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Understanding Organizational Decisions to Adopt Plug-in Electric Vehicles

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Understanding Organizational Decisions to Adopt Plug-in Electric Vehicles

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Abstract

This dissertation examines electric vehicle acquisition decision-making in public and private fleets in the United States, with an emphasis on fleets operating in California. Large numbers of vehicles are acquired for fleet use each year, however, fleet decision-making processes are largely unknown. The high average mileage and emissions of these vehicles makes the replacement of fleet vehicles with electric vehicles an important step in reaching zero-emission vehicle, air quality, and greenhouse gas emission reduction goals. Additionally, California's Advanced Clean Cars, Advanced Clean Fleets, and Advanced Clean Trucks policies have solidified the state's commitment to electrifying the on-road vehicle fleet. To support these policies, which are subsequently being adopted in other states and nations, this dissertation seeks to understand fleet decision-maker's perceptions of electric vehicles.

To understand fleets' willingness and ability to adopt electric vehicles, this dissertation utilizes data collected from interviews with decision-makers in fleets. These interviews sought to understand fleet decision-making, decision-maker's perceptions of electric vehicles, what is preventing them from adopting electric vehicles, and how these issues can be overcome. These interviews provide insights into the unique perspectives of individuals involved in the decision-making process.

In Chapter 2 of this dissertation electric vehicle adoption in fleets operating light-duty vehicles is explored. This chapter compares the acquisition processes for conventional vehicles and plug-in electric vehicles (PEVs) to provide a complete picture of the ways in which current acquisition processes allow or dissuade light-duty PEV acquisitions. Self-Determination Theory (SDT) is used to provide a deeper understanding of the underlying motivations for conventional vehicle and PEV acquisition decisions. Understanding these motivations provides a clearer view of what influences light-duty fleet acquisitions and what aspects of fleet acquisitions stakeholders should seek to influence to increase fleet electrification.

Chapter 3 of the dissertation examines barriers to electric vehicle adoption in fleets operating heavy-duty trucks. Barriers to heavy-duty electric truck adoption are classified into six categories: technological,

economic, social, socio-technological, techno-economic, and socio-economic. The research is intended to inform stakeholders about issues which need to be addressed in the pursuit of 100% electric heavy-duty trucks and the need to address social, economic, and technological issues rather than taking one-dimensional approaches to overcoming barriers.

Chapter 4 examines which actors and decision-making structures are involved in decision-making in fleets with medium- and heavy-duty trucks. This chapter is guided by a hybrid of concepts from organizational structure and Social Network Analysis. These theories are used to characterize fleets according to their internal decision-making structures and external social network heterogeneity, exploring whether these structures impact decision-making in fleets with medium- and heavy-duty trucks. Differences in internal structure, external network heterogeneity, and actor involvement between battery electric and conventional truck acquisition decisions are explored. Understanding these organizational attributes can provide insights into which fleet types will require greater levels of support to transition to electric trucks while identifying actors involved in these decisions can identify other groups that will play a role in supporting truck electrification.

The chapters presented in this dissertation present key findings which underlie fleet decision-making around electric vehicle adoption. We find that barriers to electric vehicle adoption are discussed as such because of their differences from incumbent fossil fuel vehicles. While fleets often expect electric vehicle technologies to advance to a point where they reach operational parity with fossil fuels, many perceived barriers can be partially or fully addressed through education or operational changes. Fleet managers are found to be driven by their desire to try new technologies, lessen environmental impact, improve their public image, and use grants.

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Chapter 1: Introduction and Motivation

1.1 MOTIVATIONS

The California Air Resources Board (CARB) estimated that between 2000 and 2020, transportation contributed approximately 38% of California's total greenhouse gas emissions (California Air Resources Board, 2022c). Additionally, criteria air emissions generated from on-road vehicles contribute to both regional air quality issues and local health risks, with many regions of California failing to meet federal air quality standards (US EPA, 2022). Heavy-duty trucks in particular contribute to air quality concerns as they have higher emissions rates due to their high power demand and reliance on diesel fuel (Moultak, Lutsey and Hall, 2017; Smith *et al.*, 2019; Muratori *et al.*, 2021). Diesel powered vehicles and equipment are the largest contributors of fine particulate matter from transportation while also emitting a substantial amount of harmful NO_x (Caltrans, 2016). Heavy-duty trucks often operate in urban areas and some applications, such as drayage and delivery trucks, idle for extended periods. Reducing the impacts of transportation through vehicle electrification is critical to both the environment and public health. In response to the growing concerns about air quality, state and local governments have begun to develop plans and strategies to promote vehicles with zero-tailpipe emissions, including electric vehicles.

While the market share of new personally-owned light-duty vehicles in California reached nearly 18% in 2022, much work is needed to meet the state's goal of reaching 100% of new light-duty vehicle sales being zero-emission by 2035 (California Air Resources Board, 2022a). A key component of reaching this goal is electrifying California's share of the estimated 8.1 million fleet vehicles in the United States (Bureau of Transportation Statistics, 2021).

Decisions made by private individuals are distinct from those made by organizational decision-makers as individuals in organizations are influenced by groups both within and outside of the organization. They are subject to distinct regulations and incentive programs from those of consumers and acquisition decisions are typically made by individuals who are not the primary users. These differences necessitate studies examining decision-making in organizations with fleets.

Fleets present a unique opportunity for electrification as acquisition decisions for a large number of vehicles are made by a small number of people. This presents an opportunity to electrify many vehicles with a smaller number of individuals involved than would be required to electrify the same number of personally-owned vehicles. These acquisition decisions are changing with the introduction of alternative fuel vehicles, requiring fleet decision-makers to evaluate truck acquisitions using new or modified decision-making criteria such as electric range and charging times. The need to focus on fleet electrification drives this dissertation's focus on understanding organizational decisions to adopt plug-in electric vehicles.

Chapter 2 examines the acquisition of light-duty Plug-in Electric Vehicles (PEVs), including Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs). Chapters 3 and 4 examine the acquisition of battery electric trucks only. While fuel cell and plug-in hybrid electric trucks may also contribute to a zero-emission freight system, these technologies were not commercially available for heavy-duty trucks in the U.S. at the time of data collection (CalStart, 2022).

1.2 VEHICLE CLASSIFICAITONS AND STATE OF TECHNOLOGY

This dissertation examines decision-making in organizations with vehicle fleets. Chapter 2 examines fleets with light-duty vehicles, Chapter 3 examines fleets with heavy-duty vehicles, and Chapter 4 examines fleets with medium- and heavy-duty vehicles. For the purpose of this dissertation, vehicle classes are distinguished according to the Federal Highway Administration's specifications (US DOE, no date). Light-duty vehicles include any vehicle with a gross vehicle weight rating (GVWR) under 8,500 pounds, referred to as Class 1 and 2a. Medium-duty vehicles include any vehicle with a GVWR between 8,501 and 26,000 pounds, referred to as Class 2b-6. Heavy-duty vehicles include any vehicle with a GVWR over 26,001 pounds, referred to as Class 7 and 8.

Modern light-duty electric vehicles were commercially introduced in the United States in 2008-2010 and are increasing in market share, making up over 18% of new vehicle sales in California in 2022 (California Energy Commission, 2022). The market for heavy-duty electric trucks, however, is in its nascence, making up less than 0.3% of new medium- and heavy-duty truck sales worldwide in 2021 (IEA, 2022). Light- medium-, and heavy-duty vehicles differ significantly in their energy and power demands as well as charging infrastructure requirements (Mikulin, 2016; Smith *et al.*, 2019). Given their higher annual mileage, longer drive times, and use in mainly business applications, the factors influencing electric heavy-duty truck acquisition decisions may differ compared to electric light-duty vehicle acquisition decisions (Brown, Fleming and Safford, 2020; Muratori *et al.*, 2021). These differences may lead to different perceptions and factors that influence the acquisition of light-, medium- and heavy-duty electric trucks.

There are currently over 7.4 million medium- and heavy-duty trucks operating in the United States (Federal Motor Carrier Safety Administration, 2022). Heavy-duty trucks often are driven greater annual and daily distances, have greater power demand, and may have associated specialized equipment, such as cold storage trailers. All these create differences in acquisition considerations than that of light-duty vehicles (Brown, Fleming and Safford, 2020; Nadel and Junga, 2020; Tanvir *et al.*, 2020; Fleming *et al.*, 2021; Muratori *et al.*, 2021).

US freight industry is reliant on diesel-powered trucks which contribute 40% of the on-road vehicle carbon emissions despite making up less than 10% of the vehicles on the road (Moultak, Lutsey and Hall, 2017; Smith *et al.*, 2019; Muratori *et al.*, 2021). In addition to greenhouse gas emissions, diesel-fueled vehicles emit substantial levels of particulate matter and NOx, leading to higher cancer rates, respiratory damages, and asthma (Caltrans, 2016, 2022). Freight trucks frequently operate in and around dense urban areas and disadvantaged communities, leading to adverse health effects for communities living in these areas.

Each vehicle class and each fleet face their own unique challenges in transitioning to electric vehicles and thus should be considered through the context in which they operate. While these challenges will change over time, this study seeks to capture the current state of fleet electrification.

1.3 POLICY OVERVIEW

Light-duty fleets in California are subject to the Advanced Clean Cars II regulation requiring all in-state sales of new passenger cars, trucks, and SUVs to be zero-emission by 2035 (California Air Resources Board, 2022a). This regulation requires manufacturers to sell 35% zero-emission vehicles in 2026. These sales percentages ramp up each year until 2035, when 100% of new light-duty vehicle sales must be zero-emission. This will require light-duty vehicle fleets to transition to operating only zero-emission vehicles (ZEVs) in their fleets.

As of December 2022, California light-duty fleet vehicles are eligible for several incentives, outlined here. This includes the state-run Clean Vehicle Rebate Program, which offers public fleets up to $7,000 per vehicle up to 30 rebates per fleet per year (Center for Sustainable Energy, 2022b). Car sharing and rental fleets are offered up to $4,500 per vehicle, up to 20 rebates per year. Fleets can also qualify for the federal tax credit of 30% of the acquisition cost, up to $7,500, per light-duty zero-emission vehicle. While recent changes allow tax-exempt organizations to receive this incentive directly, the interviews presented in this dissertation were conducted before this change was implemented, precluding many public fleets from utilizing it given their lack of federal tax liability. Light-duty fleets may also utilize a variety of programs aimed at incentivizing the installation of charging infrastructure including Southern California Edison's Charge Ready program and the California Energy Commission's California Electric Vehicle Infrastructure Project (CALeVIP) (Center for Sustainable Energy, 2022a; Southern California Edison, 2022).

The California Air Resources Board has set two regulatory requirements for medium- and heavy-duty fleets to transition to zero-emissions trucks. The Advanced Clean Trucks (ACT) program requires medium- and heavy-duty truck manufacturers to sell increasing percentages of zero-emission trucks each year from 2024 to 2035, when zero-emission trucks must make up 75% of straight truck and 40% of tractor-trailer sales (California Air Resources Board, 2019). The Advanced Clean Fleets (ACF) program is scheduled to be adopted in April 2023; it will place zero-emission truck acquisition requirements on fleets operating large numbers of medium- and heavy-duty trucks in California, and update the ACT requirement to 100% of all truck sales to be zero-emission by 2036 (California Air Resources Board, 2021).

As of December 2022, California medium- and heavy-duty fleet vehicles can also benefit from programs that provide financial assistance to acquisition zero-emission trucks. This includes the Hybrid and Zero Emission Truck and Bus Voucher Incentive Program (HVIP) which provides point-of-sale incentives for the acquisition of battery electric and hydrogen fuel cell trucks and buses. (California HVIP, 2022). Additionally, the Carl Moyer program, administered by the California Air Resources Board and the local air districts, provides grant funding for the acquisition of emissions-reducing truck technologies, including electric trucks and charging infrastructure (California Air Resources Board, 2022b). A tax credit for 30% of the cost of acquiring a Class 4 or larger zero-emission truck, up to $40,000 per truck is also available through the federal government's Commercial Electric Vehicle Tax Credit (US DOE, 2022). Electric truck charging infrastructure funding is available through utility programs, such as Pacific Gas & Electric's EV Fleet Program and Southern California Edison's Charge Ready Transport program (PG&E, 2022; Southern California Edison, 2022).

While this dissertation focuses on trucks operating in California, these findings can be used as a base for informing vehicle electrification efforts throughout the United States and globally. In the US, many states choose to follow California's more stringent air quality goals with 15 states and the District of Columbia having signed a memorandum of understanding to reach 100% zero emissions for new medium- and heavy-duty vehicle sales by 2050 (California Air Resources Board, 2020). Other states have similarly begun adopting California's Advanced Clean Cars II regulation for light-duty vehicles and Advanced Clean Trucks regulation for medium- and heavy-duty trucks (Bliss, 2022; Harris, 2022). These policies position California as a leader in transportation electrification, creating pathways and guidance for other states and countries looking to transition to electric vehicles. The findings presented in this dissertation also have global ramifications as they can be used to help other regions transition to electrification and meet global emissions targets, such as commitments made under the Paris Climate Agreement (UNFCC, 2015).

1.4 DISSERTATION OUTLINE

To understand fleets' willingness and ability to adopt electric vehicles, this dissertation utilizes data collected from interviews with fleet decision-makers. These interviews sought to understand decision-maker's perceptions of electric vehicles, what is preventing them from adopting electric vehicles, and how these issues can be overcome. These interviews provide insights into the unique perspectives of individuals involved in the decision-making process.

In Chapter 2 electric vehicle adoption in fleets operating light-duty vehicles is explored. It compares the acquisition processes for conventional vehicles and electric vehicles to provide a complete picture of the ways in which current fleet acquisition processes allow or dissuade PEV acquisitions. Here, Self-Determination Theory (SDT) is used to provide a deeper understanding of the underlying motivators for light-duty fleet vehicle acquisition decisions. Understanding these motivations provides a clearer view of what influences light-duty fleet purchasing and what aspects of fleet purchasing stakeholders should seek to influence to increase fleet electrification.

Chapter 3 examines barriers to electric vehicle adoption in fleets operating heavy-duty trucks. Barriers to heavy-duty electric truck adoption are classified into six categories: technological, economic, social, socio-technological, techno-economic, and socio-economic. This framework is intended to better inform stakeholders about issues which need to be addressed in the pursuit of 100% electric trucks and the need to address social, economic, and technological issues rather than taking one-dimensional approaches to overcoming barriers.

Chapter 4 examines the impact of actors and decision-making structures on decision-making in fleets with medium- and heavy-duty trucks. This chapter is guided by a hybrid of literature on organization structure and theory of Social Network Analysis. These theories are used to characterize fleets according to their internal decision-making structures and external network heterogeneity, exploring whether these structures impact decision-making in fleets with medium- and heavy-duty vehicles. Differences in internal structure, external network heterogeneity, and actor involvement between electric and conventional truck acquisition decisions are explored. Understanding these organizational attributes can provide insights into which fleet types will require greater levels of support to transition to electric trucks while identifying actors involved in these decisions can identify other groups that will play a role in supporting truck electrification.

Chapter 2: Electrifying California Fleets: Investigating the Role of Extrinsic Motivations in Fleet Purchase Decisions

2.1 INTRODUCTION

The aim of this chapter is to investigate how light-duty fleet managers make vehicle purchase decisions and how Plug-in Electric Vehicles (PEVs), including Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs), align with this. To meet this aim, we use insights from semi-structured interviews with fleet managers from 23 organizations with light-duty fleets conducted across California in 2019. Each interview examined how light-duty fleet managers make vehicle purchase decisions and explored the motivations and barriers for the adoption of PEVs. A comparison of these processes within each organization is analyzed to provide a complete picture of the ways in which current fleet acquisition processes allow or dissuade PEV purchases. In 2018, there was approximately 273.6 million total on-highway vehicles in operation in the U.S, with fleet vehicles making up just over 3% of this (8.5 million fleet vehicles) (Bureau of Transportation Statistics, 2019, 2020). While the number of fleet vehicles in California is less clear, there are 36.4 million vehicles in the state, and a similar percentage is assumed to be used in fleet operations (California Department of Motor Vehicles, 2019).

This study is the first to examine both conventional and plug-in electric vehicle adoption. Additionally, it is the first study on light-duty fleet electrification decision-making in the United States since studies by Nesbitt and Davies (2013) and Nesbitt and Sperling (2001). The 2013 study only focused on PHEVs and did not survey fleet decision-makers, these studies also predate the commercialization of PEVs and recent technological advancements. It is possible that attitudes towards, and knowledge of, PEVs have changed considerably in recent years. Therefore, there is a need to gain a more updated insight into light-duty fleet PEV adoption. This study develops an understanding of the degree to which purchase motivations are internal or external, and how PEVs are aligned with conventional vehicle purchasing. This helps create a broader understanding of how fleets make vehicle purchase decisions with a focus on the motivation of the fleet managers, how electric vehicles fit it into that, and how to foster growth in fleet vehicle electrification.

The high average mileage of most fleet vehicles makes the replacement of these vehicles with low and zero emission equivalents an important step toward reducing GHG and criteria pollutant emissions. While this work is most closely tied to helping California (and other states) meet their standards, it also has global ramifications as it can be used to help other regions transition to electrification and meet global emissions targets, such as commitments made under the Paris Climate Agreement (UNFCC, 2015). Given the centralized purchasing of fleet vehicles, there is a greater opportunity to electrify many vehicles with a smaller number of people involved.

Vehicles in light-duty fleets operating in California are eligible for several incentives including the state-run Clean Vehicle Rebate Program (up to $7,000 per vehicle up to 30 rebates per fleet per year) and a variety of local programs through the utilities and air districts. Fleets can also qualify for the federal tax credit of 30% of the acquisition cost, up to $7,500, per light-duty zero-emission vehicle. While recent changes allow tax-exempt organizations to receive this incentive directly, the interviews presented in this study were conducted before this change was implemented, precluding many public fleets from utilizing it given their lack of federal tax liability. Light-duty fleets in California are also subject to the Advanced Clean Cars II regulation requiring all in-state sales of new passenger cars, trucks, and SUVs to be zero-emission by 2035 (California Air Resources Board, 2022a). This regulation requires manufacturers to sell 35% zero-emission vehicles in 2026. These sales percentages ramp up each year until 2035, when 100% of new light-duty vehicle sales must be zero-emission. This will require light-duty vehicle fleets to transition to operating only zero-emission vehicles (ZEVs) in their fleets. The interviews presented here were conducted before this regulation was enacted but can help inform the needs of fleets to help meet these goals.

2.1.1 Introduction to Self-Determination Theory

We use Self-Determination Theory (SDT) to provide a deeper understanding of the underlying motivators for light-duty fleet managers when making purchase decisions. Understanding fleet manager motivations provides a clearer view of what influences fleet acquisitions and what aspects of fleet purchasing policymakers or other stakeholders should seek to influence to increase light-duty fleet electrification.

Figure 1 provides a simplified summary of SDT, which categorizes motivations along a spectrum of intrinsic and extrinsic motivations, as well as amotivation (Gagné and Deci, 2005). Amotivation is the lack of motivation or attention given to something; it is done without much thought or reason. Intrinsic motivations are derived from a person's own desire to do something because they receive satisfaction from doing the activity itself. This contrasts with extrinsic motivation where a person is motivated externally in some way. The theory defines four separate types of extrinsic motivations: integrated regulations, identified regulation, introjected regulation, and external regulations. "External regulations" are the most externally regulated and are controlled, initiated, and maintained by an external source. The next most controlled motivation is "introjected regulation" which includes pressures to do something to protect a person's self-esteem or ego. Here, the regulations originate from an external source, but have begun to be internalized by the individual. In the middle of the spectrum, "identified regulation" involves behaviors that are more aligned with an individual's personal goals and identities, meaning that they help them achieve something that they are working towards and are mostly from internal sources. "Integrated regulation" is the most internalized type of extrinsic motivation and involves behaviors that are seen as being a true part of a person's identity and aids in their sense of self. This type of motivation comes from a person's own understanding that the action is fundamentally the right thing to do. Though the latter two categories are partially or fully internally motivated, the goals they are working towards are still due to reasons extrinsic to the self, hence they are not intrinsic motivations.

SDT defines internalization as a process where people take the external values, attitudes, or regulatory structures and transform them into self-motivations. In this process, employees begin to accept the company's goals as their own and this commit to achieving them. This moves extrinsic motivations down the spectrum, closer to intrinsic motivations.

