electric, CNG/RNG, battery electric and fuel cell). Moreover, the experts were asked to evaluate the performance considering the case of last mile distribution, and long-haul transport.

Table 6. Criteria and sub-criteria for vehicle technology evaluation

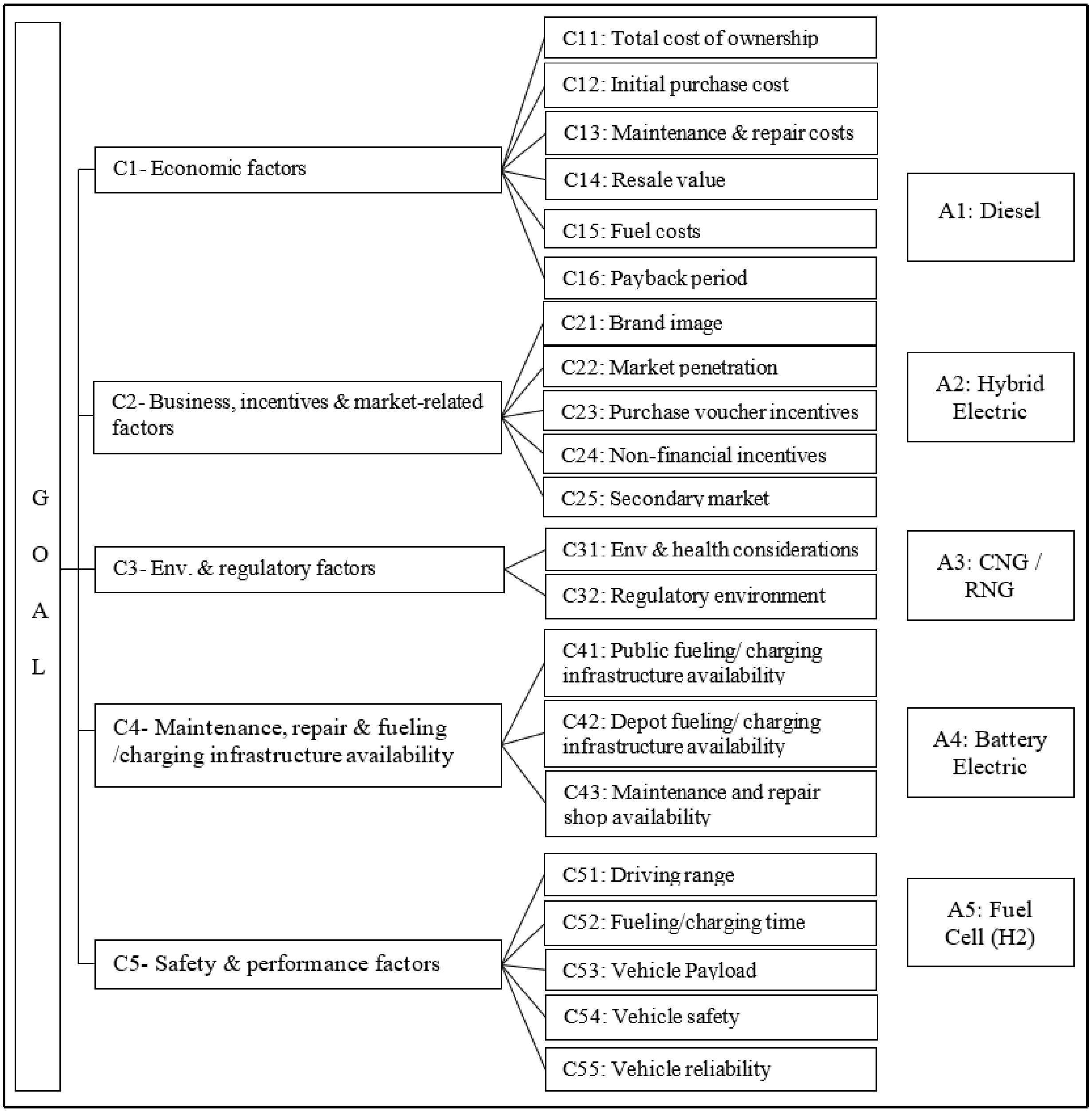


Table 7. Linguistic terms for comparative assessments

Linguistic Terms	Linguistic Terms
Absolutely Low (AL)	Medium High (MH)
Very Low (VL	High (H)
Low (L)	Very High (VH)
Medium Low (ML)	Absolutely High (AH)
Approximately Equal (AE)	

Integrated Spherical Fuzzy AHP-TOPSIS Methodology

The reader is referred to Jaller and Otay (2020) and the references within for a detailed description of the Fuzzy Analytic Hierarchy Process (AHP) based on a Spherical Fuzzy sets method. Additionally, Appendix D provides some definitions about Spherical Fuzzy sets and the different operators. Following is as description of the steps of the proposed integrated spherical fuzzy AHP-TOPSIS method based on the work of Kahraman et al. (2019) and Gündoğdu and Kahraman (2020):

Step 1: The multi-criteria decision-making (MCDM) problem is generated by representing a goal, a finite set of criteria $[C_j(X_i) = (\mu_{ij}, v_{ij}, \pi_{ij}), j = 1,2, \ldots, n]$ and sub-criteria, and an alternative set $X = \{x_1, x_2, \ldots, x_m\}$ (see Table 6).

Step 2: Collect pairwise comparison matrices based on the linguistic terms (in Table 7) with their corresponding spherical fuzzy numbers from decision maker(s).

Step 3: Check the consistency of the pairwise comparison matrices by applying the classical consistency analysis methods based on score indices (Gündoğdu and Kahraman, 2020).

Step 4: Calculate the weights of the using the Spherical fuzzy AHP.

Step 4.1: Use the SWAM operator from Eq.(A6) to obtain the Spherical fuzzy weights of the criteria.

Step 4.2: Defuzzify the weights using Eq.(A8) and normalize them by dividing each defuzzified weight by the sum of the defuzzified weights.

Step 5: Calculate the weights of sub-criteria through Step 4.1 and Step 4.2.

Step 6: Evaluate the alternatives by Spherical Fuzzy TOPSIS.

Step 6.1: Ask decision maker(s) to fill out a Spherical fuzzy decision matrix (or matrices) $D = (C_j(X_i))_{mxn}$ using the linguistic scale.

Step 6.2: Aggregate the judgments of the decision makers using the SWAM operator, and obtain the aggregated Spherical fuzzy decision matrix ($D_{\alpha gg} = (C_j(X_i))_{mxn}$).

$$D_{\alpha gg} = (C_j(X_i))_{mxn} = \begin{pmatrix} (\mu_{11}, v_{11}, \pi_{11}) & \cdots & (\mu_{1n}, v_{1n}, \pi_{1n}) \\ \vdots & \ddots & \vdots \\ (\mu_{m1}, v_{m1}, \pi_{m1}) & \cdots & (\mu_{mn}, v_{mn}, \pi_{mn}) \end{pmatrix} \quad (1)$$

Step 6.3: Estimate the aggregated weighted spherical fuzzy decision matrix.

$$D^w_{\alpha gg} = (C_j(X^w_i))_{mxn} = \begin{pmatrix} (\mu^w_{11}, v^w_{11}, \pi^w_{11}) & \cdots & (\mu^w_{1n}, v^w_{1n}, \pi^w_{1n}) \\ \vdots & \ddots & \vdots \\ (\mu^w_{m1}, v^w_{m1}, \pi^w_{m1}) & \cdots & (\mu^w_{mn}, v^w_{mn}, \pi^w_{mn}) \end{pmatrix} \quad (2)$$

Step 6.4: Defuzzify the values in the aggregated weighted decision matrix using Equation 3. Compare these scores to determine the Spherical fuzzy positive and negative ideal solutions.

$$Score\left(C_j(X_i^w)\right) = \left(2\mu_{ij}^w - {\pi_{ij}^w}/{2}\right)^2 - \left(v_{ij}^w - {\pi_{ij}^w}/{2}\right)^2 \quad (3)$$

Step 6.5: Then estimate the Spherical Fuzzy Positive and Negative Ideal Solutions (X^{PIS} and X^{NIS}).

$$X^{PIS} = \{C_j, \max_i < Score\left(C_j(X_i^w)\right) > | j = 1,2,\dots,n\},\ X^{PIS} = (\mu_{X^{PIS}}, v_{X^{PIS}}, \pi_{X^{PIS}}) \quad (4)$$

$$X^{NIS} = \{C_j, \max_i < Score\left(C_j(X_i^w)\right) > | j = 1,2,\dots,n\},\ X^{NIS} = (\mu_{X^{NIS}}, v_{X^{NIS}}, \pi_{X^{NIS}}) \quad (5)$$

Step 6.6: Calculate the distances between each alternative and X^{PIS} as well as X^{NIS} using Equations 6 and 7.

$$d(X_i, X^{PIS}) = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}((\mu_{X_i} - \mu_{X^{PIS}})^2 + (v_{X_i} - v_{X^{PIS}})^2 + (\pi_{X_i} - \pi_{X^{PIS}})^2} \quad (6)$$

$$d(X_i, X^{NIS}) = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}((\mu_{X_i} - \mu_{X^{NIS}})^2 + (v_{X_i} - v_{X^{NIS}})^2 + (\pi_{X_i} - \pi_{X^{NIS}})^2} \quad (7)$$

Step 7: Finally, derive the closeness coefficient ratio, $CCR(X_i)$ for each alternative, and rank the alternatives based on descending values of $CCR(X_i)$.

$$CCR(X_i) = \frac{d(X_i, X^{NIS})}{d(X_i, X^{PIS}) + d(X_i, X^{NIS})} \quad (8)$$

IV. Empirical Results

Stated Preference Survey

As mentioned before, the response rate was extremely low. In summary, the team received 11 responses from the first wave of deployment, with 3 out of 11 being incomplete surveys (less than 10% progress). In the second wave, the team received 42 responses, 25% had less than 10% progress, 60% (25) were complete, and the remaining contained incomplete responses at different completeness levels. About 42% of the responses are for companies operating in Southern California and 22% in the Bay Area. The companies have fleets that range from small fleets with a combination of passenger cars, small pick-up/vans, and small trucks, to companies using 150-220 diesel trucks. Besides gasoline and diesel, companies only reported using CNG/LNG vehicles with a company using more than 80 CNG/LNG class 7 trucks. The results do not show any distinctive pattern in terms of the annual mileage of vehicles, this is partially due to the small sample size and the large variability of vocations within the sample. Similarly, Figure 2 shows large variability in the vehicle operations, the tour characteristics, and the number of customers served in each delivery tour.

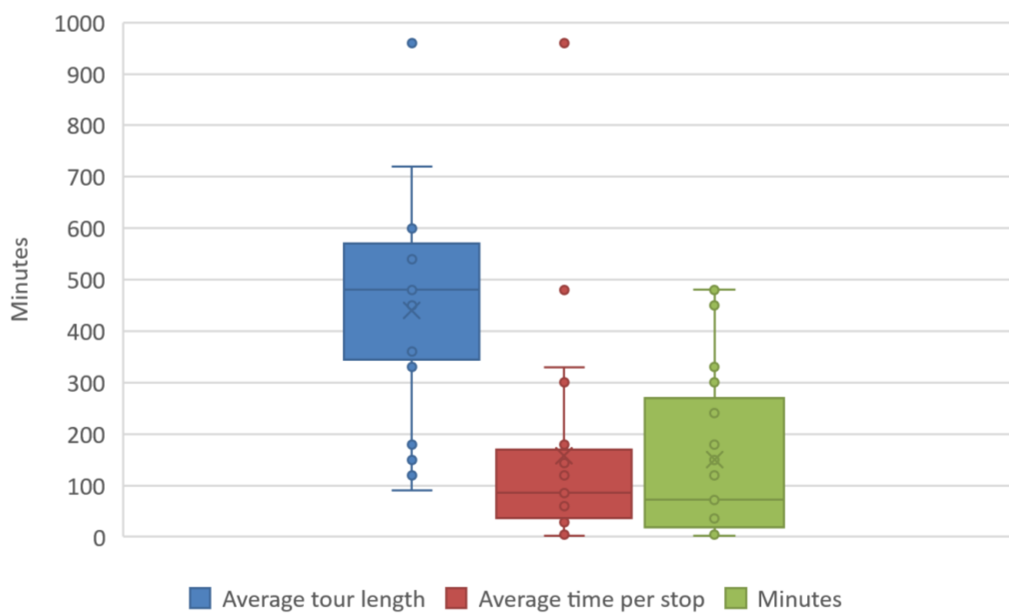


Figure 2. Reported daily vehicle operations characteristics

When making decisions about vehicle purchases, about three quarters of the response show that companies have a payback period of less than 5 years. Figure 3 shows the reported importance for different criteria when making purchase decisions. It was interesting to find that the majority of the companies (76%) said that they are not familiar with any financial incentive program that supports the adoption of zero or near-zero emission vehicles. The ones that had knowledge reported the Port Dray Grants, BAAQMD, CARL MOYER, and NRCS from SJVAPCD as the programs they know. The HVIP was not reported.

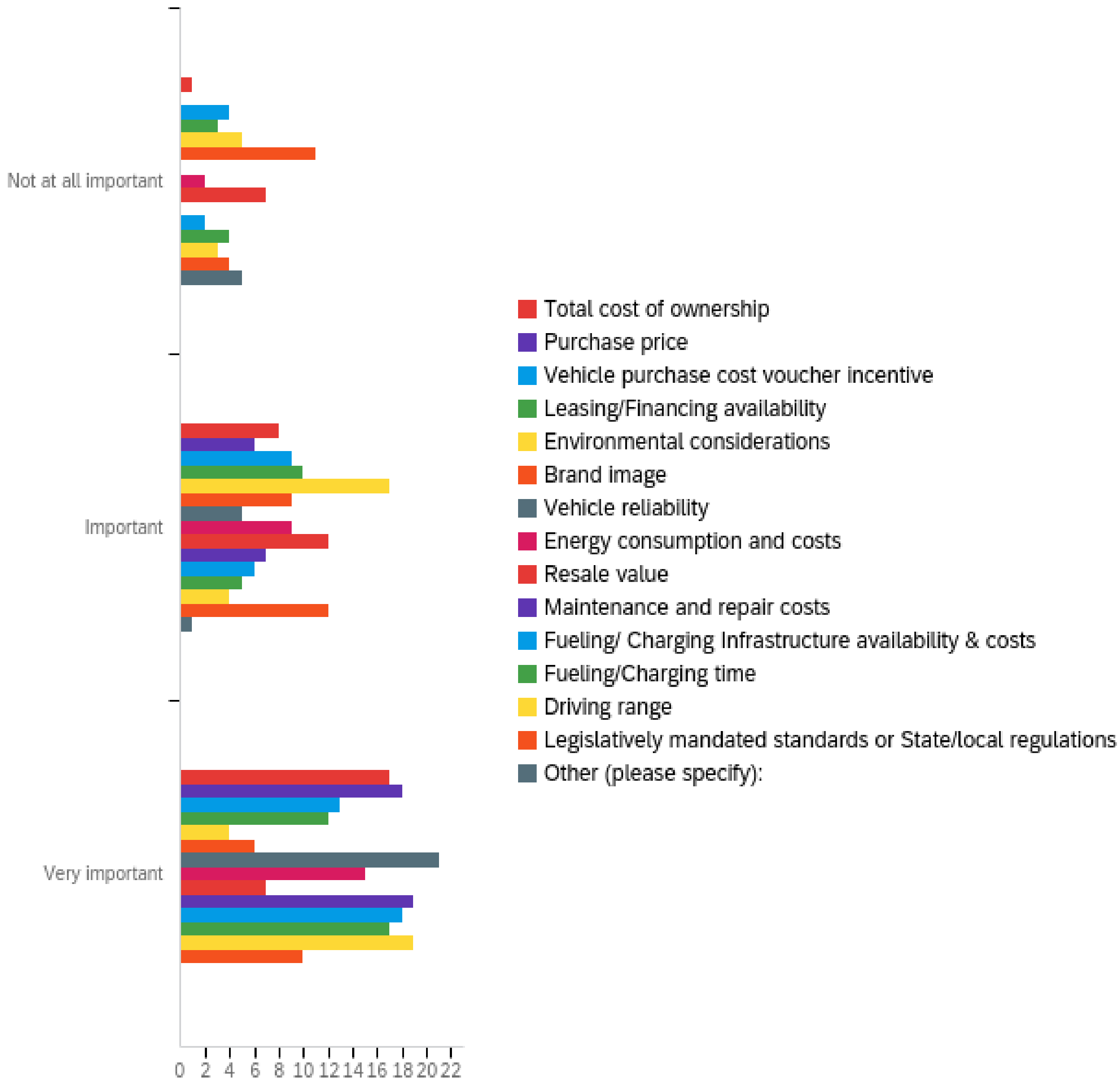


Figure 3. Importance of criteria when selecting vehicle/fuel technology

Regarding the non-financial incentives discussed in this project, Figure 4 shows the importance reported by the companies to foster zero-emission vehicles. Tax breaks and direct subsidies are the preferred incentives. It is important that comprehensive incentives packages are developed, as the companies preferred choice is still diesel. Figure 5 shows that during the next vehicle acquisition decision, the vast majority of the responses will mostly consider diesel vehicles. The reader is referred to Appendix F for additional details from the 2nd wave of the survey.