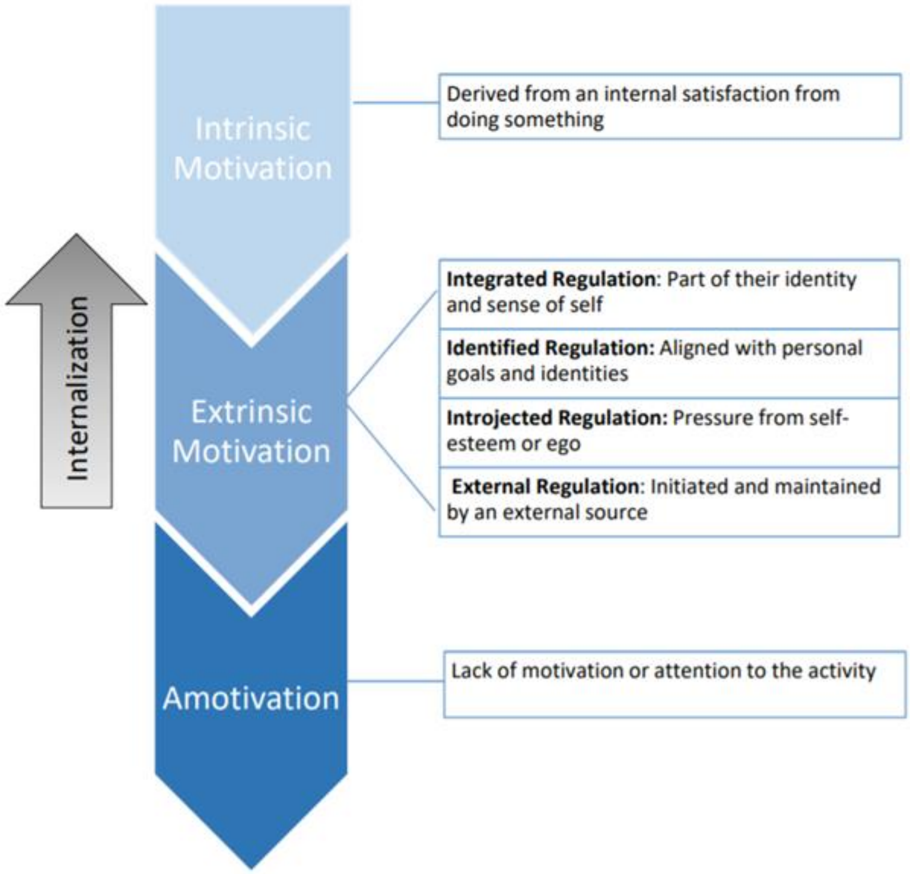

Figure 1: Overview of Self-Determination Theory (Adapted from (Gagné and Deci, 2005))

This theory describes personal motivations within an organization and is outlined by Gagné and Deci (2005) as describing "work motivation" and organizational behavior and management. It helps understand individual's motivations within organizations and how these motivations in turn affect the organization, noting that more internalized motivations help promote organizational effectiveness. They note that extrinsic motivation may be the strongest motivator for effective change within the workplace. This theory was chosen for its ability to describe the motivations of the individual within the context of the larger organization as they are the ones making the purchase decisions (Sheldon *et al.*, 2003; Chen and Bozeman, 2013; Deci, Olafsen and Ryan, 2017). Gagné and Deci (2005) report that Self-Determination Theory, "provides a fuller and more useful approach to understanding the motivational bases for effective organizational behavior."

2.2 LITERATURE REVIEW

To date, most PEV adoption research has focused on consumer adoption, with fleets receiving less attention, so their electrification potential is not fully understood (Graham-Rowe *et al.*, 2012; Ajanovic and Haas, 2016; Li *et al.*, 2017; Dua, White and Lindland, 2019; Lee and Brown, 2021). Many prior studies identified key issues that consumers have experienced with PEVs. The most commonly identified barriers to light-duty PEV adoption by consumers are range (Egbue and Long, 2012; Franke *et al.*, 2012; Schneidereit *et al.*, 2015), actual and perceived lack of infrastructure (Egbue and Long, 2012), and high vehicle costs (Adepetu and Keshav, 2015; Vassileva and Campillo, 2017; Bienias, Kowalska-Pyzalska and Ramsey, 2020), which could be prohibitive for fleets as well.

While studies on the barriers and motivations for electrification in the medium- and heavy-duty fleet sector have been conducted, the applicability of these findings to light-duty fleets has not been explored. Much of this research is conducted by consulting groups, whose work attempts to provide medium- and heavy-duty fleets with information on barriers, best practices, and the current state of technology for electric trucks (Birky *et al.*, 2017; Moultak, Lutsey and Hall, 2017; Sharpe, 2017; Mihelic and Roeth, 2018; Springer *et al.*, 2020). These studies identified more fleet specific considerations, such as financing, employee retention, and access to certain areas, all of which can be affected by fuel choice (Anderhofstadt and Spinler, 2019; Couc *et al.*, 2019; Kluschke *et al.*, 2019; Nadel and Junga, 2020).

Some early studies sought to understand and categorize the process through which light-duty fleets make their purchase decisions (Francfort and O`Hara, 1997; Nesbitt and Sperling, 1998; Rahm and Coggburn, 2007; Nesbitt and Davies, 2013). A study by Nesbitt and Sperling (2001) noted that light-duty vehicle fleets have historically been difficult to research because they are so diverse and are continuously changing. They were able to generalize light-duty fleet purchasing structures into four main groups: autocratic, bureaucratic, hierarchic, and democratic. They found that the latter two were the most common, both of which are highly formalized, rule-based processes. Sierzchula (2014) interviewed ‘early adopter’ fleets in the US and the Netherlands. They found that fleets were motivated to purchase PEVs to test new technologies, lower their environmental impact, improve their public image, and to take advantage of grants. They found that light-duty fleets were willing to pay more for the PEVs. Reduced operating costs and environmental considerations were also found to be main motivations for fleet electrification (Barfod *et al.*, 2016; Skippon and Chappell, 2019).

More recent studies have examined fleet vehicle driver experiences with electric vehicles (Globisch, Dütschke and Schleich, 2018; Wolff and Madlener, 2019). Two studies by Wikström et al. (Wikström, Hansson and Alvfors, 2015, 2016) explored the applications of PEVs in public and private fleets, finding that even after the vehicles had been integrated, if users are concerned about completing their trips with adequate range remaining, they will not use BEVs. They found that initial employee experiences with PEVs were negative, which reduced their acceptance of the vehicles. When employees began to use the vehicles, their acceptance of PEVs increased after seeing that they were able to meet the required functions. Another study by (Globisch, Dütschke and Wietschel, 2018) found that drivers of light-duty fleet vehicles perceived PEVs as having constrained range and reduced reliability, which can deter organizations from purchasing additional PEVs in the future.

Studies have also used light-duty fleet vehicle travel data to analyze appropriate applications for electric fleet vehicles (Klauenberg, Rudolph and Zajicek, 2016). In 2018, Figenbaum (2018) found that if range and infrastructure challenges are not improved, then converting light-duty commercial vehicles to BEVs will not be feasible, even with strong incentive programs. Only a few studies have looked at the impact of individual decision makers in influencing the uptake of PEVs in fleets (Pierre, Morganti and Boutueil, 2016; Wikström, Eriksson and Hansson, 2016).

This chapter expands on existing literature on light-duty fleet purchasing by investigating PEV adoption by fleets in a more mature global market with more PEVs sold, more infrastructure developed, and more PEV models available for fleets to purchase, making current fleet purchases more representative of mainstream market purchases, helping provide an understanding of how future purchases may be handled. The first widely available commercial PEVs were introduced to the market in 2010 with the model availability increasing every year. In 2019, when interviews for this chapter were conducted, 55 light-duty PEV models were available for fleets to purchase in California (*EV-Volumes*, 2020). We also utilize SDT to gain deeper understanding of the motivation behind fleet decisions.

2.3 METHODS

2.3.1 Sample

The data for this chapter comes from a series of 23 semi-structured hour-long interviews that were conducted with light-duty fleet managers in California over a seven-month period, concluding in September 2019. The research examined the purchasing of both conventional and plug-in vehicles, with one interview excluded from the PEV analysis as the fleet only purchased conventionally fueled vehicles. Interview topics were recorded through post-interview memos, allowing researchers to track the number of new topics learned, showing we began to reach topical saturation around 15 interviews.

Interviewees were purposefully selected by creating a pool of contact information for light-duty fleet managers in public and semi-public organizations from the targeted regions. We focus on public light-duty fleets due to the availability of contact information for these fleet managers. Contact information was collected from publicly available databases using a web-based search. Further contacts were recruited via snowball sampling in which participants were asked to provide contact information for other fleet managers. All interviewees were invited to participate via an email informing them study's purpose with an attached letter providing additional details. To ensure fleets from across California were represented, participants were selected from four regions: the Sacramento Area (7 fleets), the San Francisco Bay Area (6 fleets), the greater Los Angeles Area (8 fleets), and the Central Valley (2 fleets). These interviewees were purposefully selected to include fleets of various sizes and structures, ranging from approximately 250 to 50,000 vehicles and pieces of equipment in each fleet. We classified these light-duty fleets into small fleets (under 500 vehicles), medium fleets (501-2,000 vehicles), and large fleets (Over 2,000 vehicles). This showed that the sample contained a variety of fleet sizes with 6 small fleets, 7 medium fleets, and 9 large fleets. The interviews focused mostly on public organizations such as cities and counties, as shown in Figure 2. Table 1 below provides an overview of the 23 fleets interviewed, with a combined fleet size of over 91,000 vehicles. While the data comes from a set of 23 interviews, in one case, an interview contained interviewees who were from the same organization, but who were responsible for two distinct fleets (interview 22). All fleets included a combination of light-, medium-, and heavy-duty vehicles, but were composed mostly of light-duty vehicles, as this was the focus of this chapter. The percentage of light-duty vehicles in the fleets ranged from 3% to 98% of the total vehicles, with an average of 46%. Most light-duty vehicles were passenger cars. The use of passenger vehicles in the interviews included administrative work (attending meetings, travel for business, etc.), police vehicles (patrol, detective, and administrative), and pool vehicles for employees to use on an hourly or daily basis for various purposes.

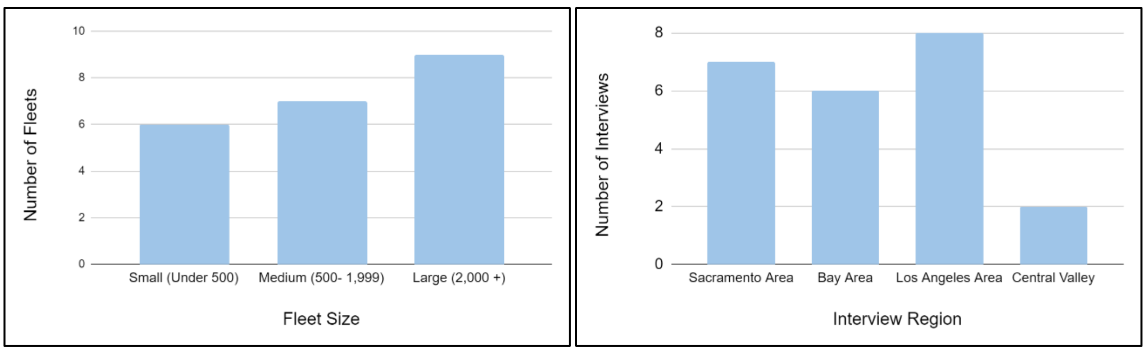

Figure 2: Breakdown of fleets in this study by fleet size (left) (n=24), and region (right) (n=23).

Table 1: Overview of fleets in this study including fleet type, location, number of vehicles and number of light-duty vehicles in the fleet, vehicle sizes, and vehicle uses as reported by the fleet managers.

Fleet #	Fleet Type	Region	# of Vehicles (Light/ Total)	All Fleet Vehicle Uses*	Purchase Location**
1	University	Sacramento Area	350/850	Passenger vehicles, police, fire, pick-up trucks, vans	Sourcewell, State contract, bid
2	City	Sacramento Area	650/2,400	Fire, police, refuse, pool cars (passenger vehicles), maintenance, bucket trucks	Sourcewell, State contract, bid
3	County	Bay Area	220/330	County operations (passenger vehicles), police, off road	Bid
4	County	Sacramento Area	1,200/2,600	Police, refuse, maintenance, general, welfare, airport vehicles etc.	Sourcewell, State contract, bid, piggyback
5	Utility	Sacramento Area	250/1,000	Utility maintenance, pool cars, maintenance and inspection	State contract, bid
6	City	Sacramento Area	40/250	Fire, police, paratransit, administrative (passenger vehicles)	State contract

7	Police	Greater LA	4,000/5,500	Police and administration	Sourcewell, bid (leased and purchased)
8	County	Greater LA	900/3,600	Road, sewer, traffic signal maintenance, administrative, rental pool	Bid
9	University	Greater LA	200/400	Maintenance, research, administrative, general travel, rental pool	Bid
10	City	Greater LA	700/2,100	Refuse, police, fire, street sweeper, helicopter, administrative, towing, parking enforcement	Bid
11	University	Greater LA	50-100/1,180	Trucks, vans, carts, police, ambulance, box trucks	Bid
12	State	State-wide	300-500/12,000	500 different types of vehicles	State Contract
13	City	Bay Area	600/800	Lawnmower, fire truck, administrative, police, bucket trucks, construction	State Contract, bid
14	Police	Bay Area	200/250	Patrol cars, detective cars, admin cars, under cover cars, SWAT, vans for transport	Sourcewell, bid
15	City	Greater LA	600/1,275	Utilities, police, administrative, fire, street cleaning	Sourcewell, bid
16	Utility	Greater LA	1,500/5,000	Diggers, boom trucks, cranes, administrative	Phoenix Industries (leased)
17	City	Greater LA	178/500	Fire/ PD/ administrative/ sewer	Enterprise (leased)
18	City	Central Valley	35/36	Lawnmower, fire, buses, sewer, police, etc.	Sourcewell, State contract, bid
19	City	Bay Area	1,100/1,825	Everything	Sourcewell, State contract, bid, piggyback
20	County	Bay Area	986/1,350	Pool cars, excavators, crane, sweeper, police	Bid
21	County	Central Valley	880/1,100	Police, administrative, dump truck, etc.	Sourcewell, bid
22	State	State-wide	4,410/4,500	Law enforcement and everything else	State contract
			30,000/50,000	Law enforcement and everything else	State contract
23	City	Bay Area	1,600/2,800	Police, fire, library, buses, public works	Sourcewell, State contract, bid

*All fleet applications are listed, although interviews focused only on light-duty applications including passenger vehicles, pool cars, police, and vans.

**A competitive bid process requires the fleet to obtain several bids to find the lowest purchase price for a vehicle that meets the specified criteria. Fleets can additionally select vehicles off competitive bids held by other fleets. Cooperative purchasing contracts (including Sourcewell, Phoenix Industries, and the California State Contract) are competitive solicitations (amongst dealers or manufacturers) conducted at a larger level than fleets can do on their own, creating a large scale leveraging of fleet purchasing power. These methods are outlined in section 5.1.

Note: Fleet 22 owned 4,500 vehicles and oversaw 50,000 more vehicles in the state of California. Fleet managers often reported rounded numbers, not exact sizes. Total number of vehicles is approximately 101,650 with 51,000 cars (~50%).

2.3.2 Interview Topics

The interviews explored topics such as how light-duty fleet managers make vehicle acquisition decisions, how fleets are managed, user experiences with PEVs, the fleet manager's perception of how PEVs could fit into their fleet, and how the decision to acquire PEVs was made (if the fleet had PEVs), among other topics. To minimize potential biases that may arise from the interview process, the researchers attempted to provide similar experiences across the sample, with all but four interviews conducted by the same two interviewers who followed the same interview protocol for each interview (see Appendix 1 for complete interview protocol).

2.3.3 Analysis

Interviews were audio recorded and transcribed, transcripts were reviewed for accuracy and coded by one of the interviewers using the software program NVIVO. Two of these interviews were not recorded, data for these interviews comes from interviewer notes and post interview memos. The dataset was analyzed using thematic analysis as outlined in the 2007 paper "Thematic Coding and Categorizing" by Gibbs (2007). This process begins with a set of categories outlined by the researcher based on key themes that emerged in the interviews. These general categories are then expanded and subcategories created as the coding process progresses. This helps identify and categorize all the information relevant to the research, providing clear patterns and themes amongst the interviewees. Codes were inductively derived from the data not from any preexisting codebook.

Once this initial coding process was completed, the interviews were further evaluated, and sub-coded according to SDT, as discussed in Section 2.1.1. This was done based on both what the fleet manager said about each factor (such as mentioning external regulations) and on the sentiment of the conversation. Electrification decisions were categorized based on the degree to which the fleet managers motivation was internalized. For example, the presence of a formal sustainability goals indicated that the decision was motivated by an external regulation. Fleet managers who report being informally directed to purchase more environmentally friendly were categorized as introjected regulations. The next category is identified regulations which includes fleet managers who indicated that they perceived it was environmentally beneficial to purchase an electric vehicle, but were not required to purchase this way. The most internalized category is integrated regulations which includes fleet managers who created sustainability goals themselves.

The figures presented in the results section are intended to report the prevalence of each category within the interview sample, they are not intended to be representative of the entire fleet population and are provided to build context around the sample. Quotations are also provided throughout the results section to give insight into how responses were categorized, they are not meant to represent the full depth of the conversation, which cannot be conveyed in a relatively short quote.

2.4 RESULTS

First, to add context, we briefly describe the process in which fleets acquire their vehicles, then we explore fleet's vehicle purchase motivations for conventional light-duty vehicles, followed by an in-depth look at fleet electric vehicle acquisition motivations. A summary of the purchase and electrification decisions for each fleet is presented in Appendix 2. The same 23 interviews were used for the conventional and electric vehicle purchases, except for one fleet who only purchased conventionally fueled vehicles. This allows for a comparison of the differences in purchase behaviors within the fleet, controlling for differences between fleets that are outside of the management decisions. These are distinct sections since the way in which all vehicles and electric vehicles are selected differs. Finally, we mention barriers to electrification among the fleets sampled, this is included since while most fleets have electric vehicles, barriers to the widespread electrification of fleets still exist.

2.4.1 Fleet Vehicle Purchase Process

Fleet managers indicated there are two main avenues they used to acquire new vehicles: competitive bidding and cooperative purchasing. A competitive bid process was used by the majority of fleets and requires the fleet to obtain several bids (typically 3 or more) to find the lowest purchase price for a vehicle that meets the criteria outlined in the bid request. Fleets often select the vehicle with the lowest purchase cost, although they can restrict vehicles based on previous experiences with them. For example, if vehicles from a certain manufacturer have historically been unreliable, they can exclude these vehicles, regardless of their lower upfront costs.

At a larger scale, vehicles are purchased through cooperative purchasing contracts. These contracts are made by conducting competitive solicitations (amongst dealers or manufacturers) at a larger level than some fleets can do on their own, creating a large scale leveraging of fleet purchasing power. Because these vehicles are already competitively bid, fleets can order the vehicles on these contracts without having to go out to bid themselves. Interviewees in this study reported purchasing through two major contracts. At the state level, fleets can procure vehicles through the California State Contract, which is managed by the California Department of General Services (DGS). Fleets also reported using Sourcewell, which is a nationwide cooperative purchasing contract. Each of these were used by approximately half of the sample. Table 1 shows where fleets purchase the vehicles from. Most fleets indicated that they purchase their vehicles upfront, and three fleets mentioned that they lease vehicles.

2.4.2 Fleet Vehicle Purchase Decisions

Table 2 shows the primary purchase considerations of fleet managers, which have been further classified according to SDT. This shows that ensuring the vehicle was fit for its purpose and could meet the requirements of the application it was intended for (compatibility of use) was the most mentioned motivation. This was often the first consideration to be mentioned by the fleet managers, which may indicate a high level of importance. For all fleets, this was an integrated regulation as there was no indication of an external defining rule that directed fleet managers to purchase this way and all fleet managers internalized this purchase motivator. This consideration is discussed by the manager for Fleet 3, showing that their organization chooses vehicles based on their ability to meet the required specifications above all else.

"There's certain criteria that they have to meet, we don't necessarily pick the lowest bid, we pick the people that can comply with all of our specifications." (Fleet 3, County)

Standardization was the second most mentioned purchase consideration. This is primarily focused on acquiring vehicles from a small number of manufacturers which decreases the number of parts the organization needs to carry, eases training for maintenance workers, and enables fleets to become warranty certified. The need for standardization is more applicable to larger fleets who do much of their own maintenance, while smaller fleets who outsource their maintenance to dealerships and other facilities may have less need to standardize as they do not have to carry the parts for each vehicle type. While this was largely driven by integrated regulations, some fleets standardized for reasons more external in nature. These include fleets with a specific rule requiring them to purchase vehicles from the same manufacturer, making the motivation an external regulation. Most fleet managers had begun to internalize this purchase consideration.

Fleet managers also indicated they were compelled to purchase the lowest cost vehicle that met their needs. This was largely driven by external regulations that are in place to help ensure “fiscal responsibility” in purchases. This purchase motivation was one of the purchase considerations that was most externally influenced. This is shown by Fleet 18 who reported that the city regulations mandated they acquire vehicles with the lowest purchase price.

“Yeah, the municipal code says we have to go with the low bid.” (Fleet 18, City)

Another commonly mentioned purchase consideration was to be more sustainable. This covered all four levels of extrinsic motivations. Some fleet managers reported making sustainable decisions to comply with regulations set by their organization or to follow the California reputation for being “green”, while others commented that it is just the right thing to do. Many fleet managers did not mention this as a purchase motivation, this may be because they faced other challenges in vehicle purchasing that are more important than sustainability. This includes the requirements for compatibility of use, standardization, and purchase price, which often must be met to keep the fleet running. Three fleet managers had integrated this into their own motivations and did not mention any external regulations directing them to purchase sustainable vehicles.

Fleet managers also mentioned purchasing vehicles to help reduce maintenance costs. These motivations were split between being a part of the required total cost of ownership (TCO) calculation, making it an external regulation, and being used to help the fleet manager ensure fiscal responsibility, which are integrated and identified regulations. For example, Fleet 20 reported that they use TCO because it is, "*the right thing to do from a financial perspective*," but that they were not mandated to include this as a purchase factor. This shows that the decision was integrated as the fleet manager say it as their responsibility to limit city expenses. Conversely, it was difficult to determine the type of extrinsic motivation for some fleet managers since they did not mention any regulation requiring this consideration, but also did not appear to have begun internalizing this.

Many fleets indicated that they were unable to use TCO due to its conflict with the competitive bid process and because of a disconnect between vehicle purchase price, maintenance costs, and fuel costs. In many fleets the vehicle was purchased by the fleet department, but fuel is paid for by the user (e.g. a department in the organization). This makes purchasing a vehicle with lower energy costs but higher purchase price less favorable to the fleet department as they do not receive any benefits from the lower fuel expenditure. Similar to maintenance costs, fleet managers reported either using TCO due to organizational regulations, or due to their understanding that they need to be fiscally responsible in their purchasing decisions.

The availability of parts was mentioned by fleet managers who reported purchasing based on their understanding that they need to keep the vehicle up and running. These were categorized as either integrated or identified regulations based on the degree to which fleet managers expressed its importance. They stressed how critical it was for them to maintain a good parts supply to avoid downtime, these managers had substantially internalized this motivation. The manager for Fleet 19 reported that choosing a vehicle with a readily available supply of parts is critical for reducing the amount of time vehicles spend out of use for maintenance.

"So if we can't get supply of parts and services for a piece of equipment then it really, saving $5,000 didn't do any good because the downtime's gonna cost you more." (Fleet 19, City)

A preference for alternative fuel vehicles (AFVs) was often classified as being motivated by external regulations as they mentioned using these vehicles to meet their organization's sustainability goals. Conversely, the manager for Fleet 19 had begun to internalize this consideration and discussed their self-motivating in procuring PEVs for their fleet.

"Number one is the fuel type, we're always looking for alternatively fueled. So that's the number one criteria." (Fleet 19, City)

Table 2: Overview of primary vehicle purchase decisions by fleet.

Purchase Decisions													
Interview Number	**Compatibility of Use**	**Standard -ization**	**Purchase Price**	**Sustain- ability**	**Maint. Cost**	**TCO**	**Availability of Parts**	**Preference for AFV**	**Proximity to Dealer**	**Maint. Trained on**	**Maint. Time**	**Fleet Manager Experience**	**Fuel Cost**
1					U	U*							
2		Int*					Int						
3	Int*	Int		Ident			Int	E	Ident				E
4	Int*	Intro			Int	Int					Ident		
5	Int	Ident				E*	Int						
6	Int*		Intro	Intro	Int							Ident	
7	Int		E*										
8	Int	Int	E		U*					Ident			
9	Int								Ident		Ident*		
10	Int*	Int		Int			Ident			Ident			
11	Int		E*		Int		Ident			Int			
12	Int		E	E	U			E*					
13			E*			Int							
14	Int*		E	Ident								Ident	
15	Int*		E										Ident
16	Int	U*		Int					Ident				
17	Int*		Intro	Intro		Ident					Ident		
18	Int*	Int	E				Ident			Ident	Ident		
19	Int	Int		Ident*	Intro		Int	Ident	Ident				
20	Int*	Int		Int	Int	Int			Ident	Ident			Ident
21	Int		E					E*					
22	Int	Int			U	E*		E			Ident	Ident	
23	Int*	Int	Intro	Ident				E					

Legend	
External (E)	Purchase motivation is classified as an external regulation (initiated and maintained by an external source)
Introjected (Intro)	Purchase motivation is classified as an introjected regulation (pressure from self-esteem or ego)
Identified (Ident)	Purchase motivation is classified as an identified regulation (aligned with personal goals or identities)
Integrated (Int)	Purchase motivation is classified as an integrated regulation (part of their identity or true sense of self)
Unclassified (U)	Purchase motivation type could not be classified in terms of SDT
*	Indicates this consideration was the first to be mentioned by the fleet manager

Lesser mentioned considerations from fleet managers include their proximity to dealerships, purchasing vehicles that their maintenance team is trained to work on, maintenance time, fuel costs, and purchasing based on the fleet manager's previous experience. Each of these motivations were primarily categorized as being an introjected regulation as fleets were not required to purchase in this way, but it was not a part of their identity. There are many other purchase considerations (shown in 'Other') that were only mentioned by one or two fleets as being primary factors in their purchase decisions, including vehicle warranties, right sizing, safety, and resale value.

2.4.3 Electric Vehicle Purchase Motivations

Out of the 23 fleets in this study, 22 have adopted at least one PEV, 18 fleet managers indicated they have conventional hybrid vehicles, and seven reported having hydrogen vehicles. Managers also commonly mentioned having CNG (compressed natural gas) and renewable diesel fueled vehicles in their fleet, with few interviewees mentioning fuels such as LNG (liquid natural gas), propane, and E85 (85% ethanol fuel and 15% gasoline fuel mix). A summary of fuel types used in each fleet is shown in Appendix 3. In this chapter we focus on PEV purchase considerations, not the other alternative fuels mentioned.

Table 3 shows that the most commonly mentioned motivation for purchasing PEVs was to meet sustainability and climate goals set by the organization in which the fleet belongs (e.g. the County or City goals) and a classification of fleet managers motivations using SDT. Fleet managers also mentioned the following motivations: being more sustainable, striving to be a "green leader", utilizing available incentives, reducing costs, and external influences outside of the fleet.

Table 3: Overview of reported motivations for vehicle electrification decisions by fleet.

Electrification Decisions				
	Sustainability and Environmental Goals	**Be a Leader**	**Grants/ Incentives**	**Reduced Costs**
Interview 1	External*			
Interview 2	Integrated*			
Interview 3	External*		External	
Interview 4		Integrated*		
Interview 5	Introjected*	Introjected		External

Interview 6	NA	NA	NA	NA
Interview 7	External*			
Interview 8	External*			External
Interview 9	External*			
Interview 10	External*			External
Interview 11	External*			
Interview 12	External	External*		
Interview 13	Integrated	Introjected*	External	
Interview 14	Identified*			
Interview 15	Introjected*	Introjected		
Interview 16				
Interview 17				
Interview 18				
Interview 19	External*			
Interview 20	External	Integrated*		
Interview 21	Integrated	Identified	External*	
Interview 22	External*			
Interview 23	External*			

Legend	
External	Purchase motivation is classified as an external regulation (initiated and maintained by an external source)
Introjected	Purchase motivation is classified as an introjected regulation (pressure from self-esteem or ego)
Identified	Purchase motivation is classified as an identified regulation (aligned with personal goals or identities)
Integrated	Purchase motivation is classified as an integrated regulation (part of their identity or true sense of self)
*	Indicates this consideration was the first to be mentioned by the fleet manager

2.4.3.1 Sustainability and Environmental Goals

Sustainability goals were often the first electric vehicle purchase motivation to be mentioned by fleets. These were most commonly a result of external regulations made within the organization in which the fleet resided (e.g. the City or County), and not from external sources (such as federal or state, regulations). In some cases, these goals came as specific mandates, such as those for buying 50% alternative fuel vehicles each year (Fleet 2, City), while in other cases, they were more general, including one calling for the fleet to buy ‘green’ vehicles where possible (Fleet 10, City). For most fleets, these goals were set by those in higher administrative levels within the city, county, utility, or university, such as by the Board of Advisors, City Council, or Mayor's office, making them an external regulation. While these motivations are externally based, the majority of these fleet managers reported being supportive of the goals, indicating that they have begun to internalize them, and are likely to continue to implement them. These general directives were given to the fleet managers, who created more structured plans to meet these goals through electrification.

"We have a formal directive that we should buy green whenever possible, that's in a city regulation, and there's a tradition, I've been here for about 5 years, and there's a tradition of buying as green as we could anyway, so we aggressively go out and look for the green options." (Fleet 10, City)

In some cases, the electrification decision came from an entirely separate entity, such as a utility company or a car manufacturer. Interviewees mentioned that they purchased an electric vehicle because they felt pressure or received help from these sources beyond what was in their formal sustainability plans. The manager for Fleet 13 noted that they first began looking into electric vehicles after their local electric utility suggested that they consider them and offered their support in the conversion process.

"We have our own electric utility here… and uh obviously they want to promote electric vehicles so they approached me and said, you know, what can we do, what's available out there for electric vehicles?" (Fleet 13, City)

Three interviewees mentioned developing their own sustainability goals, making the decision an integrated regulation as the decision results from an internal personal motivation of the fleet manager to transition to 'greener' vehicles in the fleet. Fleets in this category are demonstrating their personal commitment to sustainability and environmental issues by taking it upon themselves to create additional regulations for their department. This is shown by the manager for Fleet 13.

"We wrote it, it's gone through some, you know, a couple revisions but it's going through the process of getting finalized right now, talks about right sizing the fleet so you know, really understanding are we getting the most usage out of the fleet?" (Fleet 13, City)

Fleet managers mentioned purchasing the PEVs to be more sustainable or environmentally friendly but did not have any formal sustainability goals. They noted purchasing PEVs and performing other environmentally friendly practices based on the feeling that this was the right thing to do, not from a regulated requirement. Depending on the degree to which these attitudes were influenced by their organization, these responses fell into either introjected regulation or identified regulation. For example, the manager for Fleet 5 reported that while there were no formal goals requiring them to purchase environmentally friendly vehicles, they felt compelled to purchase this way because their CEO was such a strong advocate.

"It is definitely for the reduction in emissions 'cause it's the right thing to do environmentally. The overarching reason is what our CEO describes as demonstrating leadership in environmental sustainability." (Fleet 5, Utility)

2.4.3.2 Be a Leader

Interviewees noted that their organizations are encouraging consumers to switch to electric vehicles, so they felt like they needed to show that they are also committed to making the transition. In some cases, these leadership goals came as a directive from people in higher positions within the organization, while some of these goals came from within the fleet manager's office. Some fleet managers reported they were willing to purchase vehicles that use new technologies, even if they are not the most cost effective, because they want to show the public and other fleets that they are feasible. A few interviewees discussed how their experiences with new technologies has allowed them to help inform other fleets and even automakers about their experiences with the vehicles. These motivations seemed to come from the fleet managers themselves, rather than from external sources. This desire to be a leader in vehicle electrification is shown by Fleets 5 and 20.

"We're trying to demonstrate to other commercial fleets that it can be done and this is how you do it, come talk to us about it." (Fleet 5, Utility)

"We have been committed to being on the bleeding edge of some technologies meaning that we're okay if we're going to make some mistakes, we're gonna learn from those, share information with other fleets from making the same mistakes." (Fleet 20, County)

Not all interviewees shared the same desire to try new technologies. Managers of smaller fleets appeared to be more conservative in their adoption of new technologies, perhaps due to their smaller operating budgets and lesser resources (to conduct research on new vehicle technologies, apply for rebates, install infrastructure etc.).

"As a county, we like being first on the second wave, so we let the big guys try stuff out and then we'll come in first on the second wave. You know so that's the other thing we try not to jump into things too quickly." (Fleet 3, County)

2.4.3.3 Incentives and Grants

The next most mentioned motivation for electrifying fleet vehicles was the availability of external grant and incentive programs. Fleet managers indicated that they initially began converting their fleet to electric and alternative fuels when they heard about the availability of these programs, for example, when asked about how they made the decision to purchase electric vehicles, the manager for Fleet 21 described their experience when attending workshops on PEV grants being offered through the air district.

"So I went to a couple of those and I was like 'hey they're giving money away, let's get this free money and go buy a car,' and it's like, wow it worked, we got a car, let's do it again." (Fleet 21, County)

Other fleets offered similar sentiments, stating, *"almost everything that we've done with our charging stations or electric vehicles there has been some sort of grant or other voucher program that we use."* (Fleet 20, County).

The majority of fleets mentioned using incentives to purchase their vehicles, with many interviewees indicating that the availability of these lowered PEV costs allowed them to purchase the vehicles. Appendix 4 provides an overview of vehicle and charging station incentives used by fleets in this study. The most used incentive is from the State of California, which offers both vehicle and charging station incentives through programs such as the Clean Vehicle Rebate Program, the Carl Moyer Program, and the California Electric Vehicle Infrastructure Project. Incentives at the federal level had low participation rates, with just two fleets reporting having used funds from the federal government. One fleet noted that they were restricted from using these federal grants as public fleets are not eligible to directly receive this incentive because government agencies have no federal tax liability.

2.4.3.4 Reduced Costs

Few fleet managers mentioned economic drivers as a primary motivation in their decisions to purchase PEVs, despite nearly all of them reporting economic benefits from using PEVs in their fleets. This is likely because an understanding of these benefits (low fuel costs, low maintenance costs) emerged after taking ownership of PEVs. This encouraged fleet managers to continue purchasing these vehicles in the future, but it was not commonly reported as an initial motivation for PEV purchase. This motivation was characterized as being an external regulation as fleet managers were required to purchase vehicles with the lowest overall costs to ensure fiscal responsibility.

2.4.4 Barriers to Fleet Electrification

Fleet managers mentioned seven main barriers to electrification: lack of access to charging infrastructure, lack of model availability, limited vehicle range, upfront purchase costs, limited employee buy-in, difficulties electrifying emergency response vehicles, and public perceptions.

2.4.4.1 Charging Infrastructure Access

Fleet managers reported their ability to purchase PEVs was limited by the time and capital investment required to install charging infrastructure for these vehicles. Fleet managers reported vehicles being located in different fleet parking locations meaning infrastructure would need to be installed in several locations. This issue is discussed by Fleet 19. Difficulties in commissioning work and the cost of work to install infrastructure was also mentioned. In organizations where charging stations were already in place, there was no mention of issues with installing infrastructure. This may mean that infrastructure installation is not an insurmountable barrier.

"The only negative thing is the ability to get to charging stations, so the infrastructure and trying to coordinate because a lot of the vehicles are parked at downtown city garages, the City doesn't own the garages so coordinating with the building owner to be able to install charging stations, and then do you

make them public or private, and so if you make them public then you may not be able to get to it and so the infrastructure is the biggest challenge and coordinating efforts." (Fleet 19, City)

2.4.4.2 Lack of Model Options

Fleet managers reported that despite their desire to electrify their fleet, they were limited in their ability to do so because of the lack of vehicle options. They found that while they would be able to electrify nearly all their passenger vehicles, there are little to no options for electrification of pickup trucks, as well as medium and heavy-duty vehicles. This was especially restricting for fleets who have a large proportion of medium and heavy-duty vehicles in their fleet, as noted by Fleet 23.

"There's no factory light-duty truck electric vehicle option yet, I think when that happens, which I'm thinking it's probably not that far away, that's gonna be a complete game changer for fleets. Uh because again the majority of our fleets are light-duty trucks so not having that option is huge." (Fleet 23, City)

2.4.4.3 Range

PEV driving range was noted as a barrier to adoption by nine interviewees. Fleet managers reported this barrier was about the perceived lack of range of BEVs, rather than the actual range of the vehicle. Additionally, many fleet managers noted that the range barrier was something that they had experienced early on in their electrification process, but that once they began adopting longer range vehicles, such as the Chevrolet Bolt, with over 200 miles of range, this barrier was eliminated. Fleet 20 discussed these issues, noting that while they have electric vehicles in their fleet, they were limited in how they could use them due to driver concerns about range.

"We placed 22 Ford Focus EVs in our fleet and the range was sold as 88 miles or 86 miles and then real-world fleet condition it was between 45 and 55 miles, significantly less. So when you're telling the customers [fleet vehicle drivers], plan on needing to recharge after 45-55 miles, they get range anxiety because in their minds they want to make sure they're only driving 30 miles so they don't get stuck someplace. So then the vehicle could go 70 miles but nobody is willing to drive it past 30 which then

limits the number of vehicles that have that have that type of duty cycles, there's not very many of them." (Fleet 20, County)

While range concerns were generally focused on BEVs, some interviewees also mentioned the limited electric range of PHEVs. The manager from Fleet 20 mentioned being disappointed that they were not able to electrify more miles, which decreased the cost and emissions savings associated with these vehicles.

"The range of just operating off the batteries varies from 13 miles up to about 32 miles, 36 miles, that's not quite long enough for a government fleet, it would be much better if we had a plug-in hybrid that gave us 100 miles from driving on the battery. That would meet a lot more of our duty cycles." (Fleet 20, County)

2.4.4.4 Vehicle Costs

The higher upfront cost of PEVs was mentioned by seven fleet managers as a main barrier to their adoption. Many of these interviewees noted that while they support the push towards electrification, and had sustainability goals in place, there was uncertainty over who would be paying for the increased costs of purchasing these vehicles. The manager from Fleet 4 noted that there was no room in their budget to cover the additional costs of these vehicles.

"The city has set specific goals, you know we have a kind of goal to have the most cost-effective type of vehicle that's most economical, the lowest emissions but if it costs more we're probably not gonna do it." (Fleet 4, County)

2.4.4.5 Employee-Buy In

Lack of employee buy-in is tied to other barriers, as it is caused by issues such as lack of vehicle range, charging infrastructure, and model availability. Fleet managers reported that when PEVs were first purchased, employees were hesitant to use them. In some organizations, fleet management teams worked to overcome this through outreach and education efforts. In other fleets, PEVs were assigned to certain people or departments so they could get used to driving them. The importance of utilizing strategies to increase driver acceptance was emphasized by the manager of Fleet 2.

"You know you can take the best technology in the world and shove it at somebody, but you have to work with them and that's what we do here in fleet is to try to get people to understand there's other options, there's other technology, and work together to make everyone happy." (Fleet 2, City)

2.4.4.6 Other Barriers

Interviewees mentioned that while they were looking to electrify their fleet, they did not feel that they would be able to purchase these vehicles for emergency response purposes, which seemed to be mainly rooted in PEV's longer charging times and limited range. These fleet managers reported that they did not think police cars would ever be converted to PEVs due to their operating requirements.

Some fleet managers found public perception of PEVs to be barrier to their adoption. In many cases, they were referring to purchasing higher end >200-mile range PEVs, which they claimed to be the only vehicles that would fit their operational needs. Fleet managers reported that even if they could afford the higher price, or if they utilized incentives to lower the price, the public would perceive the purchase as a misuse of government funds. Other barriers that were mentioned include a lack of fleet authority to buy a PEV, longer procurement times, fleet managers being too busy to evaluate PEVs, and lower resale value.

2.4.4.7 Institutional Barriers

In addition to the barriers mentioned by the fleet managers, several barriers to PEV adoption were identified by the researchers. These were not specifically mentioned by fleet managers as being barriers, but nevertheless they may pose difficulties for PEV adoption.

First, the use of the competitive bid processes and higher purchase costs of PEVs may mean that fleet managers cannot purchase PEVs. Second, some interviewees reported a lack of time and resources for fleets to apply for incentives, which can reduce the purchase cost of PEVs below that of conventional vehicles.

Some fleet managers reported their organization has a system in which the central fleet purchases the vehicles, but individual departments pay for vehicle's fuel costs. This can decrease the cost savings potential associated with the vehicle from the perspective of the central fleet manager and can impact vehicle operation cost calculations.

The lower operating costs of PEVs is not necessarily sufficient to persuade fleet managers to purchase them since the need to standardize the fleet, have the most compatible vehicle, and disconnect between the payment of the vehicle could override any cost considerations. These findings suggest that a lower TCO for PEVs may have less of an influence on their market share of fleet vehicles than previously thought (Palmer *et al.*, 2018), though their lower maintenance costs do align with fleet managers purchase decision making.