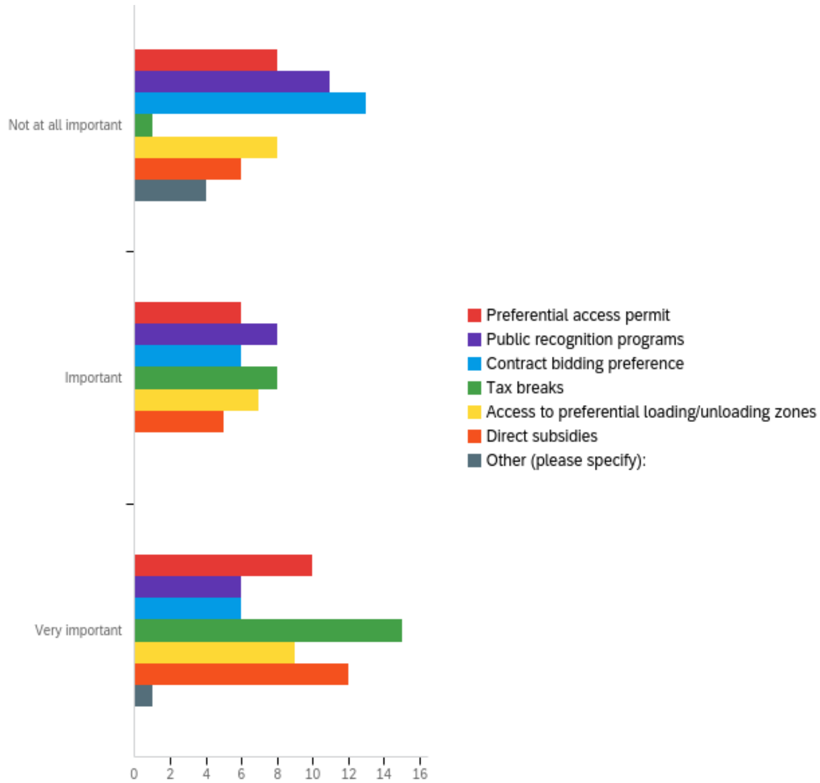


Figure 4. Importance of incentive programs for ZEVs

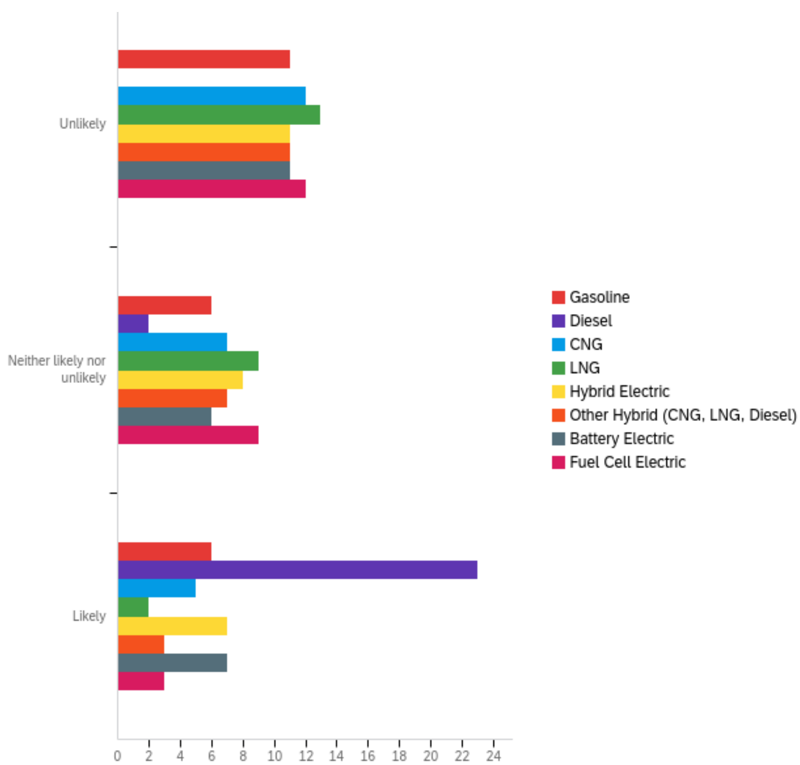


Figure 5. Vehicle considerations for future purchases

MCDM Survey and Results

After receiving the data from the 3 experts, the team conducted statistical tests to check for the consistency of the responses. The following results correspond to the analyses for the last mile distribution assessments from the experts. Recalling, the experts were asked to respond based on their knowledge of the fleets' decision-making process, and not necessarily their personal preferences.

Table 8 shows the pairwise evaluations of criteria from the three decision makers and Table 9 shows the matrix for sub-criteria C1 as an example. As explained in Jaller and Otay (2020), the process converts the linguistic values from the expert responses to their corresponding interval-valued PFSs. The consistency of all pairwise comparison matrices are checked using the score indices proposed in the study of Kutlu Gündoğdu and Kahraman (2019). After the linguistic values are converted to their corresponding Spherical fuzzy numbers, the evaluations are aggregated using the Spherical Weighted Arithmetic Mean (SWAM) operator given in Equation (A6).

Table 8. Pairwise comparison of matrix of criteria

Criteria	C1			C2			C3			C4			C5		
	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3
C1	EE	EE	EE	VH	E	VH	VH	MH	VH	H	ML	H	H	L	H
C2				EE	EE	EE	E	H	MH	ML	ML	ML	E	L	ML
C3							EE	EE	EE	ML	L	ML	ML	VL	ML
C4										EE	EE	EE	H	ML	ML
C5													EE	EE	EE

Table 9. Pairwise comparison matrix of sub-criteria of C1

Sub-criteria	C11			C12			C13			C14			C15			C16		
	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3
C11	EE	EE	EE	H	H	H	H	H	H	AH	VH	AH	MH	H	H	VH	E	VH
C12				EE	EE	EE	H	H	MH	VH	H	VH	E	H	E	VH	ML	H
C13							EE	EE	EE	MH	MH	H	ML	ML	ML	H	VL	H
C14										EE	EE	EE	VL	ML	VL	ML	VL	ML
C15													EE	EE	EE	VH	ML	VH
C16																EE	EE	EE

Following the steps of the methodology, the team estimated the Spherical fuzzy weights of criteria and sub-criteria. The weights are defuzzified using Eq. (A8) and normalized (see the weights in Table 10). In the analyses, the weights of the experts (φ_1 , φ_2 and φ_3) are taken as 1/3, 1/3, and 1/3, respectively. The results indicate that economic factors are the most important, followed by safety and performance indicators, with maintenance, repair and refueling in third place. The weights show that business incentives are not as importance as those factors directly related to vehicle operations. When analyzing the weights of the sub-criteria within the C2 group, the results indicate that the level of technology penetration in the market is more important than monetary and non-monetary incentives. Moreover, it is interesting to find that brand image has a relative importance higher than other non-financial incentives; therefore, there is an opportunity to develop a menu of non-financial incentives that include program to promote companies using cleaner technologies. Comparing the weights for financial and non-financial incentives shows that non-financial incentives have a relative importance that is 25% lower than that of financial incentives.

Table 10. Resulting weights for criteria and sub-criteria

Criteria	Criteria Weight	Sub-Criteria	Group Weight	Joint Weight
C1 - Economic factors	0.273	C11 - Total cost of ownership	0.243	0.066
		C12 - Initial purchase cost	0.198	0.054
		C13 - Maintenance and repair costs	0.143	0.039
		C14 - Resale value	0.085	0.023
		C15 - Fuel (diesel, gas, h2, electricity) costs	0.183	0.05
		C16 - Payback period	0.148	0.04
C2 - Business, incentives & market-related factors	0.168	C21 - Brand image	0.19	0.032
		C22 - Market penetration	0.252	0.042
		C23 - Purchase voucher incentives	0.23	0.039
		C24 - Non-financial incentives	0.174	0.029
		C25 - Secondary market development	0.155	0.026
C3 - Environmental & regulatory factors	0.129	C31 - Environmental & health considerations	0.427	0.055
		C32 - Regulatory environment (Compliance)	0.573	0.074
C4 - Maintenance, repair & fueling/ charging infr.	0.209	C41 - Public fueling/ charging infrastructure availability	0.257	0.054
		C42 - Depot fueling/ charging infrastructure availability	0.369	0.077
		C43 - Maintenance and repair shop availability	0.374	0.078
C5 - Safety & vehicle performance factors	0.221	C51 - Driving range	0.232	0.051
		C52 - Fueling / charging time	0.151	0.033
		C53 - Vehicle payload	0.173	0.038
		C54 - Vehicle safety	0.174	0.039
		C55 - Vehicle reliability	0.27	0.06

Evaluating the joint weights revealed additional differences among the importance of the different criteria and sub-criteria. The top five sub-criteria with weights ranging between .06 and .078 include (in descending order), maintenance and repair shop availability, depot fueling/charging infrastructure availability, regulatory compliance, total cost of ownership and vehicle reliability. On the other hand, the bottom 5 with weights ranging between .023 and .033 include (in ascending order), resale value, secondary market development, non-financial incentives, brand image, and fueling/charging time.

Table 11 shows the decision matrix (based on the linguistic scale), which evaluates each alternatives based on each criterion for the three decision makers. The decision matrix allows obtaining the aggregated weighted spherical fuzzy decision matrix as in Equation 2. After the weight estimation process, the model normalize indicator values, determines the ideal and worst solutions, estimates separation (distance) measures, determines the relative closeness to ideal solutions (CCR), and ranks the alternatives. The CCR is a measure of the relationship between the "Distance between each alternative and the Positive ideal solution" and the "Distance between each alternative and Negative ideal solution). In general, we want to be as close as possible to the positive ideal solution, and as far as possible to the negative ideal solution. For the last mile case, the distances are $d(X_i, X^{PIS})$ ={0.041, 0.044, 0.051, 0.076, 0.084} and $d(X_i, X^{NIS})$={0.088, 0.070, 0.070, 0.047, 0.045}.

Table 11. Decision matrix

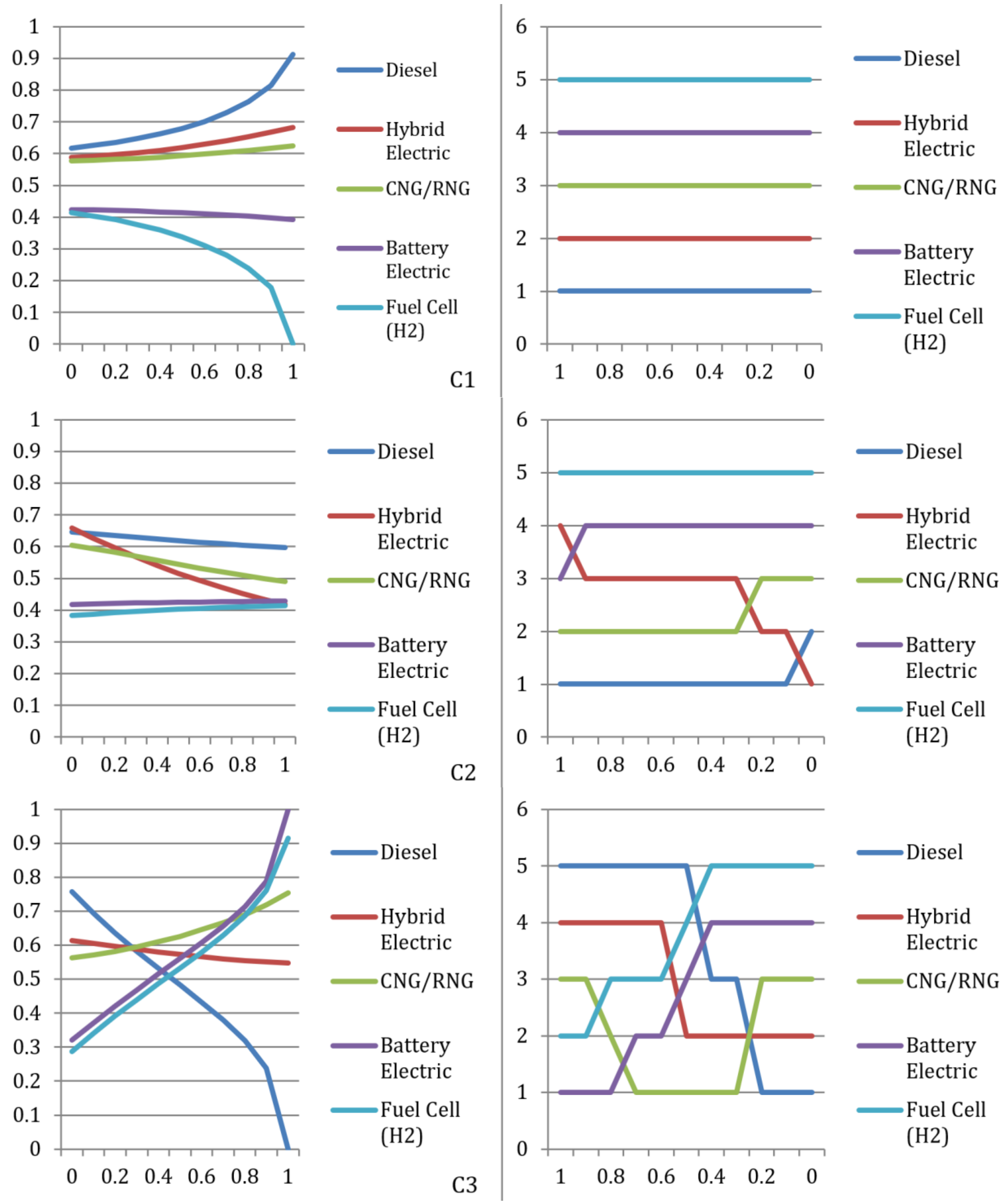
Sub-criteria	A1			A2			A3			A4			A5		
	E1	**E2**	**E3**	**E1**	**E2**	**E3**	**E1**	**E2**	**E3**	**E1**	**E2**	**E3**	**E1**	**E2**	**E3**
C11	H	H	H	H	E	H	E	H	E	VL	H	ML	VL	ML	ML
C12	H	VH	E	E	E	H	ML	E	E	VL	ML	VH	VL	L	VH
C13	H	ML	H	E	ML	H	VH	ML	H	L	H	L	VL	E	L
C14	H	VH	H	E	ML	E	E	ML	E	VL	L	VL	VL	L	VL
C15	H	E	VH	H	H	H	VH	E	VH	E	VH	E	L	ML	L
C16	H	VH	E	H	ML	H	E	E	E	VL	ML	ML	VL	VL	ML
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
C51	VH	VH	VH	VH	H	VH	E	E	E	L	L	L	L	E	L
C52	H	VH	VH	H	E	H	E	H	H	ML	L	AL	E	H	E
C53	H	VH	H	H	H	H	H	H	H	ML	L	ML	H	H	H
C54	H	E	H	E	E	E	H	E	H	E	H	E	E	H	E
C55	H	H	H	E	H	E	VH	E	VH	L	VH	L	L	E	L

Table 12 shows the ranking for alternatives for last mile distribution and long-haul. The results are strikingly similar. More importantly, battery electric and fuel cell are in a separate preference group, with their CCR values to be almost half of the preferred alternative (diesel trucks).