The interviews revealed that smaller fleets with less resources often lack the adequate time (due to them having fewer employees) and money needed to fully assess the integration of PEVs into their fleets, including understanding any barriers or benefits. Smaller fleets were frequently unaware of or did not utilize incentive programs for PEV purchase and did not consider TCO or any vehicle running costs when making their purchase decisions. Some fleets indicated purchasing vehicles based on the knowledge they had gained working in the industry and did not use any sophisticated calculations or criteria.

2.5 DISCUSSION & CONCLUSIONS

The results from the interviews conducted in this study show that PEVs are not necessarily aligned with existing purchasing consideration of California light-duty fleet managers. Fleet managers seek to purchase vehicles that are compatible with their use requirements, they desire to standardize the make of vehicles in their fleet, and often are required to purchase the cheapest vehicle available to them. Public fleets do not typically use TCO calculations as a primary decision factor in their vehicle decisions. The lower operating costs of PEVs in comparison to ICEVs therefore will not lead to light-duty fleet managers disregarding their existing considerations to purchase PEVs.

Fleet managers are purchasing light-duty PEVs despite the misalignment of PEVs to fleet vehicle purchasing and barriers to PEV adoption. Their motivations for doing so are often outside of typical acquisition considerations, which are often integrated motivations. Fleet managers are adopting light-duty electric vehicles because of sustainability goals, environmental motivations, motivations to be a 'green' leader, grants, external influences, and a desire to reduce operating costs. Fleet managers are overcoming the barriers to PEV adoption by educating fleet vehicle users about PEVs and assigning the vehicles to more receptive drivers and departments. They are also working with utilities, using existing infrastructure, and researching new infrastructure installations. Range limitations are overcome through the introduction of new vehicle models with longer ranges, assigning vehicles to tasks that fit PEV driving range, and through education. Higher acquisition prices are overcome through grants and with sustainability goals that give waivers to the lowest bid purchase requirements.

Examining light-duty fleet purchase motivations under the framework of Self-Determination Theory, we find that it is most common for fleet purchase decisions to come from more internalized extrinsic motivations including integrated and identified regulations. This is perhaps because fleet managers are accustomed to purchasing conventional vehicles and have internalized these purchase considerations due to them aligning with their own motivations. This contrasts with the electrification decisions, which primarily come from less internalized motivations that fall under external regulations. This disparity may be at least partially attributable to the relative novelty of electric vehicles, which require some level of external motivation to spur initial adoption. As fleet managers become more experienced with using and purchasing these vehicles, fleets may begin to internalize these motivations, thus moving them further along the spectrum towards integrated regulation. Until that occurs though, external regulations may be required to motivate light-duty fleet managers to continue fleet electrification.

Studies of private consumers have shown the largest barriers to the initial and continued adoption of PEVs, among others, as being a lack of awareness of electric vehicles, a lack of access to adequate charging infrastructure, limited vehicle ranges, higher purchase prices, and lack of vehicle options

(Berkeley, Jarvis and Jones, 2018; Wang *et al.*, 2018; Singh, Singh and Vaibhav, 2020; Hardman and Tal, 2021). While these barriers are also seen as issues for fleets, the way in which these barriers manifest is often different. For example, though high purchase prices are a perceived barrier for consumers, some consumers are willing to pay a premium for PEVs (Hidrue *et al.*, 2011). Whereas some light-duty fleet managers cannot purchase vehicles with a price premium even if they wish to do so. Issues with range and a perceived lack of infrastructure are also different for fleets, given their need to meet specific requirements, such as those for compatibility of use. Additional fleet specific barriers, including issues with employee buy-in, procurement under the competitive bid process, the need for vehicle standardization, lack of vehicle options, and difficulties in installing charging infrastructure and ensuring drivers charge the vehicles. Fleet managers were still concerned with the usage of electric vehicles after they were integrated into the fleet as some drivers were concerned about using new technologies, although this was not found to be as prohibitive as other barriers.

As in previous fleet studies on alternative fuel vehicle adoption (Nesbitt and Davies, 2013; Sierzchula, 2014; Wikström, Hansson and Alvfors, 2016; Figenbaum, 2018), light-duty fleets were found to be driven by their desire to try new technologies, lessen environmental impact, improve their public image, and use grants. Our study builds upon the findings of these previous studies by systematically reporting fleet managers' descriptions of barriers and motivations to light-duty PEV acquisition, categorizing the motivations according to Self-Determination Theory, and comparing fleets' PEV acquisition decisions with their conventional vehicle acquisition decisions.

Unlike in Skippon and Chappell (2019), TCO was not found to be one of the main drivers of electrification with other factors playing a larger role in decision-making. Even though 6 years have passed since the first of these papers was published, little progress has been made in these areas.

2.6 LIMITATIONS & FUTURE RESEARCH

While fleet size, organization type, and organizational structure are likely to influence light-duty fleet purchase decisions (e.g. hierarchical organizations are more external while flat organizations are more internalized), these effects were not thoroughly examined as this study sought to understand the motivation of individual decisionmakers within organizations. Self-Determination Theory was chosen as it explores the motivations of individuals within the organization, however, this, and the fact that the interviewee protocol did not focus on organizational type, limits its ability to examine the influence of organizational structures. While a detailed analysis of the impacts of organizational structure is not in the scope of the study, this may be a topic of future research.

The results of this study are limited to public and semi-public light-duty fleets, conclusions may not extend to private or medium- or heavy-duty vehicles. As discussed in this chapter, public fleets face pressures to be fiscally responsible and are often required to purchase through competitive bids or cooperative purchasing contracts. Private fleets may not face the same constrains to purchase the lowest priced vehicle and may more easily use TCO calculations in their purchase decisions. Both public and private fleets, however, may be subject to similar constrains such as range, charging infrastructure, and employee buy-in. Future studies should examine the extent to which these findings differ between fleets of different types.

2.7 POLCY IMPLICATIONS

The leading reason for light-duty fleet PEV purchase is due to regulations set by the organization the fleet belongs to. Many of the fleets studied do have not have regulations that require the purchasing of PEVs. Regulations currently exist for state owned fleets, but these do not apply to city or county fleets. To encourage the transition away from fossil fuels, California state policymakers could seek to regulate the purchasing of light-duty vehicles in public fleets beyond their state organizations.

Many traditional purchase regulations were designed with conventional vehicles in mind, which can create barriers to PEV purchases. The requirement to purchase the lowest cost vehicle under the competitive bid process and to standardize vehicle makes may prevent PEVs from being purchased. Allowing exceptions to these rules or changing them to consider TCO instead of purchase price may help encourage light-duty fleets to purchase electric vehicles.

Not all fleets who purchased electric vehicles reported using incentives. One reason was due to a lack of knowledge of incentive availability and confusion around whether they can be used in conjunction with each other. Fleets also mentioned difficulties in finding the time to apply for them. Policymakers could seek to streamline the application process to make incentives more accessible, especially to smaller fleets who may have fewer employers and may be more time constrained. This can be especially useful in helping lower the cost of PEVs, potentially allowing them to compete with conventionally fueled vehicles on price metrics.

Given that only three of the 23 fleets mentioned economic drivers in their electrification decisions, it may be important to more directly show the cost savings associated with PEVs before they are purchased, such as at the dealership or online purchasing sites. These should display not only the purchase costs, but also the running costs (both fuel and maintenance costs) and TCO estimate of the vehicle. The cost savings can also be clearly communicated through traditional advertisements which can include cost savings estimates.

A lack of larger vehicle platforms available with electric drivetrains was mentioned as a barrier to light-duty fleets electrifying more of their vehicles. At the time this study was conducted, no commercial electric pick-up trucks existed, which many fleets specifically mentioned as an obstacle to meeting their goals. California's new Advanced Clean Cars and Advanced Clean Truck regulations creates manufacturing targets for light-, medium-, and heavy-duty ZEVs, which may help spur the electrification of these vehicles and make them available for fleets (California Air Resources Board, 2019).

Difficulties accessing charging infrastructure was commonly mentioned by fleet managers as a barrier to electrification. While increasing the amount of publicly available charging infrastructure could support electrification, light-duty fleets more typically access charging stations installed at their base location or fleet yard where they can charge overnight. Incentives and policies that support the installation of workplace or fleet charging may help fleets access reliable charging when they need it while lowering the financial burden of the transition. These policies would ideally support both the equipment and installation of charging infrastructure, similar to what has been done through programs such as CALeVIP (Center for Sustainable Energy, 2022a).

While this study focuses on the adoption of light-duty PEVs in California, the results may be applicable to other states in the United States, and internationally. The results reveal where the motivation to procure electric vehicles originated from, which in many cases was at higher administrative levels in city, county, and state governments. It may be possible for policymakers in other regions to set similar policies and regulations for fleets operating in their region. Similarly fleets in other regions may have procurement rules that direct them to acquire the lowest priced vehicles. Restructuring policies to prioritize the purchase of electric vehicles and allowing for the use of TCO rather than purchase price will help fleets transition to electric vehicles. Barriers such as range, limited model availability, and lack of charging infrastructure have been shown to restrict fleet electrification across Europe (Pfriem and Gauterin, 2016; Skippon and Chappell, 2019; Vuichard, 2021).

Given the growing need for sustainability in both public and private organizations, more research is needed to create a broader understanding of how specific measures are influencing the adoption of PEVs in fleets around the world.

Chapter 3: Social, Technological, and Economic Barriers to Heavy-Duty Truck Electrification

3.1 INTRODUCTION

The disproportionate emissions of heavy-duty electric trucks and subsequent emergence of zero-emission truck policies necessitates an understanding of the ways in which fleet decision-makers perceive electric trucks. This study seeks to fill this need by speaking directly with fleet decision-makers to understand their perceptions of barriers to heavy-duty electric truck adoption.

Heavy-duty trucks have higher rates of emissions due to their higher power demand and reliance on diesel fuel (Moultak, Lutsey and Hall, 2017; Smith *et al.*, 2019; Muratori *et al.*, 2021). Diesel powered vehicles and equipment are the largest contributors of fine particulate matter from transportation while also emitting a substantial amount of harmful NO_x (Caltrans, 2016). These trucks often operate in urban areas and some applications, such as drayage and delivery trucks, idle for extended periods.

Heavy-duty fleet electrification is necessary to achieve zero-emission vehicle, air quality, and greenhouse gas emission reduction goals. The California Air Resources Board has set two regulatory requirements for heavy-duty fleets to transition to zero-emissions trucks. The Advanced Clean Trucks (ACT) program requires medium- and heavy-duty truck manufactures to sell increasing percentages of zero-emission trucks each year from 2024 to 2035, when zero-emission trucks must make up 75% of straight truck and 40% of tractor-trailer sales (California Air Resources Board, 2019). The Advanced Clean Fleets (ACF) program is still in development but will place zero-emission truck purchase requirements on fleets operating medium- and heavy-duty trucks in California. It currently requires 100% of truck purchases be zero-emission by 2040 (California Air Resources Board, 2021). Regulated fleets can also benefit from programs that provide financial assistance to purchase zero-emission trucks, including the Hybrid and Zero Emission Truck and Bus Voucher Incentive Program (HVIP) (California HVIP, 2022).

While this study focuses on trucks operating in California, these findings can be used as a base for informing heavy-duty truck electrification efforts throughout the United States and globally. In the US, many states opt to follow California's more stringent air quality goals with 15 states and the District of

Columbia having signed a memorandum of understanding to reach 100% zero emissions for new medium- and heavy-duty vehicle sales by 2050 (California Air Resources Board, 2020).

We investigate barriers to fleet compliance, focusing on fleets operating heavy-duty trucks in California—whether the fleet is headquartered in California or not. Data are collected via interviews with decision-makers directly involved in heavy-duty truck acquisition. Their perspectives are rarely included in the academic literature despite their direct involvement in purchase decisions. As the transportation sector is increasingly pushed to become more sustainable, findings from this research supports policy making towards electrification.

While modern light-duty electric vehicles were commercially introduced in the United States in 2008-2010 and are increasing in market share (16% of new vehicle sales in California (California Energy Commission, 2022)), the market for heavy-duty electric trucks is in its nascence (U.S. DOE, 2014). Light- and heavy-duty vehicles differ significantly in their energy and power demands as well as charging infrastructure requirements (Mikulin, 2016; Smith *et al.*, 2019). Given their higher annual mileage, longer drive times, and use in mainly business applications the factors influencing purchase decisions may differ compared to electric light-duty vehicles (Brown, Fleming and Safford, 2020; Muratori *et al.*, 2021). These differences may lead to different perceptions and factors that influence the purchase of heavy-duty electric trucks. Without an understanding of how fleets purchase heavy-duty electric trucks, and their first-hand accounts of why zero-emission trucks will or will not be feasible in their fleets, policies such as California's ACT and ACF regulations may not be met.

This chapter aims to fill this need by describing the barriers to heavy-duty truck electrification. This chapter reports insights from 28 semi-structured interviews with heavy-duty fleet decision-makers on the electrification of truck purchase and use. We classify the barriers they describe to heavy-duty electric truck adoption into six categories: technological, economic, social, socio-technological, techno-economic, and socio-economic. These categories are defined in the Methods section and provide a framework that shows the complexities of heavy-duty truck electrification and how barriers transcend economic, technological, and social issues to include hybrid barriers.

3.2 OVERVIEW OF THE HEAVY-DUTY TRUCKING SECTOR

For the purpose of this study, heavy-duty trucks are defined according to the Federal Highway Administration's specifications and have a gross vehicle weight rating of over 26,001 lbs. (Class 7 and 8) (US DOE, no date). There are currently over 1.7 million registered motor carriers operating 7.4 million medium- and heavy-duty trucks operating in the United States (Federal Motor Carrier Safety Administration, 2022).

Heavy-duty trucks are used in a variety of applications, including moving freight in long-haul, short-haul, and drayage applications. Here, long-haul operations are defined as those where drivers spend multiple nights per week away from home. Trucks used in this application generally account for the largest share of miles driven in the heavy-duty trucking sector, traveling up to 800 miles per day (Brown, Fleming and Safford, 2020). Short haul trucks are those that do not meet the requirements for long-haul classification (Lemke *et al.*, 2021). These trucks tend to operate in more urban areas and make more frequent stops, often travelling less than 100 miles per day, although they can be used for longer, regional trips (Fleming *et al.*, 2021). Drayage trucks are any truck that provide pickup or delivery services to a seaport (Namboothiri and Erera, 2008). Drayage is a subset of short-haul which is classified separately as they have a distinct duty cycle and their own set of regulations. These trucks typically have a limited daily mileage and return to a base location at the end of each day (González Palencia *et al.*, 2020).

While heavy-duty vehicles are used in non-freight applications (e.g., refuse hauling, coaches and transit buses, and vocational applications), these applications are out of the scope of this study.

3.3 LITERATURE REVIEW

Little is known about heavy-duty fleet operators' perceptions of electric trucks. There are a few papers examining the attitudes of light-duty fleet operators (Nesbitt and Sperling, 1998, 2001; Sierzchula, 2014; Sugihara and Hardman, 2022). These findings may not apply to fleet considerations of heavy-duty trucks.

Heavy-duty trucks often are driven greater annual and daily distances, have greater power demand, and may have associated specialized equipment, such as cold storage trailers. All these create differences in purchase considerations than that of light-duty vehicles (Brown, Fleming and Safford, 2020; Nadel and Junga, 2020; Tanvir *et al.*, 2020; US DOE, 2020; Fleming *et al.*, 2021; Muratori *et al.*, 2021). There is a high variation between heavy-duty fleets in terms of size, organizational structure, and use cases (Nesbitt and Sperling, 2001; Askin *et al.*, 2015, p. 201; Gao *et al.*, 2018; Murray and Glidewell, 2019; Muratori *et al.*, 2021). This diversity is likely to extend into their purchase considerations and requirements for zero-emission trucks.

There have been many technical studies examining the ability of electric heavy-duty trucks to meet required duty cycles (e.g. range, power, torque), i.e., while accounting for energy use of given trucks, assessments of the suitability of electrifying those trucks are made without speaking to the fleets about their experiences and attitudes (San Pedro Bay Ports, 2017; Mihelic and Roeth, 2018). Most of these studies have examined truck electrification by evaluating either the battery size needed to meet current truck use cases (Mareev, Becker and Sauer, 2017; Muratori *et al.*, 2021) or understanding the use cases in which fleets could deploy trucks given current battery technologies (Gao, Lin and Franzese, 2017; Sripad and Viswanathan, 2017; Smith *et al.*, 2019; Jahangir Samet *et al.*, 2021). Ribberink *et al.* (2021) found that, assuming a charging time of 8hr/day at a minimum of 100kW, a long-haul electric truck would, on average, need an 800-kWh battery to operate in the same conditions as a diesel truck. Regarding use cases for existing battery technology, Tanvir *et al.* (2020) conclude that if drayage trucks are given access to charging at their base location between tours (defined as "a contiguous sequence of trips starting from the home base location and ending at the home base location”), 85% of their daily tours could be met with electric trucks. Studies on this topic often discuss tradeoffs between increased range, weight, and upfront costs. They conclude that given current battery capabilities, electrifying trucks across applications will require policies that increase weight allowances and develop charging infrastructure (Çabukoglu *et al.*, 2018; Liimatainen, van Vliet and Aplyn, 2019). Both Ribberink *et al.* (2021) and Mareev *et al.* (2017)

note that while payload capacity is expected to decrease with electric trucks, current fleet operations are more often constrained by a lack of cargo space than lack of payload capacity. Given that the batteries on a tractor-trailer do not affect the cargo space of the trailer, they conclude this will not pose as much of an issue as others believe.

There has been research into the barriers to fleet electrification (NACFE, 2018; UPS, 2018; Filippo *et al.*, 2019; Hewlett Foundation, 2020; Nadel and Junga, 2020; Qasim and Csiszar, 2021), however, these studies focused primarily on listing potential barriers without an in-depth discussion of the extent to which barriers limit zero-emission truck purchases. While previous studies have discussed barriers to heavy-duty truck electrification, few consulted fleets themselves. A recent study by Bae *et al.* (2022) explored the adoption of heavy-duty alternative fuel vehicles, including electric trucks and buses, finding environmental consciousness, regulations, and financial incentives to be the strongest motivators for alternative fuel vehicle adoption. Conversely, they found functional unsuitability, commitment to other fuels, and unavailability of vehicles were the most emphasized barriers.

Our study, along with Bae *et al.* (2022), is one of the first to conduct in-depth qualitative interviews with decision-makers in fleets operating heavy-duty trucks to determine barriers to truck electrification. By speaking directly with fleet decision-makers, both real and perceived barriers can be captured. We expand upon the literature by categorizing barriers into six categories based on the interviewee's descriptions. We additionally compare results between fleets with and without experience operating electric trucks. This allows us to understand what barriers may prevent all fleet types from electrifying versus those that pose constrains only for specific fleet types.

3.4 METHODS

3.4.1 Sample

Data are from 28 semi-structured hour-long interviews conducted with heavy-duty fleet decision-makers in 2021. Interviews explored awareness and knowledge of electric trucks including barriers and opportunities to their adoption. These semi-structured interviews follow a protocol of open-ended questions which was developed using key themes from existing literature on the subject. To keep interviews consistent and minimize potential biases that may arise from the interview process, all interviews followed the same protocol (shown in Appendix 4) and discussed the same topics. Follow-up questions are asked as the conversation progresses, allowing for an in-depth exploration of topics that matter the most to the interviewee. This process is outlined by DiCicco-Bloom and Crabtree (2006). If not directly mentioned by the participant during the conversation, they were asked to speak about their views of electric trucks.

Sampling was done to reach decision-makers in fleets of different sizes and application types. Once it was confirmed that the fleet operates heavy-duty trucks in California, invitations were sent via e-mail using publicly availability contact information. Fleets did not have to be headquartered in California but did have to operate trucks in California. Interviewees were offered a $120 incentive for their participation.

Interviewees were screened beforehand via a short questionnaire asking if they were involved in truck purchasing and/or retirement decisions for their fleet. Interviews proceeded only upon confirmation of their involvement in the purchase process. The final pool of interviewees included people in positions such as corporate leads (e.g., President, CEO, Owner), fleet department leads (e.g., Director of Fleet Operations, Director of Fleet Management, General Manager, Fleet Manager, Director of Transportation, etc.), and owner-operators (individuals who both purchase and drive the trucks they own). All interviewees were “decision-makers” within their fleet with some influence over decisions affecting fleet turnover.