Table 12. Relative closeness to ideal solutions (CCR) and ranking

		A1 Diesel	**A2 Hybrid**	**A3 CNG/RNG**	**A4 Battery Electric**	**A5 Fuel Cell**
Last Mile	$CCR\ (x_i)$	0.6832	0.6166	0.5792	0.3847	0.3488
	Rank	1	2	3	4	5
Long Haul	$CCR\ (x_i)$	0.6962	0.6114	0.5441	0.3582	0.3425
	Rank	1	2	3	4	5

Additionally, the authors performed sensitivity analyses to evaluate the potential changes in the solutions for the changes in the criteria weights, and to check the robustness and applicability of the proposed model. The authors changed the weight of each criteria individually (assuming the remaining weight would split proportionally among the other 4 criteria) in the range of [0.1, 1.0] with an incremental increase of “0.1”. For all the cases, the authors estimated the CCR $(\mathrm{x_i})$ values with respect to (wrt) the criteria and calculated the changes in the CCR. Figure 6 shows the results for the sensitivity analyses (see Appendix E for values for last mile and long-haul). The left panes show the changes in CCR for the different alternatives. Right pane shows changes in alternative’s rankings.


Diesel
Hybrid Electric
CNG/RNG
Battery Electric
Fuel Cell (H2)
C1
C2
C3

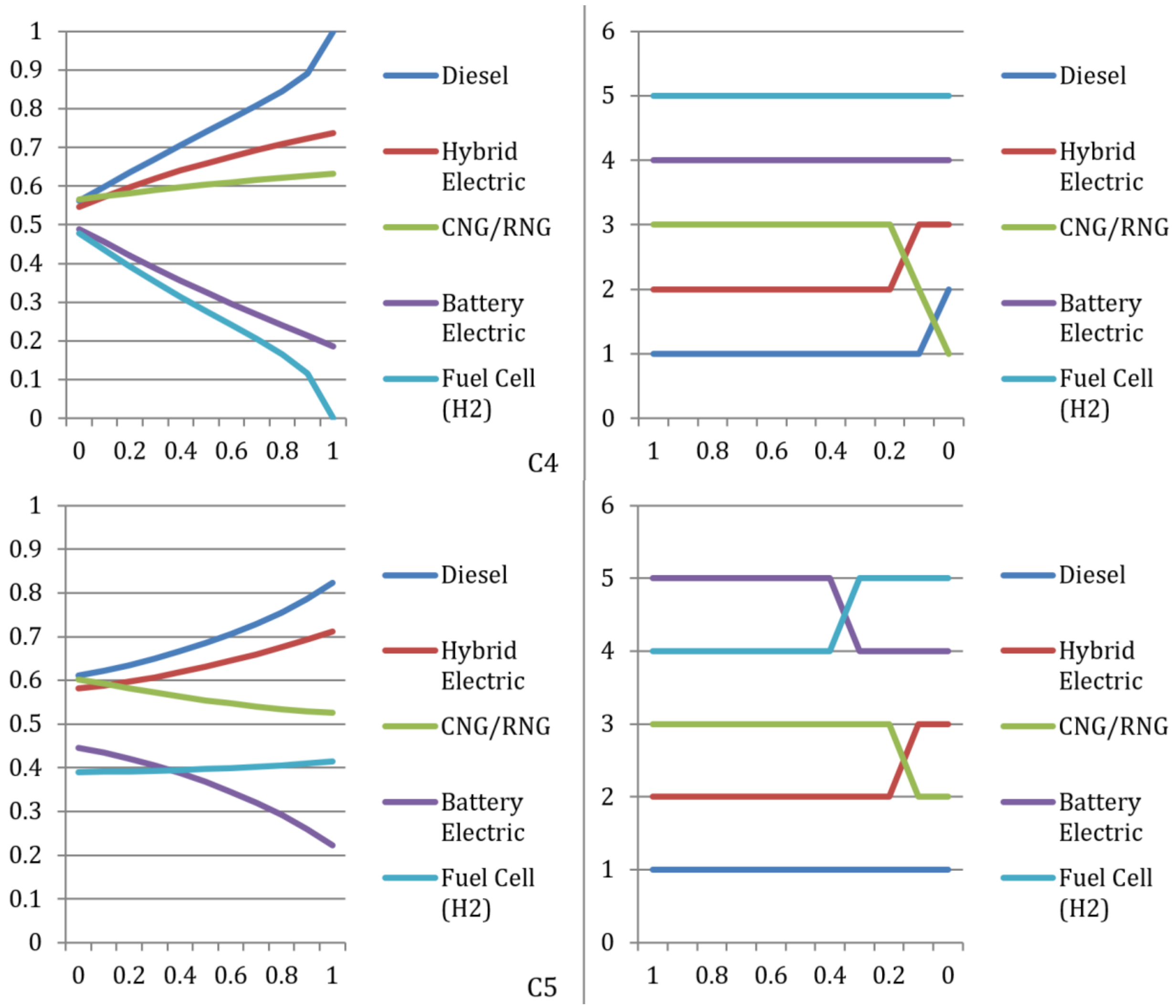


Figure 6. Sensitivity analyses with respect to each criteria

The results show low sensitivity with respect to changes in the weight of economic factors. On one hand, the CRR become more prominent at the extreme alternatives (diesel and fuel cell), whereas the middle alternatives are not affected. This is reflected in the lack of changes in the alternatives' ranking. Similar results are observed for changes in the business incentives and market-related factors criteria. However, when this criteria reaches larger weights, hybrid electric vehicles become less preferred. Maintenance repair & fueling/charging infrastructure behaves similar to the first criteria, though lower weights benefit CNG/RNG vehicles. Where the results show more variability is for changes to the environmental and regulatory factors. In this case, the higher the weights, battery electric and fuel cells become the more prevalent choices. This has important implications, as any program or initiative towards increasing the importance of these factors would have a significant role in determining the selected vehicles.

V. Discussion and Conclusions

This study concentrated on evaluating the different factors involved in the decision-making process for the selection of vehicle technologies. The study had a primary focus to evaluate the impacts of financial and non-financial incentives. In doing so, the team designed and deployed a SP survey. However, after two failed attempts which resulted in minimal response rates, the team opted to study the issue at a more aggregate level using expert's choice through the development of a multi-criteria decision making (MCDM) model using Fuzzy Analytic Hierarchy Process (AHP) based on a Spherical Fuzzy sets method.

Regarding the study process, the data collection effort evidenced the challenges in collecting behavioral data from businesses and fleets (which has traditionally been more difficult than when surveying individuals and households). More importantly, the data collection effort was conducted during a period where one of the major regulatory agencies was in the midst of developing the ACT Program, which will have tremendous implications for vehicle manufactures and fleets (small and large). Furthermore, the objective of the study is directly related to the discussions around ACT. Informal communications with ARB indicated that they also experienced a small response rate to their Advanced Clean Local Trucks Survey[7].

Another research effort conducted by NCST partners at the University of Southern California and the California State University Long Beach, with whom the research team had constant communications and collaboration in the development of the survey instrument, also experienced limited responses, even from freight stakeholders with which they have a long tradition of collaborating. Other recent data collection efforts (with direct regulatory implications) have had the same results. For instance, the warehouse inventory survey the Air Resources Board developed in 2017-2018 received negative feedback. One success store is the development of the California Vehicle Inventory User Survey (CalVIUS); however, this survey required very large budgets and resources (of orders of magnitude larger than the current study).

Overcoming this challenge, and using the expert based analyses, although not allowing for the disaggregate choice modeling initially aspired, they provided a good compromise and allowed for important analyses. The MCDM model considered diesel, compressed (renewable) natural gas (CNG/RNG), hybrid electric (HE), battery electric (BE) and fuel-cell hydrogen (H2) vehicles. Evaluated these alternatives using five criteria: economic; business, incentives & market-related; environmental & regulatory; infrastructure; and safety & vehicle performance factors; and twenty-one sub-criteria.

The estimated weights for the criteria and sub-criteria show that economic factors are the most important factors, while environmental and regulatory factors the least. Which is consistent with the revealed choices in the system, and the ultimate ranking estimated by the model resulting in Diesel vehicles to be the preferred alternative, and battery electric and fuel cell

[7] https://www.arb.ca.gov/msprog/actruck/mtg/170425draftacltsurvey.pdf

vehicles lagging. However, the results show that there is an acknowledgement that under a stricter environmental regulatory environment the preferred choices are battery electric and fuel cell vehicles. It was also interesting to find the availability of maintenance and repair shops, and depot charging/fueling infrastructure to have the largest joint weights. This is significant considering that the least important factor was fueling/charging time. Perhaps because for last mile distribution, the majority of vehicles return to the depot, and if infrastructure is available, the fueling/charging time is negligible as it could be done overnight (or after the daily activity).

Incentives do not seem to affect much the ultimate choice, which could be explained by the fact that there are no incentives for the already selected preferred alternative (i.e., diesel vehicles). This alternative is very dominant as demonstrated by the sensitivity analyses. If non-financial incentives are to be used, they have a relative weight to be about 25% lower than for financial incentives.

Overall, these results show on one hand the challenges to foster the use of zero emission vehicles, where the CCR values are almost half than for the preferred alternative. On the other hand, well-structured regulatory programs that incentivize environmental metrics, promote the technologies and support industries (repair, charging infrastructure) can have a positive impact over vehicle choices.

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Data Management

Products of Research

1. Stated-Preference Data: Collected through and online (Qualtrics) survey. The data was collected in two deployments during the first semester (1st deployment) and the summer of 2019 (2nd deployment). The team received approval (exemption from IRB). The data has no business identifier.
2. Expert Assessment Data: The team developed a collected data from three experts about pairwise comparisons among determinants and factors for vehicle technology assessment. The data helped implement a Multi-Criteria Decision-Making (MCDM) tool based on a Spherical Fuzzy Analytical Hierarchy Process model.

Data Format and Content

1. Stated-Preference Data: Excel Workbook (.xlsx). These are open datasets. There will be no changes or updates to the data. The data contains the question asked in each row.
2. Expert Assessment Data: Excel Workbook (.xlsx). These are open datasets. There will be no changes or updates to the data.

Data Access and Sharing

The team is sharing the survey and expert responses without any company identification for general use. The respondents were asked to respond to the survey anonymously. A separate data (confidential) has the contact information. However, the contact information is not linked to the survey responses.

Reuse and Redistribution

The PI and co-authors hold the intellectual property rights to the data. The team allows for the use of the data with the proper citation and attribution to the research team and project.

Jaller, Miguel et al. (2020), Project Report: Fostering the Use of Zero and Near Zero Emission Vehicles in Freight Operations, UC Davis, Dataset, https://doi.org/10.25338/B8MC8W

Appendix A. Laws, Regulations, and Programs

Table 13. State laws and regulations regarding zero emission vehicles

Establishment of Zero Emission Vehicle (ZEV) and Near-ZEV Component Rebates
Access to Plug-In Electric Vehicle (PEV) Registration Records
Alternative Fuel and Hybrid Electric Vehicle Retrofit Regulations
Alternative Fuel and Vehicle Policy Development
Alternative Fuel Tax
Alternative Fuel Vehicle (AFV) Parking Incentive Programs
Alternative Fuel Vehicle Retrofit Emissions Inspection Process
Autonomous Vehicle (AV) Testing and Operation Requirements
Biomethane Promotion
Contra Costa Transportation Authority (CCTA) Autonomous Vehicle (AV) Pilot Authorization
Electric Vehicle Supply Equipment (EVSE) Assessment
Electric Vehicle Supply Equipment (EVSE) Local Permitting Policies
Electric Vehicle Supply Equipment (EVSE) Location Assessment
Electric Vehicle Supply Equipment (EVSE) Open Access Requirements
Electric Vehicle Supply Equipment (EVSE) Policies for Multi-Unit Dwellings
Electric Vehicle Supply Equipment (EVSE) Policies for Residential and Commercial Renters
Electric Vehicle Supply Equipment (EVSE) Signage Authorization on Highways
Emission Reduction Strategy for Medium- and Heavy-Duty Vehicles
Emissions Reduction Requirements for Transportation Network Companies (TNCs)
Establishment of a Zero Emission Medium- and Heavy-Duty Vehicle Program
Fleet Emissions Reduction Requirements - South Coast
Fleet Vehicle Procurement Requirements
Freight Efficiency Action Plan
Heavy-Duty Truck Idle Reduction Requirement
Heavy-Duty Vehicle Emissions Inspection Program Regulations
Heavy-Duty Vehicle Greenhouse Gas (GHG) Emissions Regulations
Hydrogen Fuel Specifications
Hydrogen Fueling Station Evaluation
Idle Reduction Requirement at Schools
Low Carbon Fuel Standard
Low Emission Vehicle (LEV) Standards
Low-Speed Electric Vehicle (EV) Access to Roadways
Mandatory Electric Vehicle Supply Equipment (EVSE) Building Standards
Mobile Source Emissions Reduction Requirements
Neighborhood Electric Vehicle (NEV) Transportation Plan
Plug-In Electric Vehicle (PEV) Charging Access
Plug-In Electric Vehicle (PEV) Charging Electricity Exemption
Plug-In Electric Vehicle (PEV) Charging Requirements
Plug-In Electric Vehicle (PEV) Grid Integration Requirements
Plug-In Electric Vehicle (PEV) Infrastructure Information Resource

Plug-in Electric Vehicle (PEV) Parking Space Regulation
Public Utility Definition
State Agency Electric Vehicle Supply Equipment (EVSE) Installation
State Agency Low Carbon Fuel Use Requirement
State Transportation Plan
Support for Idle Reduction Efforts
Support for Plug-In Electric Vehicles (PEVs)
Support for Zero-Emission and Autonomous Vehicle Infrastructure
Tire Inflation Requirement
Utility Electric Vehicle Supply Equipment (EVSE) Allowance
Vehicle Acquisition and Petroleum Reduction Requirements
Volkswagen Group of America's (VW) Zero Emission Vehicle (ZEV) Investment Plan
Voluntary Vehicle Retirement and Replacement Grants
Zero Emission Vehicle (ZEV) Deployment Support
Zero Emission Vehicle (ZEV) Fee
Zero Emission Vehicle (ZEV) Initiative
Zero Emission Vehicle (ZEV) Production Requirements
Zero Emission Vehicle (ZEV) Programs Report
Zero Emission Vehicle (ZEV) Promotion Plan
Zero-Emission Airport Shuttle Requirement
Zero-Emission Transit Bus Requirement

Table 14. State incentive programs

Advanced Transportation Tax Exclusion
Air Quality Improvement Program Funding - San Luis Obispo County
Air Quality Improvement Program Funding - Ventura County
Alternative Fuel and Advanced Vehicle Rebate - San Joaquin Valley
Alternative Fuel and Vehicle Incentives
Alternative Fuel Vehicle (AFV) and Fueling Infrastructure Grants
Alternative Fuel Vehicle (AFV) Incentives - San Joaquin Valley
Alternative Fuel Vehicle (AFV) Rebate - Antelope Valley
Alternative Fuel Vehicle (AFV) Technical Training - San Joaquin Valley
Clean Vehicle Rebate - El Dorado County
Compressed Natural Gas (CNG) and Electricity Tax Exemption for Transit Use
Electric Vehicle Supply Equipment (EVSE) Incentive Program Support
Electric Vehicle Supply Equipment (EVSE) Incentives - San Joaquin Valley
Electric Vehicle Supply Equipment (EVSE) Loan and Rebate Program
Electric Vehicle Supply Equipment (EVSE) Pilot Programs
Electric Vehicle Supply Equipment (EVSE) Rebate - Fresno County
Electric Vehicle Supply Equipment (EVSE) Rebate - Sacramento County
Electric Vehicle Supply Equipment (EVSE) Rebate - South Coast and MSRC
Electric Vehicle Supply Equipment (EVSE) Rebate - Southern California
Emissions Reductions Grants
Employer Invested Emissions Reduction Funding - South Coast
Heavy-Duty Truck Emission Reduction Grants - San Joaquin Valley
Heavy-Duty Vehicle Emissions Reduction Grants
High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) Lane Exemption
Low Emission Truck and Bus Purchase Vouchers
Natural Gas Vehicle (NGV) Incentives
Plug-In Electric Vehicle (PEV) and Hybrid Electric Vehicle (HEV) Grant - Bay Area
Plug-In Hybrid and Zero Emission Light-Duty Public Fleet Vehicle Fleet Rebates
Plug-In Hybrid and Zero Emission Light-Duty Vehicle Rebates
Residential Electric Vehicle Supply Equipment (EVSE) Financing Program
Technology Advancement Funding - South Coast
Vehicle Emissions Reduction Grants - Sacramento
Vehicle Emissions Reduction Incentives - San Joaquin Valley
Voluntary Vehicle Retirement and Replacement Incentives
Voluntary Vehicle Retirement Incentives - San Joaquin Valley and South Coast
Zero Emission Vehicle (ZEV) and Near-ZEV Weight Exemption
Zero-Emission Transit Bus Tax Exemption

Table 15. Utility and private incentives

All-Electric Vehicle (EV) Rebate - MCE
Commercial Electric Vehicle Supply Equipment (EVSE) Rebate - Pasadena Water and Power (PWP)
Compressed Natural Gas (CNG) Credit - PG&E
Electric Vehicle Supply Equipment (EVSE) and Charging Incentives - Sonoma Clean Power
Electric Vehicle Supply Equipment (EVSE) Incentives for Commercial Customers - PG&E
Electric Vehicle Supply Equipment (EVSE) Incentives for Medium- and Heavy-Duty Fleets - PG&E
Electric Vehicle Supply Equipment (EVSE) Rebate - Alameda Municipal Power (AMP)
Electric Vehicle Supply Equipment (EVSE) Rebate - Azusa Light & Water
Electric Vehicle Supply Equipment (EVSE) Rebate - Burbank Water and Power (BWP)
Electric Vehicle Supply Equipment (EVSE) Rebate - Glendale Water and Power (GWP)
Electric Vehicle Supply Equipment (EVSE) Rebate - LADWP
Electric Vehicle Supply Equipment (EVSE) Rebate for Businesses - SCE
Electric Vehicle Supply Equipment (EVSE) Rebates - Anaheim Public Utilities (APU)
Electric Vehicle Supply Equipment (EVSE) Rebates for Businesses - SMUD
Ethanol and Renewable Diesel Volume Rebate Program - Propel Fuels
Multi-Unit Dwelling (MUD) and Workplace Electric Vehicle Supply Equipment (EVSE) Incentive - SDG&E
Multi-Unit Dwelling (MUD) and Workplace Electric Vehicle Supply Equipment (EVSE) Incentives - PG&E
Multi-Unit Dwelling (MUD) and Workplace Electric Vehicle Supply Equipment (EVSE) Rebate - MCE
Natural Gas Rate Reduction - SoCalGas
Natural Gas Vehicle Loan - SoCalGas
Non-Residential Electric Vehicle Supply Equipment (EVSE) Grants - Pacific Power
Plug-In Electric Vehicle (PEV) and Compressed Natural Gas (CNG) Rate Reduction - PG&E
Plug-In Electric Vehicle (PEV) and Natural Gas Infrastructure Charging Rate Reduction - SDG&E
Plug-In Electric Vehicle (PEV) Charging Rate Reduction - Alameda Municipal Power (AMP)
Plug-In Electric Vehicle (PEV) Charging Rate Reduction - Azusa Light & Water
Plug-in Electric Vehicle (PEV) Charging Rate Reduction - Bear Valley Electric Service (BVES)
Plug-In Electric Vehicle (PEV) Charging Rate Reduction - Burbank Water and Power (BWP)
Plug-In Electric Vehicle (PEV) Charging Rate Reduction - LADWP
Plug-In Electric Vehicle (PEV) Charging Rate Reduction - SCE
Plug-In Electric Vehicle (PEV) Charging Rate Reduction - SMUD
Plug-In Electric Vehicle (PEV) Rebate - Pasadena Water and Power (PWP)
Plug-In Electric Vehicle (PEV) Rebate - PG&E
Plug-In Electric Vehicle (PEV) Rebate - SCE
Residential Electric Vehicle Supply Equipment (EVSE) Incentives - SMUD
Residential Electric Vehicle Supply Equipment (EVSE) Rebate - Pasadena Water and Power (PWP)
Used Plug-in Electric Vehicle (PEV) Rebate Program - LADWP
Used Plug-In Hybrid Electric Vehicle (PHEV) Incentive - Peninsula Clean Energy (PCE)

Appendix B. Stated Preference Survey Cover Letter

National Center for Sustainable Transportation

ITS UCDAVIS INSTITUTE OF TRANSPORTATION STUDIES

DEVELOPMENT OF INCENTIVES PROGRAM FOR ZERO EMISSION VEHICLES IN FREIGHT DISTRIBUTION

A recent study about the total cost of ownership found that zero-emission vehicles are a feasible option for various delivery vocations. However, there are still uncertainties about the economic savings, technical specifications, and infrastructure requirements of such vehicles. Moreover, there is not a marketplace, and more importantly, savings vary depending on the actual vocation, level of use, and incentives available.

Researchers at the National Center for Sustainable Transportation from the University of California Davis, are conducting this study to understand the perception of companies like yours towards the adoption of zero-emission vehicles. The information you provide will help inform the design of better incentives and programs to facilitate the adoption of zero-emission technologies.

We need your help in this effort.

To help us, please complete this survey (or share with the most appropriate person within your company). No one knows more about the transportation needs of your business than you do. For that reason, you are the best source of good information for our study. Please access the survey by clicking the following link:

Zero Emissions Trucks Survey

If it does not work, please copy and paste or type the following web address in your browser:

http://bit.ly/truck-zev

Your participation is voluntary, and your responses are extremely important to us. The survey should take about 40 minutes to complete, and we think you will find it interesting and fun to do. Please be assured that your responses will remain confidential and we will never disclose to others outside the research team any information that you may provide.

By completing the survey, you will be entered into a drawing for the chance to win one of twenty-five $200 gift cards. Once you complete the survey, the online system will provide a link to a separate form to provide the information for the drawing. If you do not want to participate in the survey but want to be entered into the drawing, please contact us by email.

To ensure the timely inclusion of your responses in the study and entry into the prize drawing, please complete the survey by April 10th, 2019. If you are unable to fill out the questionnaire by then, we would still welcome it as soon as you can.

The survey has 6 sections and you can use the back button at the bottom of the questions to go to the previous section (except when answering section 3). You can stop answering the survey at any time.

Thank you for participating in this study. If you would like more information about the survey or have any questions, please contact Miguel Jaller at mjaller@ucdavis.edu or call the number 530-752-7062.

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IRB: 1379618-1

Appendix C. Stated Preference Survey Instrument

Standard: INTRODUCTION (1 Question)
Standard: SECTION 1: GENERAL BACKGROUND INFORMATION AND VEHICLE FLEET CHARACTERISTICS (12 Questions)
Standard: SECTION 2: VEHICLE ACQUISITION PREFERENCES AND VEHICLE TECHNOLOGIES KNOWLEDGE (17 Questions)
Standard: SECTION 3: UNDERSTANDING PREFERENCES ABOUT BATTERY ELECTRIC (2 Questions)

Block Randomizer: 1 -

Block: Block 1 (15 Questions)
Block: Block 2 (15 Questions)
Block: Block 3 (15 Questions)
Standard: Block 4 (15 Questions)

Standard: SECTION 4: COMPANY AND FACILITY INFORMATION (6 Questions)
Standard: SECTION 5: FREIGHT AND FREIGHT TRIP GENERATION (8 Questions)
Standard: SECTION 6: DAILY VEHICLE OPERATIONS (8 Questions)

Start of Block: INTRODUCTION

Q1 **DEVELOPMENT OF INCENTIVES PROGRAM FOR ZERO EMISSION VEHICLES IN FREIGHT DISTRIBUTION**

End of Block: INTRODUCTION

Start of Block: SECTION 1: GENERAL BACKGROUND INFORMATION AND VEHICLE FLEET CHARACTERISTICS

Q2
We want to collect general information about your company's operations, as well as other more specific questions related to the vehicle fleet at your facility.

Facility refers to the establishment, terminal, or any other location where you operate your vehicle fleet from. If your company operates multiple facilities, please answer the following questions based on the one you are most familiar with.

Q3 **Section 1: General Background Information and Vehicle Fleet Characteristics.**

Q4
Thank you for agreeing to answer these questions

In this section, we want to know some characteristics of your company and vehicle fleet.

Q4 1. What is your company's main type of operation?

- O Last mile delivery (1)
- O Long haul transport (2)
- O Refuse (3)
- O Construction (4)
- O Drayage (5)

- O Parcel delivery (6)
- O Other (please specify): (7) ____

Q5 2. Where does your company conduct most of the business?

- O Southern California (1)
- O The Bay Area (2)
- O San Joaquin Valley (3)
- O The Sacramento Area (4)
- O Northern California (5)
- O Other (please specify): (6) ____

Q6 3. What best describes your position in your company?

- O Owner (1)
- O Owner/Operator (2)
- O Fleet Manager (3)
- O Operations Manager (4)
- O Driver (5)
- O Dispatch Manager (6)
- O Sales Manager (7)
- O Customer Service Manager (8)
- O Other: (9) ____

Q7 4. Does your company operate a vehicle fleet at this facility?

- O Yes (1)
- O No (2)

Display This Question:
If Q7 = 1

Q8 5. Number of vehicles **operated at the facility** by vehicle class and technology

Please provide the number of vehicles by class and technology where corresponds. If you don't know the vehicle technology, please use the "Do not know" column to specify the number of vehicles for the class. Please exclude employee vehicles not used to ship goods.

	# Vehicles per technology						
	Gasoline (1)	Diesel (2)	CNG/LNG (3)	Hybrid Electric (4)	Battery Electric (5)	Fuel Cell Electric (6)	Do not know (7)
Passenger cars/ Small pickups/vans (1)							
Class 3 (GVWR 10,001-14,000 lbs.) (2)							
Class 4 (GVWR 14,001-16,000 lbs.) (3)							
Class 5 (GVWR 16,001-19,500 lbs.) (4)							
Class 6 (GVWR 19,501-26,000 lbs.) (5)							
Class 7 (GVWR 26,001-33,000 lbs.) (6)							
Class 8 (GVWR 33,001-100,000 lbs.) (7)							
Others/ not specified: (8)							

Display This Question:
If Q7 = 1

Q9 6. What is the **average annual mileage of a vehicle** in your fleet?

- O Less than 12,000 miles (1)
- O 12,001 to 24,000 miles (2)
- O 24,001 to 36,000 miles (3)
- O 36,001 to 48,000 miles (4)
- O 48,001 to 60,000 miles (5)
- O More than 60,000 miles (6)

Q10 7. Where do you park your vehicles overnight **when not in operation**? Select all that apply.

- O At the facility (1)
- O On-street (2)
- O Public parking lot, truck yard (3)
- O Other (please specify): (4) ____

Q11 8. Where do you maintain or repair the fleet? Select all that apply.

- O Authorized/Dealer Shop (1)
- O Own Shop (2)
- O Other (please specify): (3) ____

Q12 9. Do you have a vehicle fueling/charging station **at your facility**?

- O Yes (1)
- O No (2)

End of Block: SECTION 1: GENERAL BACKGROUND INFORMATION AND VEHICLE FLEET CHARACTERISTICS

Start of Block: SECTION 2: VEHICLE ACQUISITION PREFERENCES AND VEHICLE TECHNOLOGIES KNOWLEDGE

Q13 **Section 2: Vehicle Acquisition Preferences and Vehicle Technologies Knowledge**

Q14
For the purpose of this study, **it is critical that we understand how your company makes vehicle acquisition** (e.g., leasing, purchasing) decisions, and **how the company selects the type of vehicle technologies** for the fleet.

Q15 10. **Why** does your company usually acquire vehicle(s)? Select all that apply. If your company is not acquiring a vehicle in the next 2-3 years or is downsizing the fleet, please select Does not apply.

- Replacing vehicle(s) in the fleet (1)
- Adding new vehicle(s) to the fleet (2)
- The first vehicle(s) in the fleet (3)
- Comply with environmental regulations (6)
- Does not apply (7)

Display This Question:
If Q15 = 6

Q16 Your opinion is very important for us!
Even if your company is not currently acquiring or planning to acquire a vehicle, please answer the rest of the survey questions based on previous experiences.

Q17 11. **How** does your company usually acquire a vehicle? Select all that apply.

- Rent/Lease (2)
- Financed purchase (3)
- Full payment purchase (4)
- Other (please specify): (1) ____

Q18 12. During the acquisition process, what **type of vehicle** does your company consider? Select all that apply.

- New (1)
- Used (2)
- Retrofitted (3)

Q19
13. What is the expected **payback period (in years)** for a vehicle acquisition?

- 0 to 1 year (2)
- 1 to 3 years (3)
- 3 to 5 years (4)
- 5 to 10 years (5)
- 10 years or more (6)

Q20 14. For **how long (years)** does your company hold vehicles?

- O 0 to 1 year (2)
- O 1 to 3 years (3)
- O 3 to 5 years (4)
- O 5 to 10 years (5)
- O 10 years or more (6)

Q21 15. How important are the following criteria for selecting a vehicle technology?

	Not at all important (1)	Slightly important (2)	Important (3)	Very important (4)	Extremely important (5)
Total cost of ownership (1)	O	O	O	O	O
Purchase price (2)	O	O	O	O	O
Vehicle purchase cost voucher incentive (3)	O	O	O	O	O
Leasing/Financing availability (4)	O	O	O	O	O
Environmental considerations (5)	O	O	O	O	O
Brand image (6)	O	O	O	O	O
Vehicle reliability (7)	O	O	O	O	O
Maintenance and repair costs (8)	O	O	O	O	O
Energy consumption and costs (9)	O	O	O	O	O
Resale value (10)	O	O	O	O	O
Maintenance and repair shop availability (11)	O	O	O	O	O
Fueling/ Charging Infrastructure availability (12)	O	O	O	O	O

	Not at all important (1)	Slightly important (2)	Important (3)	Very important (4)	Extremely important (5)
Fueling/Charging infrastructure costs (13)	○	○	○	○	○
Fueling/Charging time (14)	○	○	○	○	○
Driving range (15)	○	○	○	○	○
Availability of different vehicles technologies and options in the market (16)	○	○	○	○	○
Legislatively mandated standards (17)	○	○	○	○	○
Other (please specify): (18)	○	○	○	○	○

Q22 16. If your company was to consider a battery electric vehicle, what would be the **minimum range requirement**?

____

Q23 17. What is your information level on new vehicle technologies?

	Not informed at all (1)	Somewhat informed (2)	Well informed (3)	Very well informed (4)
Gasoline (1)	○	○	○	○
Diesel (2)	○	○	○	○
CNG (3)	○	○	○	○
LNG (4)	○	○	○	○
Hybrid Electric (5)	○	○	○	○
Battery Electric (6)	○	○	○	○
Fuel Cell Electric (7)	○	○	○	○

Q24 18. How do you keep yourself informed about the latest vehicle technologies? Select all that apply.

- O Trucking fairs (1)
- O Trucking journals (2)
- O Truck manufacturers and dealers (3)
- O Other transport companies (4)
- O Internet (5)
- O Other (please specify): (6) ____

Q25 19. Is your company familiar with any financial incentive program that supports the adoption of zero- or near-zero-emission vehicle technologies? If yes, please indicate which one(s).

- O Yes (1) ____
- O No (2)

Display This Question:
If Q25 = 1

Q26 20. Has the company benefitted from any of these programs? If yes, please indicate which one(s).

- O Yes (1) ____
- O No (2)

Q27 21. How important is the introduction of the following **incentives programs or benefits for zero-emission vehicles**? If you think of any other not included, please list it in the "Other" option.

	Not at all important (1)	Slightly important (2)	Important (3)	Very important (4)	Extremely important (5)
Preferential access permit (1)	O	O	O	O	O
Public recognition programs (2)	O	O	O	O	O
Contract bidding preference (3)	O	O	O	O	O
Tax breaks (4)	O	O	O	O	O
Access to preferential loading/unloading zones (5)	O	O	O	O	O
Other (please specify): (6)	O	O	O	O	O

Q28 22. How likely is your company to consider the following technologies in the next vehicle acquisition decision?

	Extremely unlikely (1)	Somewhat unlikely (2)	Neither likely nor unlikely (3)	Somewhat likely (4)	Extremely likely (5)
Gasoline (1)	O	O	O	O	O
Diesel (2)	O	O	O	O	O
CNG (3)	O	O	O	O	O
LNG (4)	O	O	O	O	O
Hybrid Electric (5)	O	O	O	O	O
Battery Electric (6)	O	O	O	O	O
Fuel Cell Electric (7)	O	O	O	O	O

Q29 23. Does your company plan to acquire a vehicle in the next 12-18 months?