Fleets were classified as small (under 20 trucks), medium (21-150 trucks), or large (over 151 trucks). These categories account for the significant skew towards smaller fleets, i.e., most entities operating heavy-duty trucks are small fleets while most heavy-duty trucks are operated by large fleets. Small owner-operators are prevalent in the heavy-duty trucking sector and have been shown to have different purchasing practices than larger organizations (Schoettle, Sivak and Tunnell, 2016). The final sample contained 8 small fleets, 7 medium fleets, and 13 large fleets. These trucks were used in various applications, which were combined into three primary categories: long-haul, short-haul, and drayage. A single fleet can be categorized as multiple fleet applications, so totals shown in Figure 3 do not add to 28.

Table 4 provides an overview of the 28 fleets. Here, experience with electric trucks refers to fleets that have current or previous experience operating at least one battery electric truck, although they do not have to be currently operating it. A total of eight fleets had such experience including seven large fleets and one medium fleet. Electric trucks in these fleets had thus far only been used in short-haul and drayage applications. In some cases, fleets had previously participated in zero-emission truck demonstration projects, but no longer operated these trucks in their fleet. Interviewees representing fleets which have experience operating electric trucks provide firsthand accounts of their experiences, while fleets without similar experience report perceptions of electric trucks based on whatever information they have.

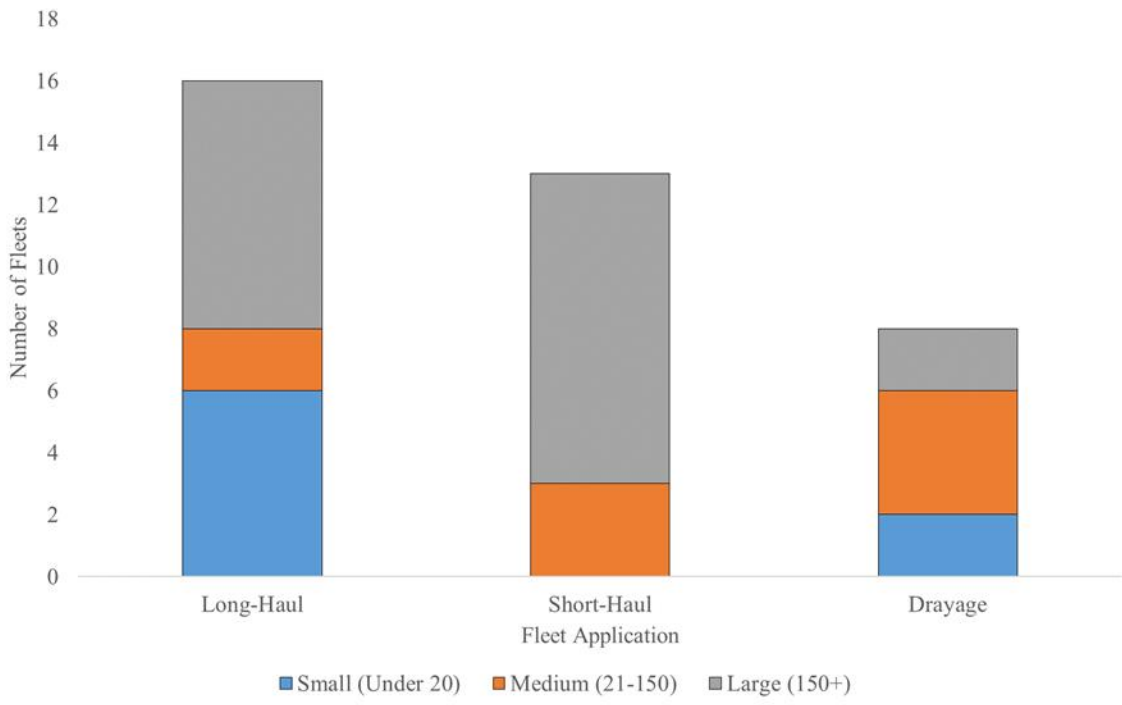

Figure 3: Breakdown of fleets in this study by fleet size and application. (n drayage= 8, n short-haul= 14, n long-haul= 16)

Table 4: Overview of fleets in this study. Fleet numbers listed here are used to identify fleets throughout the chapter.

Fleet #	Freight Specialization	Fleet Size	Applications	Truck Classes	Electric Experience
01	Food, General	70	Short-haul, Long-haul	8	No
02	Food	5	Long-Haul	8	No
03	General, food, chemical	14,000	Long-haul, drayage	8	No
04	Food	130	Long-Haul	8	No
05	General	213	Short-haul, Long-haul, Drayage	8	Yes
06	Food	1,500	Short-haul, Long-haul	7, 8	Yes
07	Municipal	600	Short-haul	2b-8	Yes
08	Chemicals	700	Short-haul, Long-haul	2b, 3, 4, 7, 8	No
09	Chemicals	55	Drayage	8	Yes
10	General	17	Drayage	8	No
11	Municipal	1,500	Short-haul	2b-8	Yes
12	General	40	Short-haul, Drayage	2b, 8	No
13	Municipal	890	Short-haul	2b-8	No
14	General	35,000	Short-haul, Long-haul	2b-8	Yes
15	General	25	Short-haul	8	No
16	General	26	Drayage	8	No
17	General, food	346	Short-haul	2b-8	No
18	Overweight	12	Drayage	8	No
19	General	1	Long-haul	8	No
20	General	22	Drayage	4, 8	No
21	Chemicals, pharmaceutical, food	1	Long-haul	8	No
22	General	1	Long-haul	8	No
23	General	1	Long-haul	8	No
24	General, event equipment	1	Long-haul	8	No
25	Food, pharmaceutical	180	Long-haul	8	No
26	General, furniture	2,424	Short-haul, Long-haul	2, 3, 4, 6, 8	No
27	Parcel	10,000	Short-haul	4-8	Yes
28	General, food	7,500	Short-haul, Long-haul	8	Yes

3.4.2 Analysis

Interviews were recorded through post-interview memos, allowing researchers to track the number of new topics learned, showing topical saturation began at around 18 interviews. This project analyzes data from 28 hour-long interviews with heavy-duty fleets. This sample size is similar to other qualitative studies on electrification topics (Graham-Rowe *et al.*, 2012; Caperello, Kurani and TyreeHageman, 2013; Bae *et al.*, 2022; Sugihara and Hardman, 2022). Interviews were audio recorded and transcribed, transcripts were reviewed for accuracy and coded by one of the interviewers using the software program NVIVO. The dataset was analyzed using a concept-driven thematic coding approach as outlined by Gibbs (2007). This is an inductive process starting with a set of categories derived by the researchers based on patterns and themes that emerged during the interviews. Initial categories are then expanded, reorganized, and subcategories are created as coding progresses. Codes were derived from the data not from any preexisting codebook, review, or results. Coding involves interpreting each line of the interview as it was stated by the interviewee. The coding and categorization synthesize the data to identify and categorize all the information relevant to the research.

To provide context, quotations are provided throughout the results section and are shown in Table 6. While these quotes provide insight into how responses were categorized, they are not meant to represent the full depth of the conversation. The fleet number and barrier categorization applied to each quote is shown.

Results summarize the interviews reported here and are not meant to represent the fleet population. Not only might the responses look different across a representative sample, but they might be different if we had interviewed someone else within the same fleets.

3.5 RESULTS

We first discuss and define barrier categories. We then present a concept map of the connections between these categories and individual barriers based on interview results. Then we outline barriers to electrification and which categories these fit into. Finally, we discuss differences between fleets with and without experience operating electric trucks.

3.5.1 Categorizing barriers to electric truck adoption

Based on the coding of interviewee transcripts, we classified barriers to heavy-duty electric truck adoption into six categories including three one-dimensional categories (technological (T), economic (E), and social (S)) and three hybrid (techno-economic (TE), socio-economic (SE), and socio-technological (ST)). These barriers provide a framework showing the complexities of heavy-duty truck electrification and how some barriers transcend one-dimensional categories. We determined our classifications based on how interviewees reported and discussed barriers, using existing literature to help define our categories.

Technological barriers are defined as functional limitations of an electric truck and its associated infrastructure that inhibit its ability to fulfill existing operations of the organization (Bae *et al.*, 2022). Such barriers occur when new technologies are seen as unable to perform the established practices of an incumbent technology (Paul, Pearlson and McDaniel, 1999; Geels, 2012; Wikström, Hansson and Alvfors, 2016). In the case of electric trucks, examples of technological barriers include differences in the driving range per refueling, time to refuel, and higher gross vehicle weight, which impact an electric truck's ability to transport goods or the ease of transporting cargo in comparison to diesel trucks.

Economic barriers are impediments to the flow of money into and through the market or organization including revenue, capital costs, operational costs, financing, investment, and market prices (Sovacool *et al.*, 2011; Cherp *et al.*, 2018). Presently for electric trucks, these include barriers such as higher purchase costs and lower resale value compared to a diesel truck. These economic challenges may outweigh potential operational cost savings (e.g. lower fuel and maintenance costs).

Social barriers originate from people's connections and relationships with the truck and its supporting infrastructure. This includes their beliefs, values, understandings, perceptions, preferences, and psychological resistance to the technology (Sovacool, D'Agostino and Jain Bambawale, 2011; Cherp *et al.*, 2018). These relationships affect user attitudes and willingness to experiment (O'Connor *et al.*, 2016). One example of this would be a decision-maker believing that operating trucks running on multiple fuels would increase complexity of buying, scheduling, fueling, maintaining, and retiring trucks.

Interviewee descriptions of barriers often overlap these categories, requiring three hybrid categories combining pairs of the individual categories. For example, while driving range per charge is a technological barrier arising from the physical capabilities of presently available electric trucks, shorter ranges may impose operational restrictions. If an interviewee connects shorter driving range to reduced earnings, their description is categorized as techno-economic—combining elements of technological and economic barriers. In cases where the interviewee discusses a barrier as having components of multiple categories, the barrier is classified as a hybrid category. No interviewee made a statement requiring a hybrid of all three individual categories, although nothing here precludes such a possible statement. While these classifications are used to categorize the way interviewees discuss each barrier, they are not an absolute description of the barrier. For example, interviewees reporting range as a purely technological barrier may experience it as techno-economic but may not have made this connection or did not discuss it as such in the interview. Categorizations are based strictly on interviewee descriptions.

Figure 4 shows a concept map of the identified barriers, the six barrier categories, and their connections. Classifications are made for each fleet for each barrier based on how it is described by the interviewee, rather than how the researcher views it. These classifications are shown in Appendix 5.

Table 5 defines each barrier identified in this study and summarizes the categories they were discussed as.

While these six categories (three individual and three hybrid) are intended to guide discussion of truck electrification, the examples presented here are not necessarily representative of all fleet decisions or all barrier categories. Furthermore, the novelty of heavy-duty electric trucks presents a dynamic landscape with barriers and interactions continuously evolving as technological capabilities and costs associated with electric trucks improve and fleets and drivers gain experience with them.

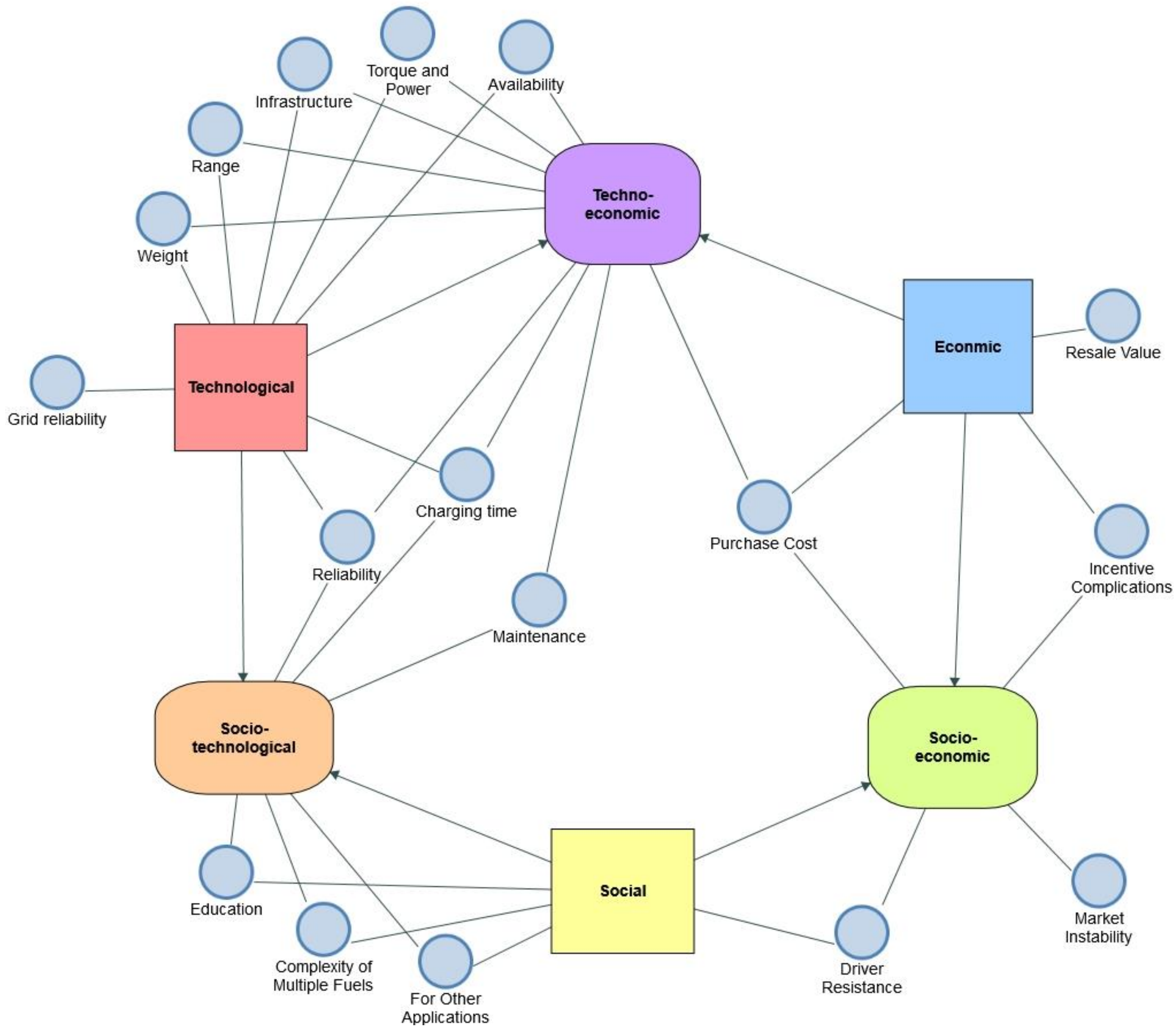

Figure 4: Concept map of barriers to electric truck adoption classified into social, technological, economic, and hybrid categories.

Table 5: Definition of barriers & categories they are reported as in this study

Barrier	Categories	Definition
Infrastructure	T, TE	Any issue related to charging infrastructure including lack of publicly available charging infrastructure and issues with installing private-use charging stations.
Purchase Cost	TE, E, SE	Issues around the higher purchase cost of heavy-duty electric trucks relative to diesel-fueled trucks.
Range	T, TE	Limited range of electric trucks per charge, in comparison to distances fleets travel and ranges achievable by diesel trucks.
Availability	T, TE	Overall lack of electric truck models available, both in specific applications and the industry more generally.
Weight	T, TE	Increased weight of electric trucks in comparison to that of a diesel truck, when subject to gross vehicle weight regulations.
Charging Time	T, TE, ST	Amount of time the truck is unable to move goods because of the need to charge.
For other applications	ST, S	Perception that the interviewee, their fleet, or their application are not responsible for testing out electric trucks; others should be responsible for this.
Driver Resistance	SE, S	Perception of the interviewee or self-reports of interviewee-drivers that drivers in their fleet are not willing to use electric trucks and may leave the company if forced to.
Maintenance	TE, ST	Any issue related to deviations in the fleet's current maintenance costs or structures.
Education	ST, S	Lack of knowledge about new technologies or regulations; self-reported or related to the industry in general.
Reliability	T, TE, ST	Concerns around the ability of electric trucks to fulfill routes.
Incentive Complications	E, SE	Issues with applying for or complying with the requirements of grant and incentive programs.
Torque/ Power	T, TE	Including issues of electric trucks having too much torque/power and with electric trucks not being able to maintain torque/power for extended periods of time.
Market Instability	SE	Uncertainty caused by frequent changes in regulations.
Resale Value	E	Any issues related to uncertainty in the resale value for used electric trucks.
Complexity of Multiple Fuels	ST, S	Concerns around the ability to manage trucks running on multiple fuel types.
Grid Reliability	T	Concerns with the impacts of potential electric grid outages on the ability of electric trucks to charge and operate.

3.5.2 Barriers to Heavy-Duty Truck Electrification

Figure 5 shows the distribution of barriers by barrier categories. This provides a breakdown of how fleets perceive these barriers and the relative prevalence of certain barrier categories. To further illustrate which fleets discus each barrier, counts sub-divided by fleet application and size (i.e., overall number of vehicles) and shown in Appendix 6 and 7. Table 6 shows example quotes from the interviews for each reported barrier. We describe each of these barriers in detail below and include Table 6 to support our discussion.

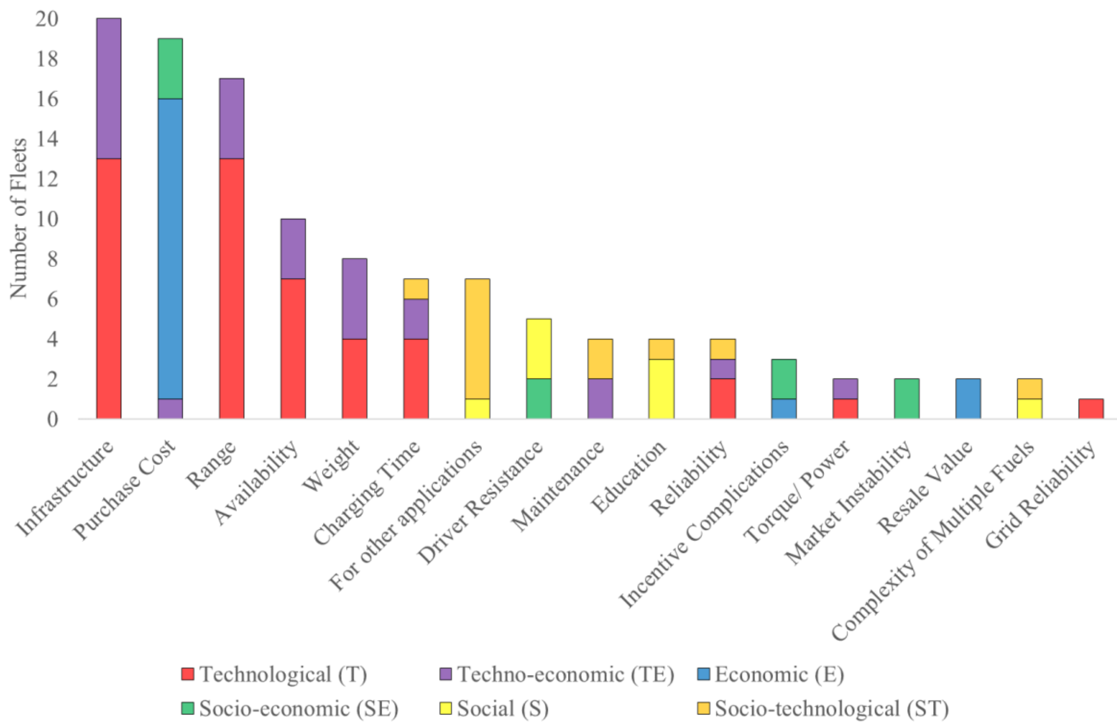

Figure 5: Reported barriers to fleet adoption of electric trucks by barrier category. (n total=28)

3.5.2.1 Infrastructure

Lack of charging infrastructure was the most mentioned barrier to heavy-duty truck electrification across fleet size, application, and experience with electric trucks. This was categorized as both a purely technological barrier and a techno-economic barrier. From a technological perspective, interviewees describe charging infrastructure as almost nonexistent outside of California, making it impossible to drive electric trucks outside of the state. Fleets across application types mentioned refueling diesel trucks at public stations and would similarly be reliant on public charging stations to recharge electric trucks. They believed that the lack of available public charging stations would prevent them from adopting trucks, even if they travel short distances. As mentioned by one interviewee, the lack of charging infrastructure is particularly an issue in the Midwest where many of the country's trucking hubs are located.

"For somebody like me who runs quite literally from Alaska to Florida and every place in between, I need something that's going to have all the infrastructure already in place and readily available." (Fleet 19, T)

A lack of coast-to-coast network for heavy-duty truck charging was especially noted by interviewees from the long-haul fleet segment. In these applications, it was noted that unless heavy-duty electric truck charging infrastructure is readily available throughout North America, electric trucks will be limited in where they can travel. These limitations prevent them from accepting certain loads, thus impacting profits, leading many fleets to report they would be unwilling or unable to use them. In this way, lack of charging infrastructure was determined to pose a techno-economic barrier, given the impact on both physical and financial operations.

The cost of installing charging infrastructure at fleet-owned facilities was also classified as a techno-economic barrier. While some fleets identified grant programs that were able to help with costs, these fleets reported issues that prevented them from applying to these programs.

3.5.2.2 Purchase Cost

High purchase cost was categorized as an economic, socio-economic, and techno-economic barrier and was mentioned by fleets with trucks operating in all application types. Of the eight fleets who had experience with electric trucks, only three have purchased an electric truck. The remaining five were involved in demonstration projects funded through the manufacturer or government grants. For fleets without electric truck experience, high purchase cost was cited as a primary reason they were not considering electric trucks, even amongst those who were aware of upcoming regulations requiring their purchase.

From an economic perspective, fleets mentioned they would be unable to pass higher costs on to their customers because they would be outbid by fleets operating diesel trucks, so they would be forced to absorb these costs within the company. Some interviewees noted that they heard the cost of electric trucks is expected to decline so they would wait for this to happen before seriously considering purchasing them.

"I don't know who can afford a brand-new electric truck, there's no 20-fleet company that can afford a half-a-million-dollar trucks, it's just not going to happen." (Fleet 10, E)

High purchase cost was categorized as a socio-economic barrier for two fleets. They emphasized the strain of increasing costs on their relationships with customers as the root cause. They believed high purchase costs would not pose as high of a barrier if they were able to pass the increased costs on to their customer. Given the highly competitive nature of the freight industry, they believed their customers may move to another fleet if they tried to do this, so they were not seriously considering purchasing an electric truck. Another fleet who contracts with owner-operators believed most of their drivers would rather leave the industry than go into debt paying higher costs for an electric truck. The fleet was not willing to risk upsetting their drivers by requiring these high-cost trucks.

One interviewee believed that higher costs could not be justified given the operational restrictions (e.g. length of time the truck can operate before needing to charge) imposed by the technology. Based on this, the barrier was identified as a techno-economic barrier. The interviewee noted that the purchase price of electric trucks is beginning to decrease, and when factoring in purchase incentives, electric trucks begin to approach a feasible price.

3.5.2.3 Range

Range was most often categorized as a purely technological barrier. Range concerns were mentioned by fleets operating in drayage, short-haul, and long-haul, not exclusive to the long-haul sector. While operating significantly fewer miles per day, interviewees from short-haul and drayage fleets mentioned they did not believe current electric trucks had sufficient range to accomplish tasks. One interviewee noted that the longest range heavy-duty electric truck currently available has 250 miles of range, which may meet their requirements, except "*you're not supposed to charge the battery to 100% all the time, so* *we're looking at 90%... so then you're limited to 110-mile radius*" (Fleet 10, T). Interviewees also reported being wary of the impacts of cold temperatures on range stating, *"it's going to be minus 10 tonight. Batteries, they just can't handle that right now"* (Fleet 02, T).

Some interviewees reported trucks driving up to 740 miles per day, indicating that if trucks are unable to maintain mileage requirements, this would impact their profits. This prevented them from considering electric trucks. In this way, limited driving range was categorized as a techno-economic barrier and as being insurmountable. One fleet discussed options for purchasing a truck with a larger battery pack to increase range but said that they would not be willing to take this option because it would increase the purchase cost.

3.5.2.4 Availability

The lack of electric truck options available was another commonly discussed barrier across fleet types, especially for fleets with strict specifications. This was categorized as a technological barrier for fleets discussing only factors such as lack of electric truck availability overall, in certain weight classes, for certain truck types (e.g. box truck, sleeper cabs), and in truck length. From a techno-economic perspective, fleets operating in short-haul applications who deliver in urban or otherwise physically constrained areas (e.g. ports) mentioned that available electric models had a longer wheelbase than the equivalent diesel truck, which lengthened the turning radius of the truck. This limited their ability to deliver to certain areas or required additional time for the delivery, reducing profits. Some fleets mentioned that even when electric trucks begin to come to market, they will wait for them to be more widely available and used in their specific application before they try them.

3.5.2.5 Weight

Interviewees across all fleet types report their trucks often operate near the federal weight limit of 80,000 pounds. Adding weight to the truck in the form of batteries would limit the weight of revenue-earning loads they could carry. One interviewee mentioned they were aware of the additional 2,000-pound allowance for natural gas and electric trucks but felt this was still not enough to make up for the additional battery weight. Another fleet called for regulators to increase the gross vehicle weight allowance by 10,000 lbs. for electric trucks to avoid financially penalizing fleets who electrify.

"The battery electric [truck] is coming in anywhere between 23-24,000 pounds where a day cab diesel is about 16,000 and a CNG truck is about 17,500… so you increase [truck weight] almost 6-7,000 pounds. Now that hurts your capacity to transport." (Fleet 05, TE)

3.5.2.6 Charging Time

Long charging times were also mentioned as a significant barrier to electric truck adoption. In many fleets, long charging times are seen as barriers because they are not aligned with the way fleets currently operate, creating a technological barrier. Interviewees commonly mention charging times should fit in with their current operating structures, including charging for a maximum of one or two 15-30 minute breaks during each 10-hour shift. One owner-operator specified that long charging times would be invasive, and he would not be willing to stop more often than he needed to, indicating a socio-technological barrier.

Some fleets noted their trucks operate in two shifts each day, leaving less than four hours during which the truck is inactive. They perceive this would not be long enough for trucks to charge to support their operations for the other 20 hours. One long-haul driver discussed regulations on their driving hours per day, noting an individual is only allowed to drive a maximum of 11 hours. He stated time spent charging during this period would cut into his driving time, limiting how far he could travel, and reducing profits. Under these constraints, he feels that charging times would need to be reduced to fit into current rest periods, otherwise they pose a techno-economic barrier.

3.5.2.7 Waiting for Other Fleets/Applications to Try Them (For other applications)

Fleets commonly mentioned they did not believe electric trucks would work for their applications and that it was the responsibility of those in other applications to demonstrate their feasibility. Notably, this shifting of responsibility was done across all truck applications and fleet sizes. This barrier was largely socio-technological with fleets suggesting that those with smaller operating territories and more fixed routes would be more suited to electrification because of their lower range requirements. Some fleets specifically pointed to drayage and short-haul applications as being best suited for electrification.

For two fleets, this was categorized as a social barrier. One decision-maker stated that fleets who operate solely in California should be the first to electrify because that is where the air quality issues are worst and electricity sources are the most regulated. A truck owner-operator stated that it wasn't necessarily that the technology would not work for him, but that he was simply too old to try new technologies. He felt that younger generations should be left to do demonstrations.

> *"I'll leave [electrification] to the younger kids who can invest more time. Like I said, I've only got 6-7 years [left driving], and I'm going to try to do it as cleanly and efficiently and with as less stress as I can."* (Fleet 24, S)

3.5.2.8 Driver Resistance

Driver resistance was mentioned as a social and socio-economic barrier to truck electrification. Discussions categorized as social barriers stem from a wider conversation around driver shortages which were mentioned by nearly all fleets as an industry-wide phenomenon. They felt that fewer people are going into the profession, increasing competition for drivers between companies.

From a socio-economic perspective, if companies are unable to keep drivers happy, they risk having too few drivers to meet their needs. Interviewees reported that drivers are generally resistant to any changes and such a large change as switching fuel types would likely be met with resistance and could lead drivers to switch companies. Two interviewees with experience contracting with independent owner-drivers stated that the drivers had threatened to leave the trucking business if they were required to purchase an electric truck. One reported that they switched entirely to company-employed drivers because of the shortage of owner-drivers who had emissions compliant trucks. From the fleet's perspective, drivers leaving the company prevents electric truck adoption because this would lessen the amount of goods they can move, decreasing profits. In this way, driver resistance is a socio-economic barrier, as it has elements of both social and economic barriers.

> *"Whether I want it or don't still hinges on them wanting it, because if they can't embrace the technology, they might leave me and go somewhere else. Well then I just shot myself in the foot because now I have a truck that nobody wants to use."* (Fleet 02, S)

3.5.2.9 Maintenance

Maintenance concerns were related to both battery longevity and the inability of the organization's mechanics to work on electric trucks. For two fleets this was categorized as a techno-economic barrier. Fleets expressed concern over the lifespan of the battery, stating that a lifespan of five to eight years would increase their costs. One decision-maker believed that continuously fast-charging the battery would damage it, requiring them to replace it sooner.

From a socio-technological perspective, decision-makers from two other fleets stated their maintenance teams were unfamiliar with electric trucks so they would have to take the trucks to a dealer for service instead. This could lead them to close their maintenance shops altogether. Notably, maintenance issues were only mentioned by large fleets, with many small fleets reporting that they did not have their own dedicated maintenance team, so this was less of a concern.

3.5.2.10 Lack of industry-wide knowledge (Education)

Interviewees noted that the lack of knowledge about new technologies and emissions regulations posed a challenge throughout the industry. This was primarily categorized as a social barrier with one fleet noting all environmental policies are negatively viewed by the trucking community where people choose to resist them rather than trying to understand how to make them work. The interviewee believed that technologies and regulations are constantly changing and vary across states, which can make it difficult for everyone to, *"deal with and cope with… they just flat out get angry"* (Fleet 01, S). Because of this, fleets noted that while they would like to try new technologies, they are too busy trying to keep up with current regulations and do not have time for additional research. These interviewees believed that while larger fleets may have people dedicated to keeping up with new technologies and regulations, smaller fleets are often run by a single person or a small group, making it difficult to keep track of everything. These fleets were seen as needing significantly more outreach and education before they consider electrifying.

"There is a stunning lack of knowledge in the industry, especially as you get down to the medium and small fleets… people start trucking companies and they end up working 70, 80, 90 hours a week and they don't have a lot of time to educate themselves, they just see regulations getting piled on them." (Fleet 01, S)

One interviewee discussed their own internal lack of knowledge about electric trucks, stating, *"it's been a challenge for me too, I mean I know a lot about internal combustion engines and how they work… but once you start taking about electric, I have no idea what I'm doing"* (Fleet 17, S).

From a socio-technological perspective, one fleet mentioned that they choose not to educate themselves about the technology because, *"I know that there isn't enough information out there yet, so I haven't even put in the research"* (Fleet 24, ST). In this way, perceived technological restrictions of the truck created a social barrier in the interviewees unwillingness to dedicate time to research the trucks.

3.5.2.11 Reliability

Concerns over how reliable an electric truck will be were centered around new technologies being seen as unproven. This was categorized as a technological, techno-economic, and socio-technological barrier. On the technological side, one fleet hauling food expressed concerns with the truck's ability to maintain "temperature integrity", fearing that they could get into "food poisoning or hazmat issues" if the truck were to fail. One fleet discussed reliability from a socio-technological perspective, mentioning that if the truck were to break down on the road, it could leave the driver in an unsafe situation. From a techno-economic perspective, fleets were concerned that if the truck were to have a "catastrophic breakdown" they would be unable to fulfill the job for the customer, which could cause them to *"find somebody who* *can… they will vote with their feet and they will move on to someone that can service them"* (Fleet 03, TE).

3.5.2.12 Incentive Complications

While interviewees mentioned grant programs are available to help fleets deal with high upfront costs, many found it difficult to comply with these programs. Some fleets believed program deadlines are too short, and that trucks often take a year or more to arrive after they are ordered, making it impossible to procure trucks within specified timelines. Another interviewee noted the utility would only begin working with them once they committed to purchasing electric trucks, but grants to purchase electric trucks were set to expire before the trucks are available. The interviewee stated that all the deadlines and requirements were overwhelming and "almost too much to handle." Others noted that the funding is too limited to make costs comparable, specifically referring to one program which they believed offered $80,000 incentives, which does not reduce the $500,000 price tag of an electric truck enough to make the purchase viable.

Fleets with CNG experience noted that they had made initial investments into these trucks with the help of grant and incentive programs, but the funding for this had since diminished. They stated that programs were created to get fleets out of diesel trucks and into alternative fuel trucks, but that once the lifetime of the CNG truck was up, there was no support for the purchase of additional CNG trucks. Given that the purchase price was not yet comparable to diesel, they had to either find additional funding sources or revert to diesel trucks. This shows the need for funding alternative fuel truck purchases beyond the initial deployment. Fleets feel that if funding won't be able to support them in the future, then there is a greater likelihood that their investments will lose value. Similarly, while complications with incentive programs and market instability are primarily economic, they are also social. Both are based on the decision-maker's perception that the fleet would be financially penalized for electrifying or the need to change the way they purchase to accommodate electric trucks.

3.5.2.13 Torque/ Power

Concerns with the torque and power of an electric truck were mentioned by two interviewees. One interviewee in a fleet without experience with electric trucks mentioned that he heard electric trucks have good power but was concerned about how durable this would be under a rigorous duty cycle. If the truck could not maintain the needed power, it would create a techno-economic barrier because they would be unable to transport goods.

In contrast, this was categorized as a technological barrier for another fleet who had experience operating electric trucks. The interviewee stated electric trucks had too much torque, creating a safety hazard. The fleet was using the electric truck to haul chemicals over short distances and the drivers reported feeling unsafe with how the truck's acceleration would pull the cargo around. After sending it back to the manufacturer twice to have the torque adjusted, they decided to remove the trucks from the fleet, noting they would revisit the idea in another five years.

3.5.2.14 Market Instability

A common concern with alternative fuels is that fleets are uncertain where the market and regulations are moving. This lack of market stability was seen as creating a socio-economic barrier. Interviewees noted that regulations previously pushed them to invest in CNG trucks and infrastructure. Since then, regulations had changed, and fleets now need to invest in zero-emission fuels to be regulatorily compliant. Some interviewees feel they are being punished for being early adopters of CNG trucks as they are now being told they cannot use them anymore. This led to similar comments about how being early investors in electric trucks may create complications if they fall out of favor when a new technology emerges. This led to calls for a guarantee that if they invest in an electric fleet, it will not be a waste of funding or become obsolete in the future.

> *"We have a $3.5 million CNG slow fill station out there that within 10 years may be obsolete because all those vehicles need to be electric. If we invest millions of dollars in electrical infrastructure, who's to say in 10 years whether that may not become out modeled in some way?"* (Fleet 11, SE)

3.5.2.15 Resale Value

Many fleets reported using resale value as a part of their truck cost calculations. One fleet believed there is less of a market for used alternative fuel trucks, including electric trucks, which would impact the truck's lifecycle costs. Another fleet stated they had received pushback from the bank when asking about financing for electric trucks because the bank was unable to determine the residual value of the truck, which is a primary factor in determining leasing rates. While the interviewee was able to negotiate with the bank and reach an agreement, they felt that the uncertain resale value will challenge other fleets looking to lease electric trucks until better data becomes available.

3.5.2.16 Complexity of Operating Trucks with Multiple Fuels (Complexity of Multiple Fuels)

One interviewee operating a small long-haul fleet discussed operating trucks running on multiple fuel types as a socio-technological issue. The interviewee did not feel they would be able to accommodate electric trucks because it would be too complicated to have multiple fuel types in the fleet. The interviewee noted that he would need to find new places to fuel the trucks and would have to adjust the routes to accommodate range restrictions. He felt that larger fleets would more easily be able to experiment with electric trucks, but with so few, they did not have the capacity to do these trials. Another interviewee noted this as a social issue, believing that having drivers handle multiple fuels causes issues.

"I can't get my drivers to put the right fuel in a vehicle, gas or diesel. Having them plug a vehicle in every night may be a little touchy." (Fleet 26, S)

3.5.2.17 Grid Reliability

The ability of the electric grid to support electric truck charging was also mentioned as a barrier to truck electrification. The interviewee did not believe that the electric grid would be able to support the additional load electric trucks would add. This concern extended to whether his facilities would be able to get sufficient power and whether it would be reliable, given the potential for Public Safety Power Shutoffs (in which the electric grid is preemptively powered off to prevent power lines from sparking wildfires in extreme weather scenarios) at his California facility. With the power being off for hours to weeks, he feared his operations would need to shut down in these events.

3.5.3 Differences in stated barriers between fleets with and those without experience with electric trucks

Figure 6 presents differences between fleets with and without experience operating electric trucks that report each barrier. While these percentages are not intended to be representative of the fleet population, they provide an indication of where differences in perceptions of these two groups may exist. The presence of barriers for fleets without experience with electric trucks may indicate issues with the initial adoption of electric trucks while barriers expressed by fleets with electric truck experience may signal barriers to the adoption of additional electric trucks.

Of the primarily social-based barriers (i.e. for other applications, driver resistance, education, incentive complications, market instability, and complexity of multiple fuels), all but market instability were mentioned only by fleets without experience operating electric trucks. This may indicate these barriers are overcome through experience or that they must be overcome before a fleet can consider using electric trucks.

In contrast, each of the technological (infrastructure, range, availability, weight, charging time, reliability, torque/power, and grid reliability) and economic (purchase cost, market instability, and resale value) based barriers were mentioned by fleets with experience operating electric trucks. Each of these, except for grid reliability and resale value were also mentioned by fleets without experience operating electric trucks. This indicates that these barriers have not yet been overcome through experience with currently available heavy-duty electric trucks, and the successful deployment of electric trucks will require further changes to truck technology, operational or economic structures of the organization, government policies, etc.

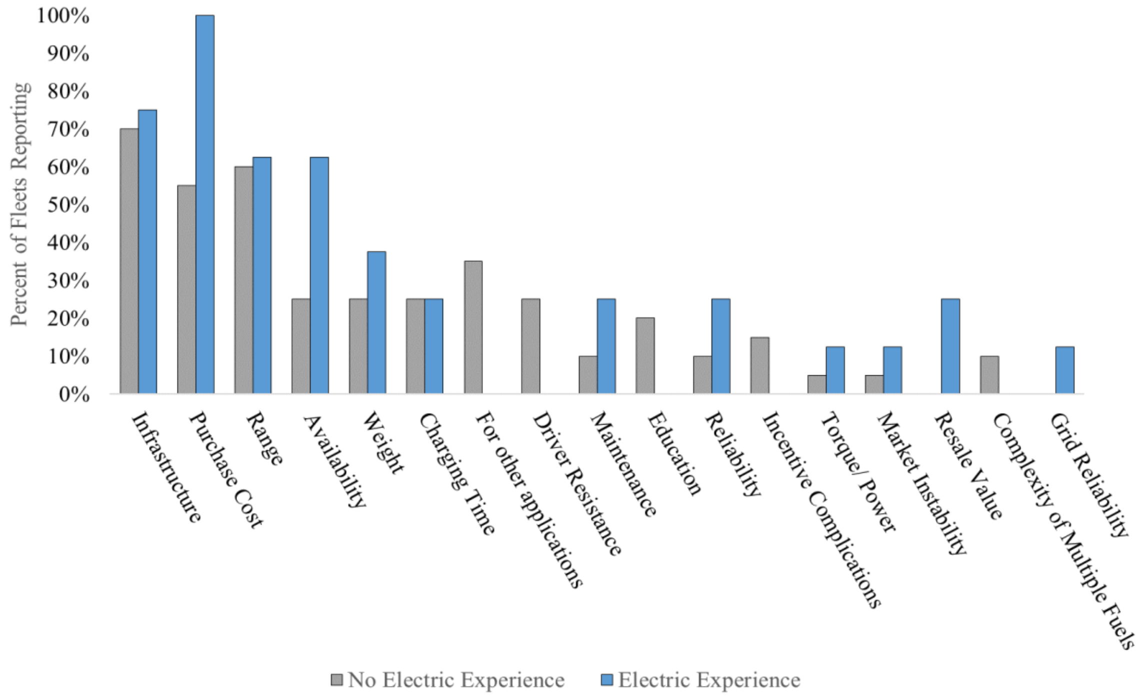

Figure 6: Percent of fleets reporting each barrier to electric truck adoption by experience with electric trucks. (n no electric experience=20, n electric experience=8)

Purchase cost, availability, maintenance, reliability, and resale value were mentioned by a relatively larger percentage of fleets with experience. This may indicate that these barriers are more present for fleets who are more seriously considering purchasing an electric truck.