- O Yes (1)
- O No (2)

End of Block: SECTION 2: VEHICLE ACQUISITION PREFERENCES AND VEHICLE TECHNOLOGIES KNOWLEDGE

Start of Block: SECTION 3: UNDERSTANDING PREFERENCES ABOUT BATTERY ELECTRIC

Q30 Section 3: Understanding Preferences about Battery Electric Vehicles

Q31

In the following questions, **we want to understand your company's perception towards battery electric vehicles. Please answer the next five question sets independently from each other.**

Each question set has three steps. First, please choose between the three vehicle configurations Conventional Diesel Vehicle, Battery Electric Vehicle Package 1 and Battery Electric Vehicle Package 2. Second, select only between the two battery electric vehicle package configurations. And finally, indicate the likelihood of acquiring the selected battery electric vehicle package configuration compared to a conventional diesel vehicle. Each battery electric truck configuration has different specifications for the following attributes:

Purchase voucher incentive	Value of incentive you receive based on a percentage of the price of the battery electric vehicle.
Fuel efficiency	Percent change (increase or decrease) of fuel efficiency equivalent compared to the comparable diesel vehicle.
Maintenance and repair costs	Percent change (increase or decrease) of maintenance and repair costs compared to the comparable diesel vehicle.
Driving range	Miles until the battery is depleted.
Permission to park, load or unload in designated areas in the city/corridor (Priority Parking Permit)	Assume that the city will designate areas and zones to park/load/unload goods. This permit will provide preferential access to those areas to the battery electric vehicle.
Permission to use bus lanes and high-occupancy vehicle (HOV, HOT) lanes (Special Lane Use Permit)	The battery electric vehicle will be allowed to use these lanes.
Public recognition program	Public agencies will develop a recognition program that publicizes the companies that participate in environmentally friendly initiatives such as the use of zero-emission vehicles.
Preference during official bidding/contracting	Public agencies will give preference to companies using environmentally friendly initiatives such as the use of zero-emission vehicles when selecting winning contract bids.
Market share of battery electric vehicles	Market share (percentage) of battery electric vehicles in your area.

24. Please select the vehicle class to be used as reference for the following questions.

- O Class 3 (GWVR 10,001-14,000 lbs.) (1)
- O Class 4 (GWVR 14,001-16,000 lbs.) (2)
- O Class 5 (GWVR 16,001-19,500 lbs.) (3)
- O Class 6 (GWVR 19,501-26,000 lbs.) (4)
- O Class 7 (GWVR 26,001-33,000 lbs.) (5)
- O Class 8 (GWVR 33,001-100,000 lbs.) (6)

End of Block: SECTION 3: UNDERSTANDING PREFERENCES ABOUT BATTERY ELECTRIC

Start of Block: Block 1

Q32 Option Set 1. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes

25. Considering the following **vehicle configurations**, please select your preferred alternative:

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	60% increase	0%
Change in maintenance and repair costs compared to diesel vehicle	None	30% decrease	0%
Driving range (miles)	Class Average	500	150
Financial and non-financial incentives			
Purchase voucher incentive	None	50%	15%
Incentive package A	None	Priority Parking Permit	Priority Parking Permit AND Special Lane Use Permit
Incentive package B	None	Public Recognition Program	Public Recognition AND Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Early adopters [5%]	Mass production [15%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q33 26a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q34 26b. How likely is your company to acquire the selected ${Q33/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q35 Option Set 2. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices vehicle for your ${Q4/ChoiceGroup/SelectedChoicesTextEntry} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

27. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	0%	80% increase
Change in maintenance and repair costs compared to diesel vehicle	None	30% decrease	0%
Driving range (miles)	Class Average	150	300
Financial and non-financial incentives			
Purchase voucher incentive	None	50%	15%
Incentive package A	None	Priority Parking Permit AND Special Lane Use Permit	Priority Parking Permit
Incentive package B	None	Public Recognition AND Contract and Bidding Preference	Public Recognition
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Successful Pilot Testing [1%]	Mass production [15%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q36 28a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q37 28b. How likely is your company to acquire the selected ${Q35/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q38 Option Set 3. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

29. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	0%	60% increase
Change in maintenance and repair costs compared to diesel vehicle	None	10% decrease	0%
Driving range (miles)	Class Average	500	150
Financial and non-financial incentives			
Purchase voucher incentive	None	15%	30%
Incentive package A	None	Priority Parking Permit	None
Incentive package B	None	Public Recognition AND Contract and Bidding Preference	Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Successful Pilot Testing [1%]	Mass production [15%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q39 30a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q40 30b. How likely is your company to acquire the selected ${Q39/ChoiceGroup/SelectedChoices} battery electric vehicle configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q41 Option Set 4. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

31. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	60% increase	0%
Change in maintenance and repair costs compared to diesel vehicle	None	10% decrease	0%
Driving range (miles)	Class Average	500	300
Financial and non-financial incentives			
Purchase voucher incentive	None	15%	50%
Incentive package A	None	Special Lane Use Permit	None
Incentive package B	None	Contract and Bidding Preference	None
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Mass production [15%]	Early Adopters [5%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q42 32a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q43 32b. How likely is your company to acquire the selected ${Q42/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q44 Option Set 5. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

33. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	0%	80% increase
Change in maintenance and repair costs compared to diesel vehicle	None	0%	30% decrease
Driving range (miles)	Class Average	500	300
Financial and non-financial incentives			
Purchase voucher incentive	None	15%	0%
Incentive package A	None	None	Priority Parking AND Special Lane Use Permit
Incentive package B	None	Contract and Bidding Preference	Public Recognition AND Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Successful Pilot Testing [1%]	Mass production [15%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q45 34a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q46 34b. How likely is your company to acquire the selected ${Q45/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

End of Block: Block 1

Start of Block: Block 2

Q47 Option Set 1. Imagine you are deciding on acquiring a ${Q81/ChoiceGroup/SelectedChoices} vehicle for your ${Q15/ChoiceGroup/SelectedChoices} operation in ${Q16/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

25B. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	0%	60% increase
Change in maintenance and repair costs compared to diesel vehicle	None	30% decrease	10% decrease
Driving range (miles)	Class Average	300	150
Financial and non-financial incentives			
Purchase voucher incentive	None	0%	50%
Incentive package A	None	Special Lane Use Permit	Priority Parking Permit
Incentive package B	None	Public Recognition	None
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Successful Pilot Testing [1%]	Mass production [15%]

- Conventional Diesel Vehicle (1)
- Battery Electric Vehicle Package 1 (2)
- Battery Electric Vehicle Package 2 (3)

Q48 26B-a. If you only had to choose among the two battery electric packages, which one would you select?

- Battery Electric Vehicle Package 1 (1)
- Battery Electric Vehicle Package 2 (2)

Q49 26B-b. How likely is your company to acquire the selected ${Q48/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- Extremely unlikely (1)
- Somewhat unlikely (2)
- Neither likely nor unlikely (3)
- Somewhat likely (4)
- Extremely likely (5)

Q50 Option Set 2. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

27B. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	60% increase	0%
Change in maintenance and repair costs compared to diesel vehicle	None	10% decrease	30% decrease
Driving range (miles)	Class Average	150	500
Financial and non-financial incentives			
Purchase voucher incentive	None	0%	15%
Incentive package A	None	None	Priority Parking AND Special Lane Use Permit
Incentive package B	None	Public Recognition AND Contract and Bidding Preference	None
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Successful Pilot Testing [1%]	Early Adopters [5%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q51 28B-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q52 28B-b. How likely is your company to acquire the selected ${Q51/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q53 Option Set 3. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

29B. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	80% increase	60% increase
Change in maintenance and repair costs compared to diesel vehicle	None	10% decrease	30% decrease
Driving range (miles)	Class Average	500	150
Financial and non-financial incentives			
Purchase voucher incentive	None	0%	30%
Incentive package A	None	None	Special Lane Use Permit
Incentive package B	None	Contract and Bidding Preference	None
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Early Adopters [5%]	Successful Pilot Testing [1%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q54 30B-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q55 30B-b. How likely is your company to acquire the selected ${Q54/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q56 Option Set 4. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes

31B. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	0%	80% increase
Change in maintenance and repair costs compared to diesel vehicle	None	0%	10% decrease
Driving range (miles)	Class Average	150	300
Financial and non-financial incentives			
Purchase voucher incentive	None	0%	15%
Incentive package A	None	Priority Parking Permit	None
Incentive package B	None	Public Recognition	Public Recognition AND Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Mass Production [15%]	Early Adopters [5%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q57 32B-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q58 32B-b. How likely is your company to acquire the selected ${Q57/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q59 Option Set 5. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

33B. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	80% increase	60% increase
Change in maintenance and repair costs compared to diesel vehicle	None	10% decrease	0%
Driving range (miles)	Class Average	150	300
Financial and non-financial incentives			
Purchase voucher incentive	None	50%	30%
Incentive package A	None	Special Lane Use Permit	Priority Parking Permit
Incentive package B	None	None	Public Recognition AND Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Mass Production [15%]	Successful Pilot Testing [1%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q60 34B-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q61 34B-b. How likely is your company to acquire the selected ${Q60/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

End of Block: Block 2

Start of Block: Block 3

Q62 Option Set 1. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

25C. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	60% increase	80% increase
Change in maintenance and repair costs compared to diesel vehicle	None	0%	30% decrease
Driving range (miles)	Class Average	300	500
Financial and non-financial incentives			
Purchase voucher incentive	None	0%	30%
Incentive package A	None	Special Lane Use Permit	None
Incentive package B	None	None	Public Recognition
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Early Adopters [5%]	Mass Production [15%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q63 26C-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q64 26C-b. How likely is your company to acquire the selected ${Q63/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q65 Option Set 2. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

27C. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	80% increase	60% increase
Change in maintenance and repair costs compared to diesel vehicle	None	0%	30% decrease
Driving range (miles)	Class Average	300	500
Financial and non-financial incentives			
Purchase voucher incentive	None	50%	15%
Incentive package A	None	Special Lane Use Permit	None
Incentive package B	None	Contract and Bidding Preference	None
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Successful Pilot Testing [1%]	Mass Production [15%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q66 28C-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q67 28C-b. How likely is your company to acquire the selected ${Q66/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q68 Option Set 3. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

29C. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	80% increase	0%
Change in maintenance and repair costs compared to diesel vehicle	None	10% decrease	30% decrease
Driving range (miles)	Class Average	500	150
Financial and non-financial incentives			
Purchase voucher incentive	None	30%	15%
Incentive package A	None	Priority Parking AND Special Lane Use Permit	None
Incentive package B	None	Public Recognition	Public Recognition AND Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Successful Pilot Testing [1%]	Early Adopters [5%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q69 30C-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q70 30C-b. How likely is your company to acquire the selected ${Q69/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q71 Option Set 4. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

31C. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	60% increase	80% increase
Change in maintenance and repair costs compared to diesel vehicle	None	0%	30% decrease
Driving range (miles)	Class Average	500	300
Financial and non-financial incentives			
Purchase voucher incentive	None	0%	30%
Incentive package A	None	Priority Parking AND Special Lane Use Permit	Priority Parking Permit
Incentive package B	None	Public Recognition	Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Early Adopters [5%]	Mass Production [15%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q72 32C-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q73 32C-b. How likely is your company to acquire the selected ${Q72/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q74 Option Set 5. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

33C. Considering the following vehicle configurations, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	80% increase	0%
Change in maintenance and repair costs compared to diesel vehicle	None	0%	10% decrease
Driving range (miles)	Class Average	500	150
Financial and non-financial incentives			
Purchase voucher incentive	None	50%	30%
Incentive package A	None	Special Lane Use Permit	Priority Parking AND Special Lane Use Permit
Incentive package B	None	Pub Public Recognition AND Contract and Bidding Preference	Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Mass Production [15%]	Early Adopters [5%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q75 34C-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q76 34C-b. How likely is your company to acquire the selected ${Q75/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

End of Block: Block 3

Start of Block: Block 4

Q77 Option Set 1. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

25D. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	60% increase	80% increase
Change in maintenance and repair costs compared to diesel vehicle	None	10% decrease	0%
Driving range (miles)	Class Average	300	500
Financial and non-financial incentives			
Purchase voucher incentive	None	50%	0%
Incentive package A	None	Special Lane Use Permit	Priority Parking Permit
Incentive package B	None	Pub Public Recognition	None
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Early Adopters [5%]	Successful Pilot Testing [1%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q78 26D-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q79 26D-b. How likely is your company to acquire the selected ${Q78/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q80 Option Set 2. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

27D. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	0%	80% increase
Change in maintenance and repair costs compared to diesel vehicle	None	10% decrease	30% decrease
Driving range (miles)	Class Average	500	150
Financial and non-financial incentives			
Purchase voucher incentive	None	30%	15%
Incentive package A	None	Special Lane Use Permit	Priority Parking AND Special Lane Use Permit
Incentive package B	None	Public Recognition AND Contract and Bidding Preference	Public Recognition
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Successful Pilot Testing [1%]	Mass Production [15%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q81 28D-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q82 28D-b. How likely is your company to acquire the selected ${Q81/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q83 Option Set 3. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

29D. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	0%	80% increase
Change in maintenance and repair costs compared to diesel vehicle	None	10% decrease	30% decrease
Driving range (miles)	Class Average	300	500
Financial and non-financial incentives			
Purchase voucher incentive	None	50%	0%
Incentive package A	None	Priority Parking AND Special Lane Use Permit	Special Lane Use Permit
Incentive package B	None	Public Recognition	Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Mass Production [15%]	Early Adopters [5%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q84 30D-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q85 30D-b. How likely is your company to acquire the selected ${Q84/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q86 Option Set 4. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

31D. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	80% increase	0%
Change in maintenance and repair costs compared to diesel vehicle	None	0%	10% decrease
Driving range (miles)	Class Average	500	300
Financial and non-financial incentives			
Purchase voucher incentive	None	30%	0%
Incentive package A	None	Priority Parking AND Special Lane Use Permit	None
Incentive package B	None	Public Recognition AND Contract and Bidding Preference	None
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Early Adopters [5%]	Successful Pilot Testing [1%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q87 32D-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q88 32D-b. How likely is your company to acquire the selected ${Q87/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

Q89 Option Set 5. Imagine you are deciding on acquiring a ${Q31/ChoiceGroup/SelectedChoices} vehicle for your ${Q4/ChoiceGroup/SelectedChoices} operation in ${Q5/ChoiceGroup/SelectedChoices}.

For your reference, the following table compares average diesel and battery electric vehicles for the various classes.

33D. Considering the following **vehicle configurations**, please select your preferred alternative.

	Conventional Diesel Vehicle	Battery Electric Vehicle Package 1	Battery Electric Vehicle Package 2
Vehicle attributes			
Change in fuel efficiency compared to diesel vehicle	None	80% increase	0%
Change in maintenance and repair costs compared to diesel vehicle	None	0%	10% decrease
Driving range (miles)	Class Average	500	150
Financial and non-financial incentives			
Purchase voucher incentive	None	50%	30%
Incentive package A	None	Special Lane Use Permit	Priority Parking AND Special Lane Use Permit
Incentive package B	None	Public Recognition AND Contract and Bidding Preference	Contract and Bidding Preference
Vehicle technology penetration			
Market share of battery electric vehicles [percentage]		Mass production [15%]	Early Adopters [5%]

- O Conventional Diesel Vehicle (1)
- O Battery Electric Vehicle Package 1 (2)
- O Battery Electric Vehicle Package 2 (3)

Q90 34D-a. If you only had to choose among the two battery electric packages, which one would you select?

- O Battery Electric Vehicle Package 1 (1)
- O Battery Electric Vehicle Package 2 (2)

Q91 34D-b. How likely is your company to acquire the selected ${Q90/ChoiceGroup/SelectedChoices} battery electric configuration compared to a diesel vehicle?

- O Extremely unlikely (1)
- O Somewhat unlikely (2)
- O Neither likely nor unlikely (3)
- O Somewhat likely (4)
- O Extremely likely (5)

End of Block: Block 4

Start of Block: SECTION 4: COMPANY AND FACILITY INFORMATION

Q91 **Thank you for providing the information about your fleet and vehicle acquisition preferences!**

To help us to project the response from this small sample to the population as a whole, we'd like to ask a few questions about your company.

Q92 Section 4: Company and Facility Information

Q93 35. Facility information.

- O City (1) ____
- O State (2) ____
- O Postal code (3) ____
- O Hours of operation (4) ____
- O Number of docks at the facility (5) ____

Q94 36. How many employees work at this facility?