Table 6: Example quotes by barrier and number of interviews in which the barrier was raised (Fleet number, coded barrier category)

Barrier	# of interviews in which barrier is raised	Example Quotes	
Infrastructure	20	*"My trucks are running all over the West Coast and they have to be able to work wherever I go. And if they don't, I can't buy the trucks, it's just not going to work."* (Fleet 04, TE)	*"There's really no infrastructure for them in this part of the world, or for the for the most part, you know, and I mean anywhere, you know no truck stop is offering electricity."* (Fleet 02, T)
Purchase Cost	19	*"Battery electric trucks are up to $650,000 and then when you add Federal excises tax and sales tax... you come up with $814,000... Our demo on the battery electric, the highest we got was seven hours in one day and then that truck had to go in and charge for six to eight hours. So I cannot afford to buy an $814,000 truck and get six hours out of it and then charge for the next shift, there's no way."* (Fleet 05, TE)	*"To replace five trucks all at a quarter million dollars, you know we're looking at over a million dollars and it's um, I mean to do that all at the same time for a small company like ours it's just not feasible."* (Fleet 10, E)
Range	17	*"You got to make sure the drivers are aware of the limitations, you gotta kind of pay attention to where you're going and how far you're going.... The fleet manager is not going to look for a larger battery pack than they need because it costs more money."* (Fleet 07, TE)	*"[The truck will] lose anywhere from 20 to 40% of range when the weather gets cold and we just couldn't deal with that in a trucking company, I mean we just couldn't, there's just no way."* (Fleet 01, T)
Availability	10	*"The Class 8 electric trucks, the first iteration are day cabs. And so in a lot of cases sleeper cabs aren't even on the, the [manufacturer's] roadmap and you know when you have a trucking fleet with mostly sleeper cabs, that becomes a barrier."* (Fleet 28, TE)	*"Tesla announced an electric truck what, two years ago, three years ago and it still hasn't come to market. It has to get to a little bit more of a mass scale for it to be accepted."* (Fleet 15, T)
Weight	8	*"Battery electric [trucks] are coming in anywhere between 23 to 24,000 pounds were a conventional day cab diesel is about 16 and a CNG truck is about 17.5, so you're increase*	*"Weight is the first issue, the electric trucks are much heavier than diesel trucks. The gross vehicle weight limit for a diesel truck is 80,000 pounds. From what*

		that almost 6-7000 pounds. Now that hurts your capacity to transport." (Fleet 05, TE)	*I've heard, electric trucks are allowed 2,000 extra pounds... but that's still not enough."* (Fleet 10, T)
Charging Time	7	*"If we stopped and had to plug in, we'd go to the bathroom, we'd make a sandwich, you know, make lunch or get a bite to eat, you know, half-hour goes by pretty darn fast. So I think that would be fine. I don't know about, I don't know about doing it twice, that would start to get invasive I think."* (Fleet 19, ST)	*"Our teams might run 23 hours out of the day... They're running long enough that until they find something that keeps it charged going down the road, which I mean I don't see how they can, but it's not even a question."* (Fleet 25, TE)
For other Applications	7	*"What I know right now about battery electric vehicles is they don't have the same range as a diesel truck with bigger fuel tanks, so is it more of a regional application? It generally is. Will it go 500 miles in a day? The trucks at this point that I've seen don't have that same range capability so there's certain applications at this point where some of those alternative vehicles will apply to, others where they won't be able to apply to until the technology changes or improves."* (Fleet 03, ST)	*"I'll leave that to the younger kids who can invest more time. I've only got 6-7 years [left driving] and I'm going to try to do it as cleanly, efficiently, and with as less stress as I can."* (Fleet 24, S)
Driver Resistance	5	*"Once it gets close to that [electric truck purchase mandates], we might have issues finding drivers because I could guarantee you this, the drivers that we have right now, I will say a third of all of them are willing to buy [electric] trucks. Most of them are already saying that they're going to sell the trucks and probably do something else."* (Fleet 20, SE)	*"Whether I want it or don't want it still hinges on them wanting it, because they if they can't embrace the technology... and want to leave me to go somewhere else, well then I just shot myself in the foot, because now I have a truck that nobody wants to use."* (Fleet 02, S)
Maintenance	4	*"These trucks can handle fast chargers... well what's that going to do to the batteries, how long are those batteries within that charge at 20 minutes?... if you are going to charge batteries from state of charge 20% to 90-95% in 20 minutes, something's going to happen to those batteries, so we need to make sure that we at least get six to eight years off of the battery."* (Fleet 05, TE)	*"That would be a big, big hurdle to get over... on the electric side, I might have to just shut my shop doors and take them somewhere else."* (Fleet 25, ST)

Education	4	*"It's been a challenge too for me, cuz I mean, I know a lot about internal combustion engines and how they work... but once you start talking about electric I have no idea what I'm doing."* (Fleet 17, S)	*"There is a stunning lack of knowledge in the industry, especially as you get down to the medium and small fleets."* (Fleet 01, S)
Reliability	3	*"In the trucking business, if you can't serve your customer, they're going to find somebody who can. So you want to try to get technology that's going to work and not stop a customer's load... because they will shop with their feet, vote with their feet, and they will move on to someone that can service them, so that's always a concern with the technology."* (Fleet 03, TE)	*"When you're hauling food, the temperature integrity, has to be there, we don't want to get into any food poisoning or hazmat issues whatsoever."* (Fleet 06, T)
Incentive Complications	3	*"We're taking a look at some of the incentives that are out there like the HVIP program... it's only a small percentage, like for example, my tractors, the big trailers, we only get about $80,000 from HVIP, but if you buy the electric truck outright, it's about half a million dollars. So I mean, it's still something, right $80,000, but you know, turning that into $500,000 could be a driver for somebody to be a little bit more interested, but right now, since our business is still trying to recover from the recent events, we are asking our clients to put up those upfront costs."* (Fleet 17, E)	*"It's tough for fleets to take advantage of grants and incentives because of the deadlines, most of the trucks we buy now, if we get a PO [purchase order] today, the truck won't be here in our possession for a year. And so most of time we pass that deadline date."* (Fleet 13, SE)
Torque/ Power	2	*"It took the driver enough time to really get to understand the torque... the torque would pull all the weight of the vehicle back and then the freight would move forward, he felt unsafe... We had to send it back twice to get it re-torqued with less torque because we're moving chemicals, so we figured that it wasn't for us at the moment."* (Fleet 09, T)	
Market Instability	2	*"We have a three and a half million-dollar CNG slow fill station that within 10 years may be obsolete by CARB because all those vehicles need to be electric. If we [electrify] and invest millions of dollars in electrical*	*"If you have an electric truck that's costing $50,000 more and you've got your three-year-old diesel and someone comes out with a new fuel that produces less pollutants than electric, well there goes your electric,*

		infrastructure, who's to say in 10 years whether that may not become outmoded in, in some way?" (Fleet 11, SE)	*that's gone, whoever bought that, no one's going to touch them again."* (Fleet 15, SE)
Resale Value	2	*"The reason we're having an issue with EVs is because no one knows what they're gonna be worth, and the banks are having a significant issue determining the residual value of that vehicle... So, definitely a challenge and will be until there's some of these vehicles in the resale market where they can sort of valuing what the actual residual should be."* (Fleet 27, E)	
Complexity of Multiple Fuels	2	*"For us, probably the biggest challenge that we have is I can't get my drivers to put the right fuel in a vehicle, gas or diesel. Having them plug a vehicle in every night, may be a little touchy."* (Fleet 26, S)	*"To have something different in the fleet would cause me to have to adjust more... it gets complicated quickly."* (Fleet 02, ST)
Grid Reliability	1	*"Things that keep me awake at night when we start talking about battery electric vehicles, the biggest one, the grid. Existing grid capacity can't support all this additional utilization ... Then what about, what about the Public Safety Power Shut-offs or PG&E flips a switch and other utilities flip a switch, it could be a couple hours, it could be a week. And if you're an all-electric operation, you don't have many alternatives."* (Fleet 07, T)	

3.6 DISCUSSION

Interviews with fleet decision makers indicate they have some concerns that are similar to those seen in evaluations of technological capabilities of electric heavy-duty trucks. These include infrastructure, purchase cost, range, availability, weight, and charging time—all previously evaluated, though from a purely technological or economic standpoint (Moultak, Lutsey and Hall, 2017; Sidbrant and Börjesson, 2018; Liimatainen, van Vliet and Aplyn, 2019; Fleming *et al.*, 2021; Muratori *et al.*, 2021; Nykvist and Olsson, 2021). Our study corroborates some existing findings, but qualitative data gives greater insight into how these barriers are perceived by fleet decision-makers. Interviewees discussed barriers as technological, economic, social, and as hybrid barriers that transcend boundaries between technological, economic, and social categories. This complicates the way these barriers manifest within and across fleets. While some fleets discuss barriers from a purely technological perspective, these issues tie back to the economic effects they have on the organization or their ability to run the business profitably. Hybrid barriers may require different or multiple approaches.

Some barriers revealed through interviews in this study were not widely discussed in prior studies and two barriers (for other applications and market instability) were not previously reported. These lesser mentioned barriers were more commonly social and social-hybrid barriers which may have been undetectable without speaking with decision-makers. Of the barriers categorized here as social or social hybrids, two previous studies provided most of the discussion. Bae *et al.* (2022) conducted interviews with decision-makers from 20 fleets while Mohammed, Niesten, and Gagliardi (2020) present a literature review. Both studies provide a broader look into the adoption of alternative fuel vehicles, discussing factors we describe as social and social hybrid as they relate to alternative fuel adoption. The findings presented in our study build off these previous studies by examining barriers as they pertain to electric trucks, allowing more specific barriers to emerge. For example, while they discuss factors such as perceived compatibility and perceived complexity, they did not identify specific barriers of range, weight, and charging infrastructure that are identified in our study. Our study additionally presents these barriers within a framework of six barrier categories, allowing for a deeper understanding of the way barriers affect each fleet.

Our research echoes infrastructure, purchase costs, and range as the most prevalent barriers to heavy-duty truck electrification, but indicates these may defy categorization as solely technological, economic, and social barriers. Each of these barriers was mentioned by over half of the interviewees, indicating they are on the forefront of fleet perceptions about electric trucks and that they need to be resolved before decision-makers can more fully consider heavy-duty truck electrification. The frequency with which barriers are discussed may be a metric of present attention to heavy-duty truck electrification rather than ultimate importance. Therefore, less frequently discussed barriers may loom equally large once they capture the attention of fleet decision-makers.

While social, socio-economic, and socio-technological barriers were mentioned by a comparatively small number of interviewees, these barriers provide an important perspective into the complexities fleets may face with incorporating electric trucks into their fleets. These barriers were often mentioned after discussions of technological, economic, and techno-economic barriers. Mentioning interviewees indicated their fleet had more thoroughly examined the impacts and consequences of heavy-duty truck electrification, allowing them to evaluate issues beyond commonly mentioned barriers. These conversations may provide insights into future considerations of other fleet decision-makers. These are typically attributed to individuals rather than organizational structures or practices (e.g. to drivers rather than to the business model or logistical operations of the fleet).

3.7 CONCLUSION & POLICY IMPLICATIONS

We investigate reports of perceived barriers to the adoption of electric heavy-duty trucks by decision makers within fleets operating heavy-duty trucks in California. This qualitative research allows for a deeper understanding of the impacts of barriers on fleets including which barriers are most prevalent across electric truck experience levels. We classify barriers into six categories: technological, economic, social, socio-economic, socio-technological, and techno-economic. While social, socio-technological, and socio-economic barriers were the least commonly detected, this does not mean these barriers are less important. Rather, it may mean that fleets have not begun considering electric trucks to the point where these barriers could emerge. That is, if electric trucks are rejected for technological or economic reasons, fleets may not have gone so as far as considering barriers with social implications.

Meeting heavy-duty truck electrification goals, such as California's ACF and ACT rules will require substantial support and may implicate actors outside of a single fleet (California Air Resources Board, 2019, 2021). Following California's lead, 15 US states and the District of Columbia have signed a memorandum of understanding to reach 100% zero emission for new medium- and heavy-duty vehicle sales by 2050 (California Air Resources Board, 2020). Many European cities have begun implementing zero emission zones which restrict medium- and heavy-duty delivery vans and trucks to zero emissions (Government of the Netherlands, 2021). As these efforts move the heavy-duty trucking sector towards electrification, a greater understanding of the barriers to adoption is needed to inform solutions that are sensitive to differences between fleets. While multiple interviewees may discuss the same barriers, those barriers manifest in different fleets in different ways, suggesting multiple approaches may be required even to address conceptually similar barriers.

Economic barriers may be partially overcome through incentive programs. The California HVIP program provides incentives for new truck purchases which could alleviate concerns over truck cost (California HVIP, 2022). This program has previously run out of funding within 24 hours of approved spending, so more reliable or better funded incentive mechanisms may be needed. More stable funding was also reported by interviewees as an important consideration for incentive programs. Economic concerns extend beyond truck acquisition to include the cost of charging infrastructure. Prior research has shown policies which provide financial assistance for the purchase of electric vehicles and their associated charging infrastructure have helped overcome some of these barriers for light-duty electric vehicles (Sierzchula *et al.*, 2014; Lutsey *et al.*, 2018).

Technological and techno-economic issues include driving range, charging time, and vehicle availability. Truck and battery manufacturers are working to improve battery technologies to increase range and reduce charging time while decreasing weight. However, this may be a longer-term solution (Mihelic and Roeth, 2018; Volvo Trucks USA, 2022). For light-duty vehicles, the Advanced Clean Cars Program, or ZEV mandate, had a role in the technological development of light-duty ZEVs (Axsen, Hardman and Jenn, 2022). It is possible that ACT and ACF regulations, once passed, will have similar effects in the truck sector. Another technoeconomic issue was vehicle range and weight. In the European Union, weight constraints are being addressed by allowing zero-emission trucks to carry an additional 2 metric tons (4,400 pounds), allowing fleets to adopt zero-emission trucks without sacrificing their ability to transport (EUR-Lex, 2019).

While policies such as the above address technological and economic barriers, our findings show social barriers also exist. Social barriers may be best solved through education, outreach, technical assistance from policymakers and stakeholders, and through streamlined or optimized process changes, including logistics. These could include programs that introduce drivers and decision-makers to the technology (Wikström, Hansson and Alvfors, 2016; Globisch, Dütschke and Wietschel, 2018). For example, the limited range of electric trucks compared to their diesel counterparts might be mitigated through increased charging frequency or altering existing routes to allow for electric truck use. Upfront cost constraints suggest the need for financial models that focus on total cost of ownership or creating partnerships with manufacturers or governments to participate in demonstration or grant programs. In some cases, ZEV trucks may have a positive TCO for fleets and fleets may have routes which ZEV trucks can complete. Policymakers could work with fleets to provide technical assistance on understanding how to integrate trucks into their fleets including on implementing TCO models and route planning. Smaller fleets may especially benefit from this assistance due to a lack of in-house resources. For light-duty vehicles, public funding has been used for outreach (Veloz, 2022), policymakers have formed public private partnerships (Hyundai Motor Company, 2017), and policymakers have directed private companies to conduct outreach activities (California Air Resources Board, 2018). Similar efforts may be needed for ZEV trucks and fleet operators.

This framework is intended to inform future research and policy into these barriers to better inform stakeholders about issues which needed to be addressed in the pursuit of reaching 100% electric heavy-duty trucks. Such research could include drawing connections between the stakeholders to better understand barriers derived from the relationships between fleets and external stakeholders. Future work could also explore the willingness and ability of heavy-duty fleets to experiment with electric trucks including their ability to adjust physical and financial operations to accommodate the risks involved in the adoption of new technologies, such as electric trucks.

This study additionally highlights the ways in which barriers to heavy-duty truck electrification are varied and transcend technological, economic, and social issues to include socio-technological, techno-economic, and socio-economic issues. Policy considerations should target social, economic, and technological issues rather than taking one dimensional approaches to overcoming the barriers to ZEV truck introduction.

Chapter 4: Who decides which trucks to buy? Implications for electrifying freight fleets

4.1 INTRODUCTION

The US freight industry is reliant on diesel-powered trucks which made up 82% of new medium- and heavy-duty truck sales in 2019 and 2020 (Davis and Boundy, 2022). Diesel contributes 40% of the on-road vehicle carbon emissions despite making up less than 10% of the vehicles on the road (Moultak, Lutsey and Hall, 2017; Smith *et al.*, 2019; US DOE, 2020; Muratori *et al.*, 2021). Diesel-fueled vehicles emit substantial levels of particulate matter, NO_x and SO_x, leading to higher rates of cancer, respiratory damages, and asthma (Caltrans, 2016, 2022). Freight trucks frequently operate in and around dense urban areas and disadvantaged communities leading to adverse health effects in communities living in these areas (American Lung Association, 2022). For the purpose of this study, heavy-duty trucks are defined according to the Federal Highway Administration's specifications and have a gross vehicle weight rating of over 26,001 lbs. (Class 7 and 8) while medium-duty truck have a gross vehicle weight rating between 8,501 and 26,000 lbs. (Class 2b-6) (US DOE, no date).

To mitigate the climate and health impacts of the freight industry, policies such as California's Advanced Clean Fleets (ACF) and Advanced Clean Truck (ACT) rules have been developed. Under the ACT policy, medium- and heavy-duty truck manufactures must increase the percentage of zero-emission trucks they sell each year from 2024 to 2035. Beyond 2035, 75% of straight truck and 40% of tractor-trailer sales must be zero-emission trucks (California Air Resources Board, 2019). The proposed ACF policy, which is scheduled to be adopted in April 2023, would place requirements for large fleets operating medium- and heavy-duty trucks in California to acquire increasing percentages of zero-emission trucks, ramping up to 100% (California Air Resources Board, 2021). It would also update the ACT requirement to include 100% of all truck sales being zero-emission by 2036. To support fleets in achieving these requirements, the state offers incentives such as the Hybrid and Zero Emission Truck and Bus Voucher Incentive Program (HVIP) (California HVIP, 2022).

While this study focuses on medium- and heavy-duty vehicles operating in California, results may help inform medium- and heavy-duty truck electrification efforts broadly. In the US, California's more stringent air quality goals are followed by 15 other states and the District of Columbia. Under a memorandum of understanding (MOU) signed by these jurisdictions, new medium- and heavy-duty vehicle sales must reach 100% zero-emissions by 2050 (California Air Resources Board, 2020). Additionally, some European cities have implemented zero emission zones which restrict entry for medium- and heavy-duty delivery vans and trucks not meeting zero emissions requirements (Government of the Netherlands, 2021).

While California's ACT and ACF—along with the multi-state MOU—provide a pathway for truck electrification, an understanding of organizational decision-making for vehicle acquisitions and how social networks are implicated in these decisions may refine policy design and inform supporting programs. If organizations alter the decision networks they use for diesel trucks when they consider electric trucks, those changes may present new barriers and new opportunities to sustain transitions. Vehicle acquisition decisions typically are not made by individuals in isolation, but within the context of an organization's social dynamics and the overall fleet industry (Nesbitt and Sperling, 2001). An organization's internal decision-making structure and external network heterogeneity have been shown to impact an organization's ability to innovate (Arad, Hanson and Schneider, 1997; Carlsson and Sandström, 2008; Ahmady, Mehrpour and Nikooravesh, 2016).

In this study, we use interviews with 25 fleet decision-makers to describe the social context of truck acquisition decision-making using concepts of organizational structure and Social Network Analysis. We investigate whether internal network structure and external network heterogeneity are likely to affect the acquisition and use of electric trucks. We examine whether differences in fleets' internal decision-making structure and external social networks explain differences in their interest and ability to acquire and operate electric trucks. The exploratory data brings new insights to this unresearched topic and helps describe the complexities of truck fleet decision-making. While results are not representative of the entire heavy-duty truck sector, they do help identify issues, where interventions may be needed, and can inform future research.

Internal actors include any individual or group employed by the organization in which the fleet resides. External actors include any individual, group, or organization outside the organization. The role these actors play in truck acquisition decisions is examined through two steps. The first characterizes fleets based on the involvement of internal and external actors in truck acquisition decisions, examining what role actors play in acquisition decisions for electric and conventional truck purchasing. The second step examines differences between electric and conventional truck decision making including differences in actor involvement and attempts to understand why decision-making varies between conventional and electric trucks. Results provide insights into which actors are involved in the transition to electric trucks and what their role is. It will reveal real and perceived levels of control over conventional and electric truck acquisition decisions. The research may also help policymakers and truck manufacturers identify types of fleets which need greater levels of support in transitioning to electric trucks and where to direct support. It will also provide insight into who fleet decision-makers rely on for information and support, revealing individuals beyond fleet decision-makers that will require education and training to support fleet electrification efforts.

Truck acquisition decisions are changing with the introduction of alternative fuel vehicles, requiring fleet decision-makers to evaluate truck acquisitions using new or modified decision-making criteria such as electric range and charging times. This study evaluates potential changes in actor involvement caused by the introduction of electric trucks to fleets operating medium- and heavy-duty trucks. It begins by establishing a baseline network through which each fleet makes decisions, then evaluates changes in the role or presence of actors in that process. For example, electric trucks may necessitate the involvement of electric utility companies which were previously not involved in the process. Other actors may be involved in both electric and diesel truck acquisition decisions, but with different roles. For example, governments who were previously seen only as regulators may now be seen also as funding sources for electric truck acquisitions.