- O Total number of employees except drivers (1) ____
- O Total of number of drivers only (if applicable) (2) ____

Q95 37. What NAICS* codes are applicable to your business?
*(*NAICS: North American Industry Classification System, if not known, please write your primary business activity*)

____

Q96 38. Please rate the impact of the following factors in your daily operations?

	Extremely negative (1)	Somewhat negative (2)	Neither positive nor negative (3)	Somewhat positive (4)	Extremely positive (5)
Vehicle size restrictions (1)	○	○	○	○	○
Parking availability (2)	○	○	○	○	○
Fuel prices (3)	○	○	○	○	○
Traffic/congestion (4)	○	○	○	○	○
Bidding/Contracting requirements (5)	○	○	○	○	○
Environmental regulations (6)	○	○	○	○	○
Driver hours of operation rules (7)	○	○	○	○	○
Driver shortages (8)	○	○	○	○	○
Customer's window hour to receive or ship goods (9)	○	○	○	○	○
Noise regulations (10)	○	○	○	○	○
Other (please specify): (11)	○	○	○	○	○

End of Block: SECTION 4: COMPANY AND FACILITY INFORMATION

Start of Block: SECTION 5: FREIGHT AND FREIGHT TRIP GENERATION

Q97
Thank you! You have provided great information in the last sections.

In the next 2 sections, we want to understand the freight transport activity generated by your facility, and how you conduct your delivery or distribution operations. This is important for us to understand about the vocation requirements, and level of use of the vehicles.

Q98 Section 5: Freight and Freight Trip Generation

Q99 39. On a typical day, how many shipments/orders does your company transport from this facility on average?

____

Q99 40. On a typical day, how many vehicles are used to transport those shipments out of your facility?

____

Q100 41. What type(s) of goods does your company transport? Select all that apply.

- O Perishables (1)
- O Non-Perishables (2)
- O Clothing (3)
- O Food (4)
- O Bulk (5)
- O Parcel (6)
- O Non-alcoholic beverages (7)
- O Alcoholic beverages (8)
- O Grocery (9)
- O Furniture (10)
- O Electronics (11)
- O Office supplies (12)
- O Chemicals (13)
- O Other (please specify): (14) ____

Q101 42. On a typical day, how many shipments/orders does your facility receive on average?

____

Q102 43. On a typical day, how many vehicles arrive at your facility bringing those shipments?

____

Q103 44. Do you transport or fulfill any rush deliveries? e.g., same-day, 2-hour, 1-hour deliveries

- O Yes (1)
- O No (2)

End of Block: SECTION 5: FREIGHT AND FREIGHT TRIP GENERATION

Start of Block: SECTION 6: DAILY VEHICLE OPERATIONS

Q104 Section 6: Daily Vehicle Operations

Q105 For the cargo that your transport in a typical day, we would like to know how the company conducts the delivery operations. Specifically, we want to understand the daily distribution patterns.

Q106 45. On average, how many delivery/distribution tours does a vehicle in your fleet make in a typical day?

____

Q107 46. What is the average number of stops in a typical tour?

____

Q108 47. On average, how many customers do you serve in a typical tour?

____

Q109 48. On average, how many miles does your vehicle travel in a typical tour?

- O Under 50 miles (1)
- O 51 to 100 miles (2)
- O 101 to 150 miles (3)
- O 150 to 300 miles (4)
- O 300 miles or more (5)

Q110 49. How long (in hours) does it take to complete a typical tour?

____

Q111 50. On average, what time are the vehicles in the fleet not in operation?

- O Between 0 – 4 hours between 7AM-9PM (1)
- O Between 4 – 8 (or more) hours between 7AM-9PM (2)
- O Between 0 – 4 hours between 9PM-7AM (3)
- O Between 4 – 8 (or more) hours between 9PM-7AM (4)

End of Block: SECTION 6: DAILY VEHICLE OPERATIONS

Appendix D. Preliminaries on Spherical Fuzzy Sets (SFS)

In spherical fuzzy sets, comprised of membership $(\mu(x))$, non-membership $(v(x))$,, and hesitancy $(\pi(x))$, parameters, the squared sum of these parameters cannot exceed "1" while each of these parameters ranging from "0" and "1" (Kutlu Gündoğdu and Kahraman, 2019).

Definition 1. Let $\tilde{A}_s$ of the universe of discourse set U be a spherical fuzzy set.

$$\tilde{A}_s = \{x, (\mu_1(x), \mu_1(x), \mu_1(x)) | x \in U\} \tag{A1}$$

$$\text{where } 0 \leq \mu_1^2(x) + v_1^2 + \pi_1^2(x) \leq 1 \quad \forall x \in U \text{ and}$$
$$\mu_1(x): U \rightarrow [0,1], v_1(x): U \rightarrow [0,1] \; and \; \pi_1(x): U \rightarrow [0,1]$$

Definition 2. Basic arithmetic operations for$\tilde{A}_1$ $\left(\tilde{A}_1 = \{\langle x, (\mu_{\tilde{A}_1}(x), v_{\tilde{A}_1}(x), \pi_{\tilde{A}_1}(x)) | x \in U_1\}\right)$ and $\tilde{B}_2\left(\tilde{B}_2 = \{\langle x, (\mu_{\tilde{B}_2}(x), v_{\tilde{B}_2}(x), \pi_{\tilde{B}_2}(x)) | x \in U_2\}\right)$ of the universe of discourse sets U_1 and U_2 are presented below (Kutlu Gündoğdu and Kahraman, 2019):

Addition

$$\tilde{A}_1 \oplus \tilde{B}_2 = \left\{\left(\mu_{\tilde{A}_1}^2 + \mu_{\tilde{B}_2}^2 - \mu_{\tilde{A}_1}^2 \mu_{\tilde{B}_2}^2\right)^{1/2}, v_{\tilde{A}_1}^2 v_{\tilde{B}_2}^2, \left((1 - \mu_{\tilde{B}_2}^2)\pi_{\tilde{A}_1}^2 + \left(1 - \mu_{\tilde{A}_1}^2\right)\pi_{\tilde{B}_2}^2 - \pi_{\tilde{A}_1}^2 \pi_{\tilde{B}_2}^2\right)^{1/2}\right\} \tag{A2}$$

Multiplication

$$\tilde{A}_1 \otimes \tilde{B}_2 = \left\{\left(\mu_{\tilde{A}_1} \mu_{\tilde{\boldsymbol{B}}_1}, (v_{\tilde{A}_1}^2 + v_{\tilde{B}_2}^2 - v_{\tilde{A}_1}^2 v_{\tilde{B}_2}^2)^{1/2} + \right)^{1/2}, ((1 - v_{\tilde{B}_2}^2)\pi_{\tilde{A}_1}^2 + (1 - v_{\tilde{A}_1}^2)\pi_{\tilde{B}_2}^2 - \pi_{\tilde{A}_1}^2 \pi_{\tilde{B}_2}^2\right\} \tag{A3}$$

Multiplication by scalar and Power of $\tilde{A}_s$ $(\lambda > 0)$

$$\lambda \cdot \tilde{A}_1 = \{(1 - \left(1 - \mu_{\tilde{A}_1}^2\right)^{\lambda})^{1/2}, v_{\tilde{A}_1}^{\lambda}, (\left(1 - \mu_{\tilde{A}_1}^2\right)^{\lambda} - \left(1 - \mu_{\tilde{A}_1}^2 - \pi_{\tilde{A}_1}^2\right)^{\lambda})^{1/2}\} \tag{A4}$$

$$\tilde{A}_1^{\lambda} = \{\mu_{\tilde{A}_1}^{\lambda}\left(1 - \left(1 - v_{\tilde{A}_1}^2\right)^{\lambda}\right)^{\frac{1}{2}}, \left(\left(1 - v_{\tilde{A}_1}^2\right)^{\lambda} - \left(1 - v_{\tilde{A}_1}^2 - \pi_{\tilde{A}_1}^2\right)^{\lambda}\right)^{1/2}\} \tag{A5}$$

Definition 3. The values of the Spherical Weighted Arithmetic Mean (SWAM) and Spherical Weighted Geometric Mean (SWGM) can be calculated with Equations (A6)-(A7) (Gündoğdu and Kahraman, 2020).

$$SWAM_w(\tilde{A}_{S1}, \dots, \tilde{A}_{Sn}) = \{[1 - \prod_{i=1}^{n}(1 - \mu_{\tilde{A}_{Si}}^2)^{w_i}]^{1/2}, \prod_{i=1}^{n} v_{\tilde{A}_{Si}}^{w_i}, [\prod_{i=1}^{n}(1 - \mu_{\tilde{A}_{Si}}^2)^{w_i} - \prod_{i=1}^{n}(1 - \mu_{\tilde{A}_{Si}}^2 - \pi_{\tilde{A}_{Si}}^2)^{w_i}]^{1/2}\} \tag{A6}$$

$$SWAM_w(\tilde{A}_{S1}, \dots, \tilde{A}_{Sn}) = \{\prod_{i=1}^{n} \mu_{\tilde{A}_{Si}}^{w_i} [1 - \prod_{i=1}^{n}(1 - v_{\tilde{A}_{Si}}^2)^{w_i}]^{1/2}, \prod_{i=1}^{n}(1 - v_{\tilde{A}_{Si}}^2)^{w_i} - \prod_{i=1}^{n}(1 - v_{\tilde{A}_{Si}}^2 - \pi_{\tilde{A}_{Si}}^2)^{w_i}]^{1/2}\} \tag{A7}$$

where $w = (w_1, w_2, \dots, w_n), w_i \in [0,1], \sum_{i=1}^{n} w_i = 1$

Definition 4. The value of the score function can be calculated for a Spherical fuzzy number $\tilde{A}_s$ ($\tilde{A}_s = \langle \mu_{A_s}, v_A, \pi_A \rangle$) as follows (Otay et al., 2020):

$$Sc(\tilde{A}_S) = (\frac{\mu_{\tilde{A}_S}+1-2v_{\tilde{A}_S}+1-\pi_{\tilde{A}_S}}{3}) \tag{A8}$$

Appendix E. TOPSIS Sensitivity Analyses

Table 16. Changes in ranking from sensitivity analyses for last mile distribution

Rank	weights	Diesel	Hybrid Electric	CNG/RNG	Battery Electric	Fuel Cell (H2)
C1	1	1	2	3	4	5
	0.9	1	2	3	4	5
	0.8	1	2	3	4	5
	0.7	1	2	3	4	5
	0.6	1	2	3	4	5
	0.5	1	2	3	4	5
	0.4	1	2	3	4	5
	0.3	1	2	3	4	5
	0.2	1	2	3	4	5
	0.1	1	2	3	4	5
	0	1	2	3	4	5
	weights	**Diesel**	**Hybrid Electric**	**CNG/RNG**	**Battery Electric**	**Fuel Cell (H2)**
C2	1	1	4	2	3	5
	0.9	1	3	2	4	5
	0.8	1	3	2	4	5
	0.7	1	3	2	4	5
	0.6	1	3	2	4	5
	0.5	1	3	2	4	5
	0.4	1	3	2	4	5
	0.3	1	3	2	4	5
	0.2	1	2	3	4	5
	0.1	1	2	3	4	5
	0	2	1	3	4	5
	weights	**Diesel**	**Hybrid Electric**	**CNG/RNG**	**Battery Electric**	**Fuel Cell (H2)**
C3	1	5	4	3	1	2
	0.9	5	4	3	1	2
	0.8	5	4	2	1	3
	0.7	5	4	1	2	3
	0.6	5	4	1	2	3
	0.5	5	2	1	3	4
	0.4	3	2	1	4	5
	0.3	3	2	1	4	5
	0.2	1	2	3	4	5
	0.1	1	2	3	4	5
	0	1	2	3	4	5

	weights	Diesel	Hybrid Electric	CNG/RNG	Battery Electric	Fuel Cell (H2)
C4	1	1	2	3	4	5
	0.9	1	2	3	4	5
	0.8	1	2	3	4	5
	0.7	1	2	3	4	5
	0.6	1	2	3	4	5
	0.5	1	2	3	4	5
	0.4	1	2	3	4	5
	0.3	1	2	3	4	5
	0.2	1	2	3	4	5
	0.1	1	3	2	4	5
	0	2	3	1	4	5
	weights	**Diesel**	**Hybrid Electric**	**CNG/RNG**	**Battery Electric**	**Fuel Cell (H2)**
C5	1	1	2	3	5	4
	0.9	1	2	3	5	4
	0.8	1	2	3	5	4
	0.7	1	2	3	5	4
	0.6	1	2	3	5	4
	0.5	1	2	3	5	4
	0.4	1	2	3	5	4
	0.3	1	2	3	4	5
	0.2	1	2	3	4	5
	0.1	1	3	2	4	5
	0	1	3	2	4	5

CCR = Coefficient for Relative Degree of Closeness

Table 17. Changes in the coefficient for relative degree of closeness (CCR) from sensitivity analyses for last mile distribution

CCR	weights	Diesel	Hybrid Electric	CNG/RNG	Battery Electric	Fuel Cell (H2)
C1	0	0.61735	0.587494	0.577569	0.4237616	0.414098
	0.1	0.625211	0.591567	0.57942	0.4224825	0.404026
	0.2	0.634969	0.596687	0.581913	0.4208685	0.391689
	0.3	0.646939	0.60292	0.585059	0.4188895	0.376786
	0.4	0.661534	0.61033	0.58886	0.4165146	0.358913
	0.5	0.679332	0.618976	0.593303	0.413713	0.337486
	0.6	0.701197	0.628915	0.598364	0.4104565	0.31159
	0.7	0.728553	0.640203	0.604004	0.4067222	0.279627
	0.8	0.764114	0.652894	0.610173	0.4024972	0.238338
	0.9	0.814506	0.667043	0.616807	0.3977846	0.178882
	1	0.91184	0.682713	0.623829	0.3926117	0
	weights	Diesel	Hybrid Electric	CNG/RNG	Battery Electric	Fuel Cell (H2)
C2	0	0.646118	0.658449	0.605039	0.417321	0.383389
	0.1	0.640623	0.626989	0.593976	0.4192179	0.387603
	0.2	0.634969	0.596687	0.581913	0.4208685	0.391689
	0.3	0.629345	0.568026	0.569308	0.4222987	0.395556
	0.4	0.623893	0.541198	0.55655	0.4235433	0.399148
	0.5	0.618708	0.516242	0.543951	0.4246405	0.40244
	0.6	0.613844	0.493125	0.531757	0.4256265	0.40543
	0.7	0.609326	0.471776	0.520152	0.4265337	0.408132
	0.8	0.605152	0.452115	0.509277	0.4273892	0.410567
	0.9	0.601309	0.434064	0.499229	0.4282152	0.412763
	1	0.597774	0.417552	0.490079	0.4290292	0.414747
	weights	Diesel	Hybrid Electric	CNG/RNG	Battery Electric	Fuel Cell (H2)
C3	0	0.757714	0.614268	0.562233	0.3203038	0.286582
	0.1	0.692925	0.60558	0.571022	0.3711529	0.34077
	0.2	0.634969	0.596687	0.581913	0.4208685	0.391689
	0.3	0.581816	0.588041	0.594784	0.4686006	0.439839
	0.4	0.531655	0.579934	0.609562	0.5147575	0.486206
	0.5	0.48274	0.572535	0.626263	0.5603354	0.53203
	0.6	0.433123	0.565921	0.645033	0.6068085	0.578888
	0.7	0.380148	0.560105	0.666208	0.6564249	0.629062
	0.8	0.319146	0.555062	0.690415	0.7132915	0.686613
	0.9	0.238243	0.550739	0.718786	0.7879095	0.761511
	1	0	0.547075	0.75351	1	0.914902

	weights	Diesel	Hybrid Electric	CNG/RNG	Battery Electric	Fuel Cell (H2)
C4	0	0.561273	0.546769	0.566171	0.4887947	0.477498
	0.1	0.598077	0.572377	0.574068	0.4550834	0.433824
	0.2	0.634969	0.596687	0.581913	0.4208685	0.391689
	0.3	0.670931	0.61924	0.589495	0.3875202	0.351741
	0.4	0.705763	0.639966	0.59671	0.3555828	0.313803
	0.5	0.739759	0.658995	0.603529	0.3251377	0.277278
	0.6	0.773574	0.676545	0.609964	0.2960213	0.241273
	0.7	0.808305	0.692854	0.616046	0.2679371	0.20448
	0.8	0.845966	0.708156	0.621814	0.2404991	0.164644
	0.9	0.891585	0.722659	0.627307	0.2132263	0.116274
	1	1	0.736551	0.632558	0.1854804	0
	weights	**Diesel**	**Hybrid Electric**	**CNG/RNG**	**Battery Electric**	**Fuel Cell (H2)**
C5	0	0.611684	0.58129	0.602362	0.4455961	0.389599
	0.1	0.622357	0.588213	0.592111	0.4343241	0.390555
	0.2	0.634969	0.596687	0.581913	0.4208685	0.391689
	0.3	0.649536	0.606645	0.572103	0.405243	0.393056
	0.4	0.666094	0.618002	0.562915	0.3874437	0.394716
	0.5	0.684721	0.630668	0.554497	0.3674238	0.396733
	0.6	0.705575	0.644552	0.546926	0.3450584	0.399174
	0.7	0.728953	0.659578	0.540225	0.3200927	0.402107
	0.8	0.755401	0.675684	0.534383	0.2920501	0.4056
	0.9	0.785956	0.692835	0.529361	0.2600405	0.409716
	1	0.822837	0.711024	0.525108	0.2222789	0.41451

Appendix F. Summary Report from SP Survey Data (2nd Wave)

1. What is your company's main type of operation?

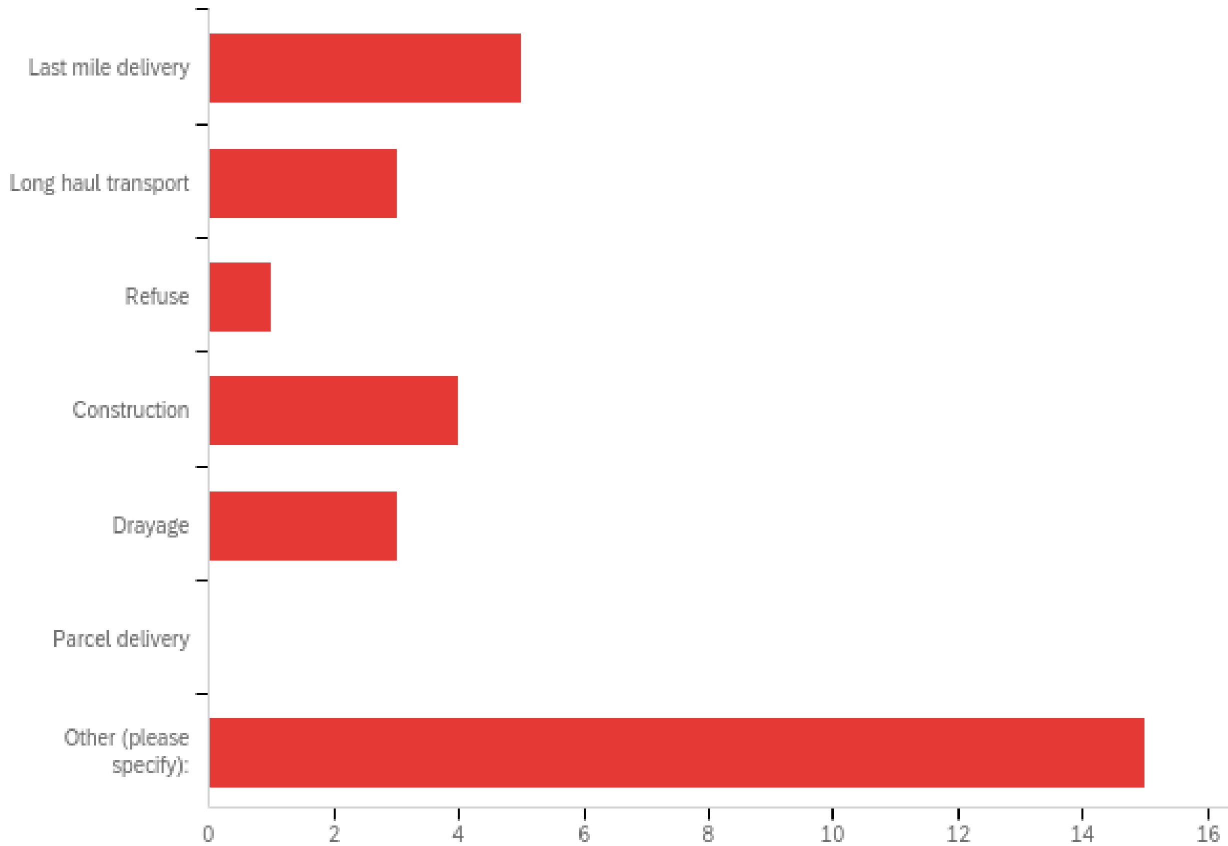

Figure 7. SP – Company's main type of operation

Other (please specify):

Tractors	Airport pick-up and delivery
Heavy Equipment Transportation	Delivery of Material to customer locations
Regional Refrigerated Transportation	agriculture
Local & Long Distance Household Goods Moving	Local liquid waste hauling
Self storage	Bottled water delivery
Local dump truck.	Ag products and equipment
Household goods	Moving household goods
Moving Household and commercial goods	

2. Where does your company conduct most of the business?

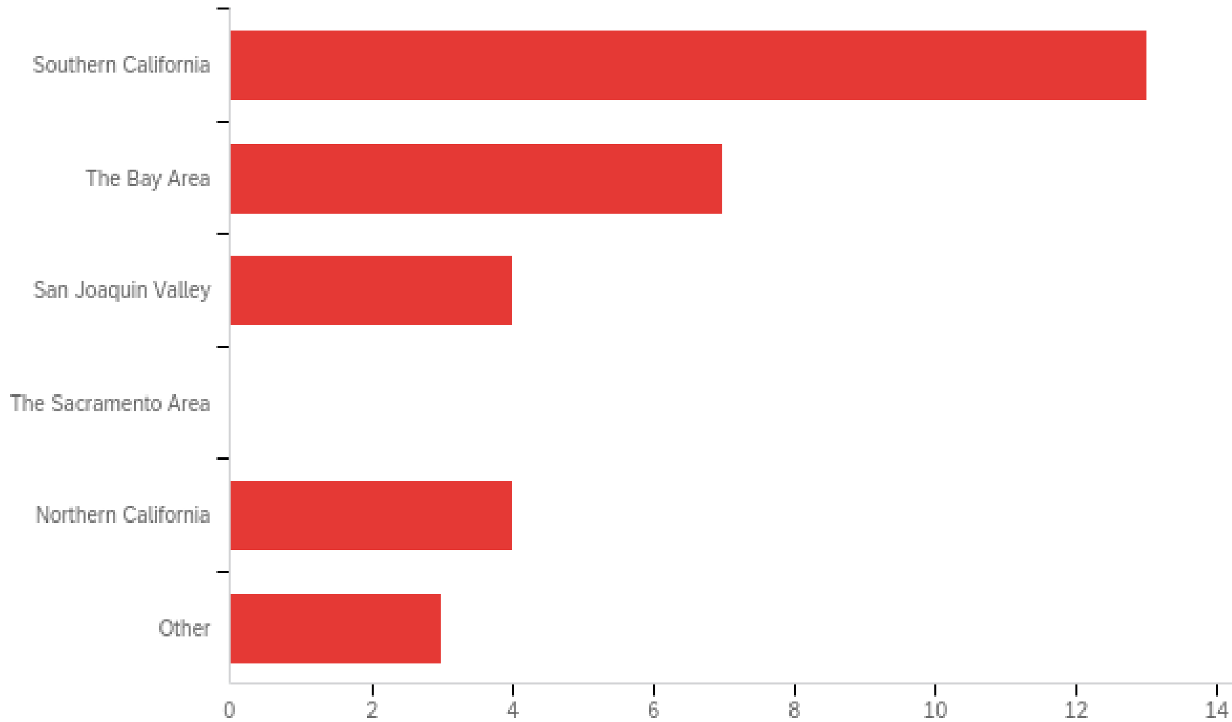

Figure 8. SP – Company's main geographic area

3 - NUMBER OF VEHICLES OPERATED FROM THIS FACILITY BY TYPE AND ENGINE TECHNOLOGY

Passenger cars/ Small pickups/vans - Gasoline/ Diesel

5	4
3	1
10	20
4	35
45	2
35	1
2	7

Passenger cars/ Small pickups/vans - CNG/LNG

1

Class 3 (GVWR 10,001-14,000 lbs.) - Gasoline/ Diesel

1
8
7
5

Class 4 (GVWR 14,001-16,000 lbs.) - Gasoline/ Diesel

4
5
1
5

Class 4 (GVWR 14,001-16,000 lbs.) - CNG/LNG

10

Class 5 (GVWR 16,001-19,500 lbs.) - Gasoline/ Diesel

6	3
4	7
2	1

Class 6 (GVWR 19,501-26,000 lbs.) - Gasoline/ Diesel

2	10
12	1
2	8
2	3
1	3
3	5
10	9

Class 6 (GVWR 19,501-26,000 lbs.) - CNG/LNG

1

Class 7 (GVWR 26,001-33,000 lbs.) - Gasoline/ Diesel

4	10
150	1
2	

Class 7 (GVWR 26,001-33,000 lbs.) - CNG/LNG

82

Class 8 (GVWR 33,001-100,000 lbs.) - Gasoline/ Diesel

24	1
1	15
5	220
36	6
1	3

Others/ not specified: - Gasoline/ Diesel

6
6

4. What is the average annual mileage of a vehicle in your fleet?

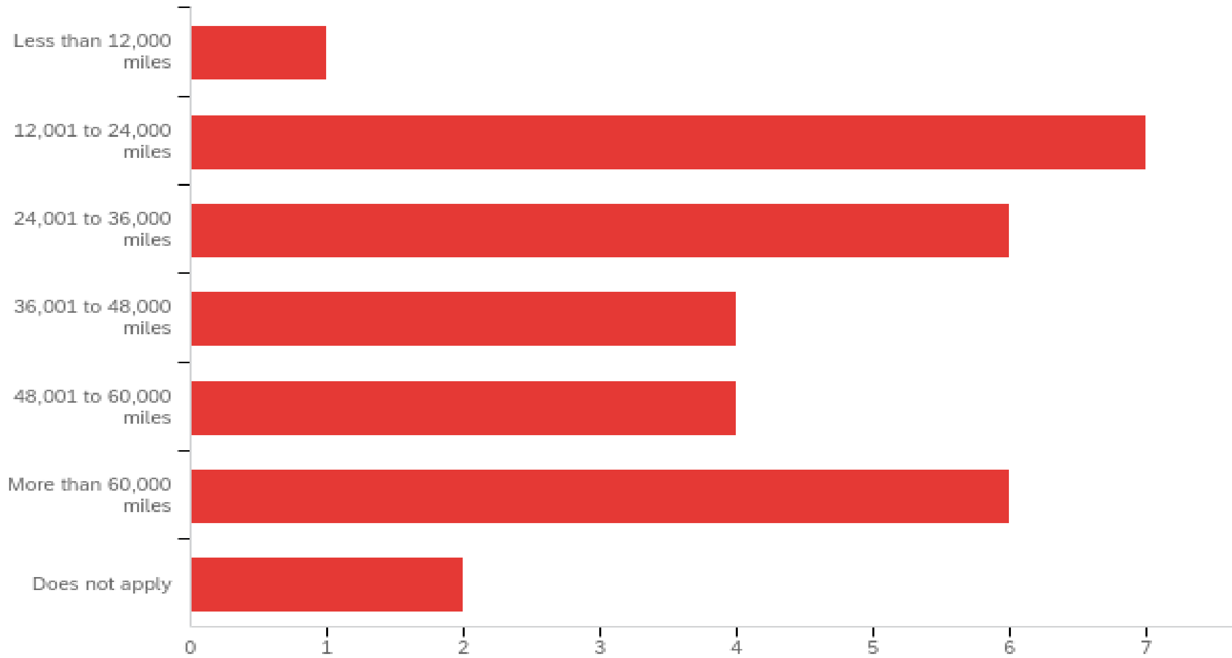

Figure 9. SP – Average annual mileage of vehicles

5. What is the expected payback period (in years) for a vehicle acquisition?

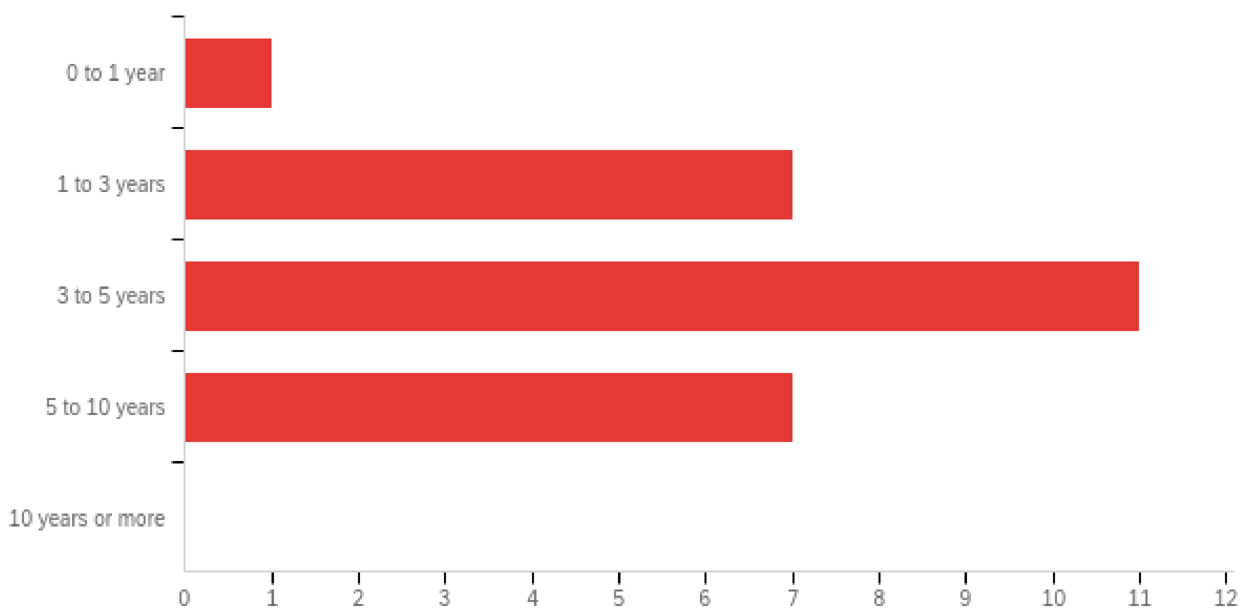

Figure 10. SP – Payback period (years)

6. How important are the following criteria if your company were to consider a vehicle engine/fuel technology?

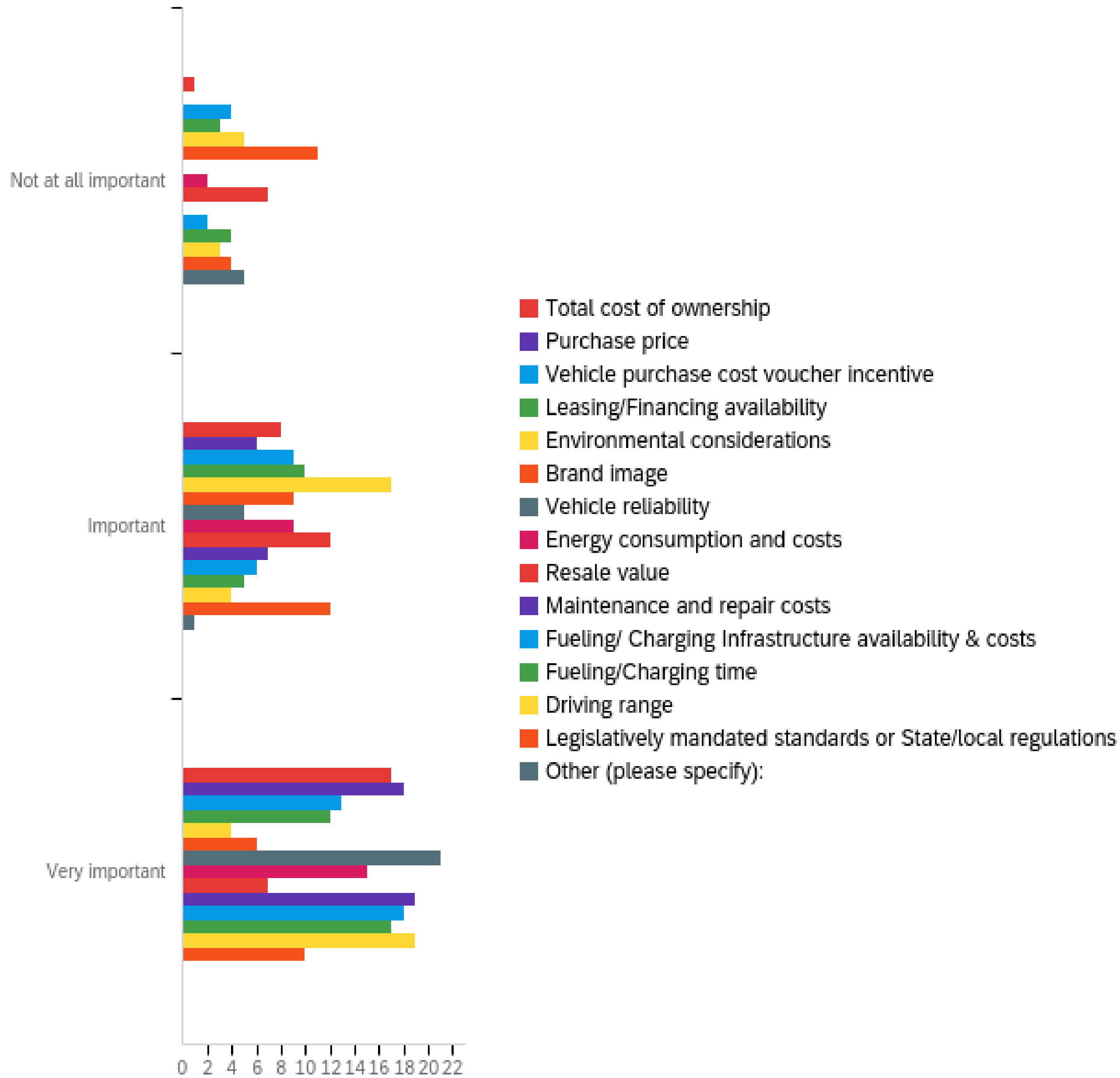

Figure 11. SP – Importance of criteria when selecting vehicle/fuel technology

7. Is your company familiar with any financial incentive program that supports the adoption of zero- or near-zero-emission vehicle technologies? If yes, please indicate which one(s).

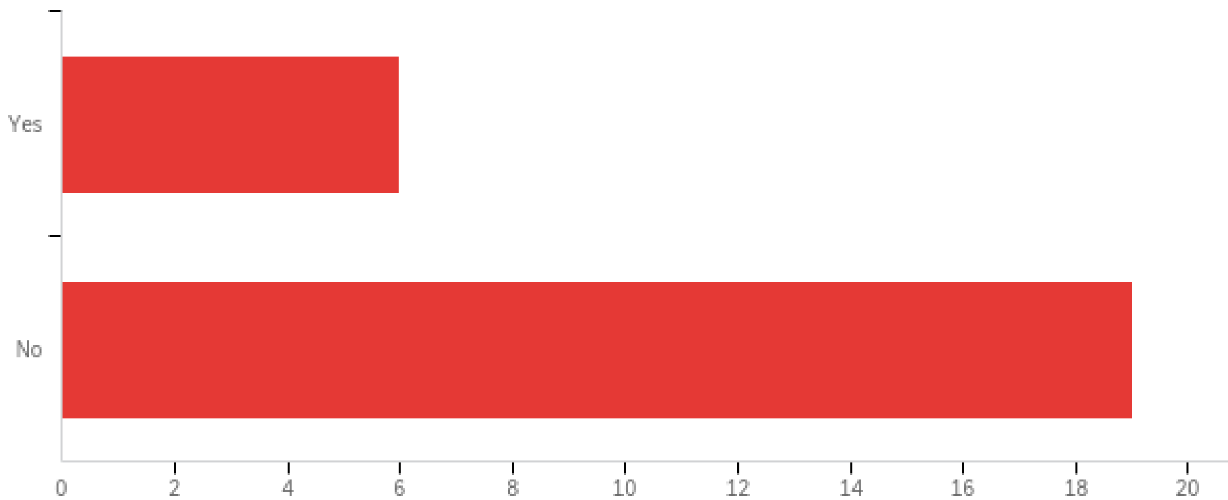

Figure 12. SP – Familiarity with incentives programs

TEXT - Yes

Port Dray Grants
BAAQMD
CARL MOYER GRANT
NRCS. SJVAPCD

8. How important is the introduction of the following incentives programs or benefits for zero-emission vehicles? If you think of any other not included, please list it in the "Other" option.

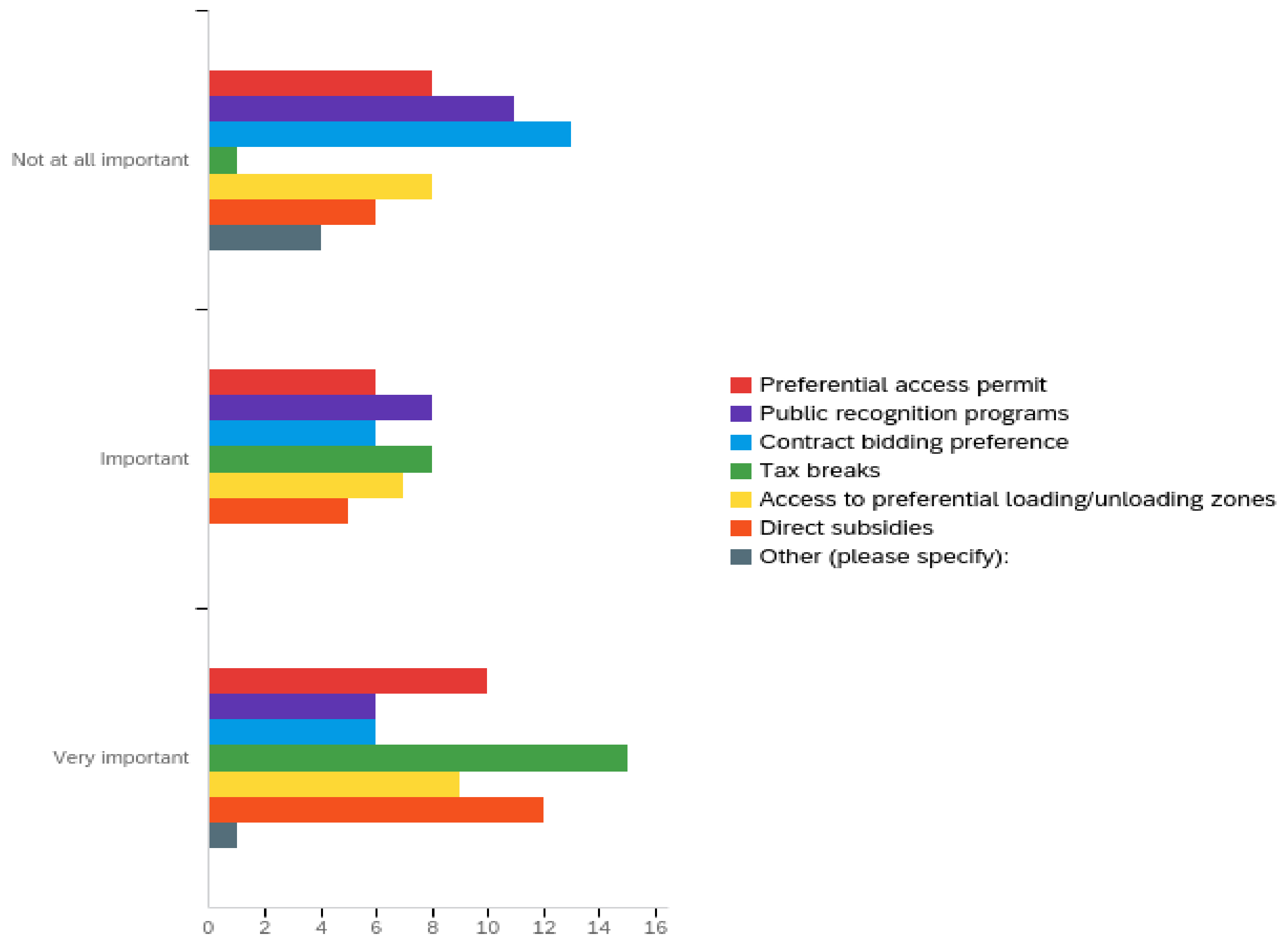

Figure 13. SP – Importance of incentive programs for ZEVs

#	Question	Not at all important		Important		Very important		Total
1	Preferential access permit	33.33%	8	25.00%	6	41.67%	10	24
2	Public recognition programs	44.00%	11	32.00%	8	24.00%	6	25
3	Contract bidding preference	52.00%	13	24.00%	6	24.00%	6	25
4	Tax breaks	4.17%	1	33.33%	8	62.50%	15	24
5	Access to preferential loading/unloading zones	33.33%	8	29.17%	7	37.50%	9	24
6	Direct subsidies	26.09%	6	21.74%	5	52.17%	12	23
7	Other (please specify):	80.00%	4	0.00%	0	20.00%	1	5

9. How likely is your company to consider the following technologies in the next vehicle acquisition decision?

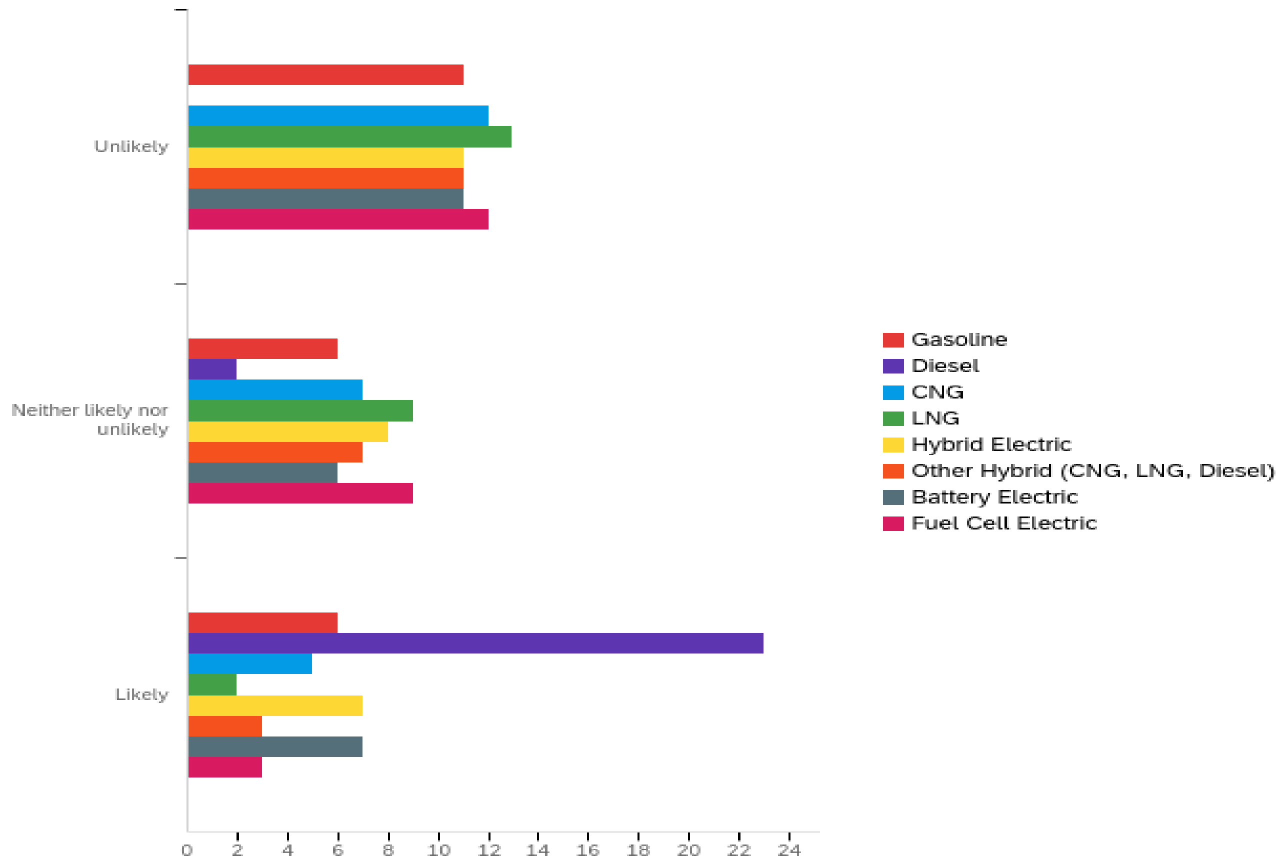

Figure 14. SP – Vehicle considerations

#	Question	Unlikely		Neither likely nor unlikely		Likely		Total
1	Gasoline	47.83%	11	26.09%	6	26.09%	6	23
2	Diesel	0.00%	0	8.00%	2	92.00%	23	25
3	CNG	50.00%	12	29.17%	7	20.83%	5	24
4	LNG	54.17%	13	37.50%	9	8.33%	2	24
5	Hybrid Electric	42.31%	11	30.77%	8	26.92%	7	26
6	Other Hybrid (CNG, LNG, Diesel)	52.38%	11	33.33%	7	14.29%	3	21
7	Battery Electric	45.83%	11	25.00%	6	29.17%	7	24
8	Fuel Cell Electric	50.00%	12	37.50%	9	12.50%	3	24

SP Choice Set Questions (10-21): Omitted from this report due to the small number of responses. Recalling each respondent was randomly assigned 1 out of 4 blocks of 5 SP questions. There were only 23-31 potential respondents that progressed up to or past the choice sets.

22. On average, how many delivery/distribution tours does a vehicle in your fleet make in a typical day?

2	1
8	3
2-3	8
2	2
75	40
1	4
5	2
8	1
8	15
20	10
2-4	

23. On average, how many miles does your vehicle travel in a typical tour?

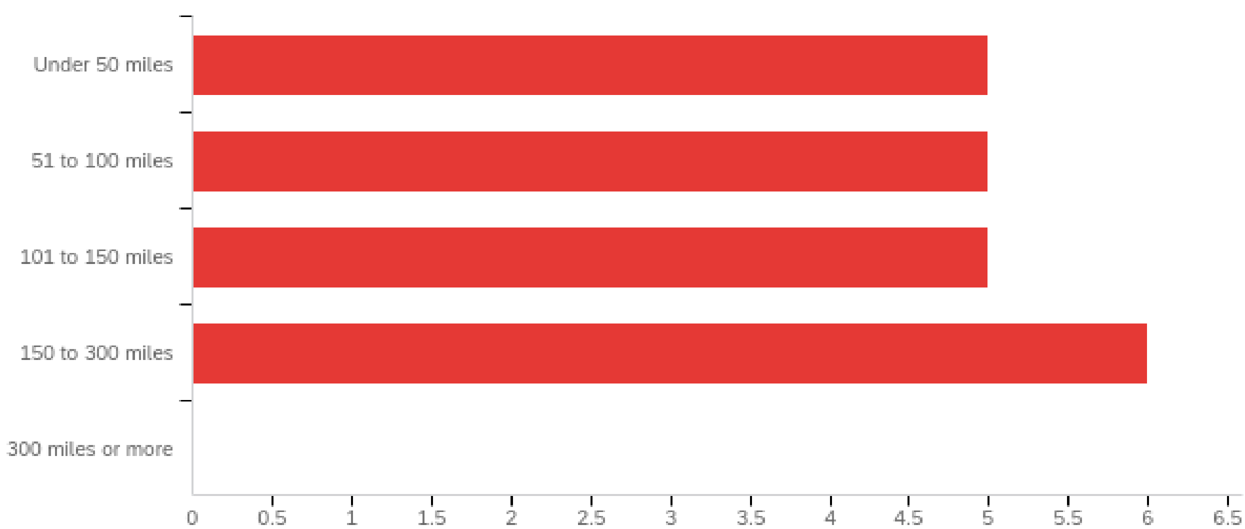

Figure 15. SP – Miles per tour

24. What is the average number of stops in a typical tour?

1	1
6	2
2-3	1
4	5
7	500 (Refuse)
120	1
1	2
8	60
16	15
10	2
2-4	

25. On average, how many customers do you serve in a typical tour?

1	1
4	1
1-2	50
10	20
78	500
120	1
2-3	2
10	60
1	15
5	1
1	

26. How long (in hours) does it take to complete a typical tour?

5.5	8
9	2.5
4-8 hours	16
8	6
10	12
10	3
1-3 hours	10
8	6 hours
7.5	9
6	2
8	