The study uses interviews with 25 fleet decision-makers. Analysis is guided by a hybrid framework combining organizational structures and social network theory, described in the Literature Review. We demonstrate these structures through case studies of fleets with different organizational structures and social networks and explore how different types of fleets make decisions, and whether structures and networks impact decisions.

4.2 LITERATURE REVIEW

4.2.1 Internal Organizational Structure

Organizational structure plays an important role in a company's decision-making and their ability to innovate and experiment with novel technologies (Arad, Hanson and Schneider, 1997; Belyh, 2015; Ahmady, Mehrpour and Nikooravesh, 2016). Two of the most commonly studied structural variables are formalization and centralization (Rapert and Wren, 1998). Formalization is the level to which formal rules, procedures, and guidelines dictate the decision-making process (Arad, Hanson and Schneider, 1997). In a highly formalized organization, the role and responsibilities of individuals are well defined and codified, and the decision-making process has been systemized. Formalization is often seen as more important for larger organizations than smaller ones (Belyh, 2015). Formalization has also been found to inhibit organizational innovation (Schulman, 2020).

Centralization is a measure of how decision-making authority is distributed within an organization (Johari and Yahya, 2009). In centralized organizations, decisions are made by a few people (Oldham and Hackman, 1981). Organizations with low levels of centralization involve many different individuals in decision-making (Arad, Hanson and Schneider, 1997). Arad, Hanson and Schneider (1997) relate an organization's centralization to its ability to innovate. They conclude flat, decentralized structures may be better suited to innovation as new ideas spread easily and employees feel empowered to act whereas multi-level, centralized organizations are more efficient under routine conditions. This concentrated decision-making authority, however, typically makes organizations less likely to innovate (Arad, Hanson and Schneider, 1997).

As centralization and formalization increase, an organization's ability to innovate is reported to decrease (Arad, Hanson and Schneider, 1997; Rapert and Wren, 1998). High levels of centralization and formalization restrict communication between individuals in the organization, lessening their ability to effectively contribute to decision-making (Oldham and Hackman, 1981; Rapert and Wren, 1998; Johari and Yahya, 2009). Organizations with less formalized and less centralized structures are better able to quickly adapt in dynamic environments (Rapert and Wren, 1998).

Arad, Hanson, and Schneider (1997) did not find a direct relationship between organizational size and innovativeness or centralization. They instead find that organizations of all sizes can be capable of innovation if their structures allow for it. This study therefore examines the relationship between organizational structure and the innovation of acquiring an electric truck.

4.2.2 Internal Organizational Structure in Fleet Decision-making

While truck acquisition decisions may be made by one or a few individuals in an organization, those decisions may be influenced by opinions and actions of even more people in the organization. High-level, public facing executives may be inclined to acquire vehicles that enhance the company's image while operational fleet managers may be more concerned with direct costs (Demeulenaere, 2019). Decision-makers may be influenced by other internal actors, such as drivers, who care more about user experience (Demeulenaere, 2019; Mohammed, Niesten and Gagliardi, 2020).

As shown in Table 7, Nesbitt and Sperling (2001) applied the concepts of centralization and formalization to organizations with fleets of light-duty vehicles (LDVs) to classify fleets as democratic, autocratic, bureaucratic, or hierarchic. They examined the impact of these structures on likelihood of acquiring alternative fuel LDVs. A summary of their findings is presented in the paragraphs below.

Table 7: Typology used to categorize fleets in Nesbitt and Sperling (2001)

		Centralization	
		Low	**High**
Formalization	**Low**	Democratic	Autocratic
	High	Bureaucratic	Hierarchic

Democratic organizations have low levels of formalization and centralization. These are typically smaller fleets with several individuals involved in decision-making. This structure generally favors simple solutions and metrics or avoids making decisions by repeating the same acquisitions. Because decisions are made as a group, it is possible for a single individual to prevent a decision being made or implemented. This can create significant delays in reaching a solution or implementing a new technology. Actions can be initiated from multiple places in the organization.

Autocratic organizations are characterized as having high levels of centralization and low levels of formalization. Decisions are generally made by one or two individuals who draw on their experiences and recommendations from colleagues to make decisions. Decisions require little to no approval by others allowing the fleet to quickly make changes. However, autocratic fleets typically have limited financial resources, which restricts their ability to acquire new technologies. Autocratic internal structures are typically associated with a smaller external network as decision-makers belong to fewer associations and subscribe to fewer publications.

Bureaucratic organizations are characterized as having low levels of centralization and high levels of formalization. These are often the largest fleets with several people influencing decisions. Decisions are typically made based on findings from objective calculations. Bureaucratic fleets typically operate in a routine manner until there is a need to change. This leads to decision-making that is efficient, but not innovative.

Hierarchic organizations have high levels of centralization and formalization. This is characteristic of medium to large fleets. Decisions are typically made by one or two individuals at a high level of the organization who are guided by organizational policies. Other departments are consulted on safety, training, public relations, and legal components of acquisitions. These fleets are likely to proactively engage with new technologies, responsive to financial incentives, but most likely to resist government mandates.

4.2.3 Social Network Analysis

Organizational decision-making is further influenced by actors outside of, or external to, the organization. Organizations have been found to modify their practices to meet expectations from external actors or market pressures (Soderstrom and Weber, 2020). Social networks allow for information to be exchanged, influencing attitudes around new technologies (He *et al.*, 2014; Kim, Rasouli and Timmermans, 2018). The relationship between actors is often studied through Social Network Analysis, which maps and analyzes characteristics of a central actor's social network including number of connections, geographic distance, relationship duration, and relationship strength (Kim, Rasouli and Timmermans, 2018). The decision-maker's social network consists of any group of people or organizations (actors) which can influence the decision-maker's decisions, from providing information, goods, financial support, opportunities to trial a new product or practice, and requirements affecting acquisitions and operations. This includes all interactions, whether cooperative, adversarial, formal, or informal (Bodin, Mancilla García and Robins, 2020).

An important metric used in Social Network Analysis is heterogeneity, a measure of the diversity of actors in the network. Heterogeneous networks contain actors from different backgrounds, groups, and organizations than the subject of analysis while homogenous networks are made up of actors similar to the subject. Carlsson and Sandström (2008) report involvement of different types of actors leads to a stronger network with better access to resources, which leads to more efficient and innovative decision-making. According to (Arad, Hanson and Schneider, 1997), innovation in organizations is also advanced when a large and diverse number of information sources are consulted.

4.2.4 External Network Heterogeneity in Fleet Decision-making

Organizations looking to promote a green image were seen as influenced by customers seeking to lessen their environmental impact (Mohammed, Niesten and Gagliardi, 2020). In addition to traditional actors, electric trucks will require decision-makers to form new relationships and engage actors who are not typically involved in truck acquisitions. This includes electric utilities, charging station providers, permitting agencies, etc. (Fenton and Kailas, 2021). These relationships require time to develop as parties are not accustomed to working with one another. Changes may also necessitate the changing or dissolving of existing relationships.

In studies of private consumers, light-duty plug-in hybrid electric vehicle acquisition was found to be influenced by interpersonal relationships such as neighbors and friends, as well as opinions posted online (Axsen and Kurani, 2012; He *et al.*, 2014). Higher levels of network connectivity are positively related to levels of innovation, meaning individuals with connections to a larger number of actors are more likely to acquire alternative fuel vehicles earlier. This influence was found to be especially pronounced for first-time purchasers.

Our study builds off prior research on the impacts of organizational structure and network heterogeneity on organizational innovation. We test whether differences in organizations' internal decision-making structure and external networks explain differences in their interest and ability to acquire and operate medium- and heavy-duty electric trucks. This provides insights into which fleet types may require different support to transition to electric trucks.

4.3 METHODS

4.3.1 Sample & Recruitment

Interviewees were identified via a web search of publicly available information to generate contact information for decision-makers in fleets operating medium- and heavy-duty trucks in California. All potential interviewees were recruited via email, offered a $150 incentive, and asked to complete a pre-interview questionnaire to ensure they were involved in the fleet's truck acquisition process. Interviewees who stated they held some responsibility for decision-making in their fleet were invited to participate in a one-hour long semi-structured interview. In total, 25 one-hour interviews were conducted with corporate leads (e.g., President, CEO, Owner), fleet department leads (e.g., Director of Fleet Operations, Director of Fleet Management, General Manager, Fleet Manager, Director of Transportation, etc.), and owner-operators (individuals who both acquire and drive their own truck). Fleets were selected to cover a diverse set of applications (e.g., long-haul, short-haul, and drayage) and number of trucks. An overview of fleets in this study is shown in Appendix 8.

4.3.2 Analysis

All interviews were conducted and recorded via Zoom by two interviewers. Once interviews concluded, transcripts were created and reviewed for accuracy by a member of the research team and an undergraduate assistant. Transcripts were uploaded to the qualitative analysis software program Dedoose, which was used to code the transcripts.

Transcripts were coded for thematic analysis following Gibbs (2007) in a process to identify patterns and themes in the transcripts and the "ideas that help explain why those patterns are there." In a first reading, codes for factors such as price, power, and fuel economy describing fleet's acquisition considerations were inductively derived from the data rather than a preexisting codebook. Each interview was then coded a second time to establish which internal and external actors were connected to each factor. For example, in the first round of coding, an interviewee may state the importance of low maintenance cost when they acquire vehicles. That passage in the transcript would first be coded, *maintenance cost*. If the interviewee mentioned maintenance costs were important because the company's leadership team instructed the interviewee to reduce costs, then the code *leadership team* would be added to the same passage. All internal and external actor involvement discussed in this paper are based on this analysis.

Once connections between factors, internal actors, and external actors were established, diagrams depicting these relationships were created for each interview. Diagrams were first created for each organization's decisions on which conventionally-fueled vehicles they acquire. Then, a second diagram is created to depict the organization's real or hypothetical consideration of electric trucks. A comparison of each organization's two diagrams reveals similarities and differences in the decision-making structure and involvement of internal and external actors for that fleet's decisions and consideration of conventionally fueled and electric vehicles.

4.3.3 Typology

Each organization is classified according to their internal structure and external network heterogeneity using the diagrams produced from the thematic coding of the interview with a decision-maker in that organization. To classify an organization's internal decision-making structure, we first categorize based on formalization (formal or informal) and centralization (centralized or decentralized) to assign internal structure. Drawing from the typology presented in Nesbitt and Sperling (2001), the organization's decision-making process was categorized as formal if decision-makers were guided by written rules and guidelines, and informal if not. This was assessed via responses to the interview question, "*does your company have any policies that impact your truck acquisition process?*" and verified using responses to the questionnaire question, "*are there policies, requirements, or guidelines that assure a level of consistency in truck purchase and leases across these multiple offices or locations?*" Organizations were classified as having a centralized decision-making process if decisions are made by one or two individuals in the organization. This was assessed via responses to interview questions, "*are there any other people or groups of people within your company who are involved in these decision-making processes?*" and, "*with regard to decision-making how much control do you have?*" These two metrics are used to classify organizations as democratic (informal and decentralized), autocratic (informal and centralized), bureaucratic (formal and decentralized), or hierarchic (formal and centralized).

The organization's network heterogeneity is determined based on the number of external actors, including individuals, groups, or organizations, involved in the organization's overall decision-making process, including both their general and electric truck decision-making. To determine a fleet's network heterogeneity, connections were drawn between the organization and any external actor reported to have influence on the acquisition decision. Fleets were then divided into three categories based on the observed sample variation, shown in Figure 7. Decisions within an organization involving one to three external actors were categorized as having low heterogeneity, those with four to five actors were categorized as having a mid-level heterogeneity, and those with more than six external actors were categorized as having high heterogeneity.

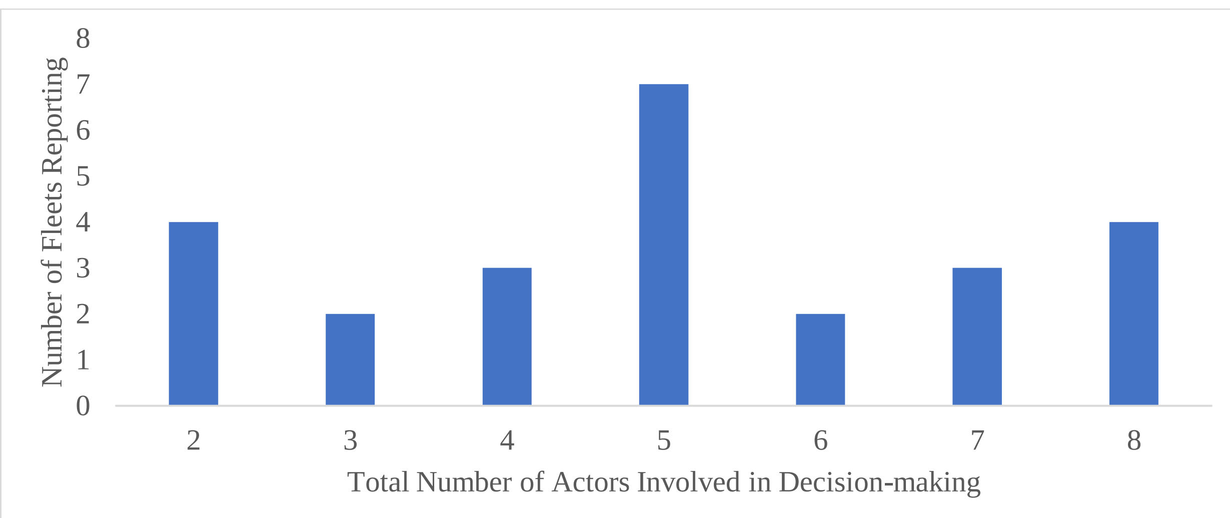

Figure 7: Number of actors reported by interviewees as being involved in their organization's overall decision-making process

4.3.4 Decision-making Network Structure

Of the 12 possible decision-making structures created using these metrics, seven are present in the sample. Decision-making for each of these seven structures are examined via case studies. Case studies begin by describing the case study fleet's acquisition considerations for general vehicles, followed by a description of their acquisition considerations for electric vehicles including whether they have acquired an electric truck, considered doing so but decided to not acquire one yet, or have not consider one at all. General acquisitions include any routine truck acquisitions made by the fleet such as diesel, gasoline, or natural gas trucks. While natural gas trucks are considered novel acquisitions for some fleets, fleets in our sample reported natural gas truck acquisitions as being a routine decision. The decision to acquire natural gas trucks is therefore reported as part of the general truck acquisition decision for these fleets.

Case studies illustrate the relationships between decision-maker(s), other internal actors, and external actors identified as influencing truck acquisition decisions. The interviewee is the subject decision-maker within the organization. Internal actors include any other individual or group employed in the organization in which the fleet resides. External actors include any individual, group, or organization outside of the decision-maker’s organization. In this study, all vehicles were acquired and used by the same organization. While it is possible for an organization to contract with other fleets to move freight, these contractors are considered to be their own fleet. The relationship between contractors and larger organizations is not considered on this paper.

The general outline of the diagrams for fleet truck acquisition decision-making is shown in Figure 8. Internal actors are depicted as square boxes at the top of each diagram. These are connected to decisions (shown as triangles at the bottom of the figure) through the factors affecting that decision (shown as circles in the middle of the diagram. Thus, the organization is connected to its decisions along a vertical axis more-or-less central to the diagram. External actors are shown to the left or right side of this axis (as space allows) as diamonds connected to the factor they influence. The interviewee describing the social network is depicted with an *. Lines may depict direct (e.g., requirements to acquire a certain vehicle) or indirect (e.g., providing information that one vehicle is more reliable) influence on a factor or decision.

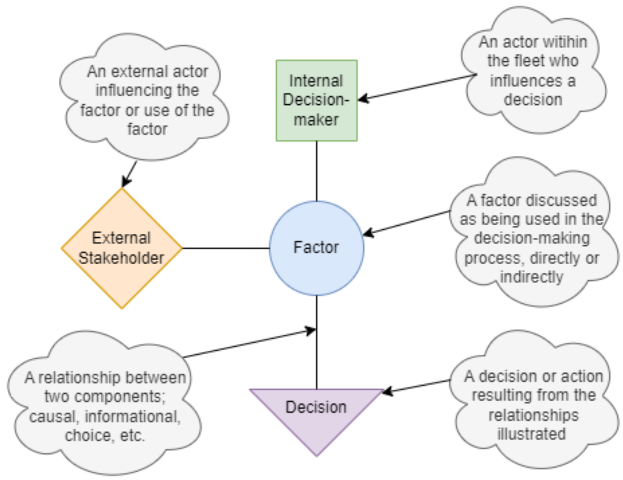

Figure 8: Legend for fleet decision-making network diagrams

For general truck acquisitions, the decisions represent which vehicle is acquired by the fleet. For electric truck acquisitions, the decision represents the "yes" or "no" decision of whether or not to acquire an electric truck. Fleets making a "yes" decision to acquire an electric truck are presented in the diagram with ** next to the decision. Each case study describes the decision-making network and process for a single fleet. The interviewee representing each case study organization is referred to with the same number as the organization, for example, the interviewee representing Fleet 23 is referred to as Interviewee 23 and is noted in the figures with an asterisk.

Each case study answers the following questions:

- What is the organization's internal decision-making structure for general truck acquisitions? How does this structure shape the organization's truck acquisition decisions?
- What is the organization's external network heterogeneity for general truck acquisitions? How does this external network heterogeneity impact the organization's acquisition decisions?
- How does the organization's internal structure and external heterogeneity differ for electric truck acquisition decisions?
- What effect do these differences have on the organization's perceptions of electric trucks?

Once all the case study diagrams have been prepared, they are compared and a set of summary results are prepared. Each case study is accompanied by a standardized set of descriptors defined in Table 8.

Table 8: Fleet descriptor definitions

Descriptor Category	Descriptor	Definition
Ownership Model	Owner-operator	Organizations who contract with drivers who own or lease their own truck. Owner-operators use their truck to move goods on behalf of the organization but are not direct employees.
	Centrally-owned	Organizations in which the drivers are direct employees. The organization provides the employee with a truck to use.
	Mixed	Organizations containing both owner-operator and centrally-owned trucks.
Fleet Size	Small	Fleets with 1-20 trucks.
	Medium	Fleets with 21-149 trucks.
	Large	Fleet with 150 or more trucks.
Vehicle Classes	Class 2b, 3, 4, 5, 6, 7, and/or 8	Classifications made according to the Federal Highway Administration’s specifications. Heavy-duty trucks have a gross vehicle weight rating of over 26,001 lbs. (Class 7 and 8). Medium-duty truck have a gross vehicle weight rating between 8,501 and 26,000 lbs. (Class 2b-6).
Application	Long-haul	Operations where drivers spend multiple nights per week away from home.
	Short-haul	Operations that do not meet the requirements for long-haul classification.
	Drayage	A subset of the short-haul application referring to trucks that provide pickup or delivery services to a seaport.
	Vocational	A subset of the short-haul application referring to work trucks assigned to non-freight tasks, such as construction, municipal services, dump trucks, etc. These trucks often include power take-off unit.
Acquisition Type	Purchase	Fleets who only purchase trucks.
	Lease	Fleets who only lease trucks.
	Mixed	Fleets containing both purchased and leased trucks.
Truck Acquisition Condition	New	Fleets who acquire only new trucks.
	Used	Fleets who acquire only used trucks.
	Mixed	Fleets who acquire both new and used trucks.
Electric Truck Experience	None	Fleets with no current or previous experience operating electric trucks.
	Previously	Fleets who previously, but no longer, operate electric trucks.
	Currently	Fleets who currently operate electric trucks, whether purchased, leased, or used as part of a demonstration project.

4.4 RESULTS

Table 9 shows the number of organizations categorized according to our typology, including their organizational structure and external network heterogeneity. Of the 12 possible fleet types, we identified the presence of seven in the sample. We did not identify any fleets that were democratic with low network heterogeneity, autocratic with high network heterogeneity, bureaucratic with low network heterogeneity, or hierarchical with low or mid network heterogeneity. Case studies were prepared for each fleet type present in the sample.

Table 9: Number of organizations categorized as each type according to their organizational structure and external network heterogeneity

				External Network Heterogeneity		
		Formalization	**Centralization**	**Low**	**Mid**	**High**
Internal Structure	**Democratic**	Informal	Decentralized	0	2	4
	Autocratic	Informal	Centralized	6	5	0
	Bureaucratic	Formal	Decentralized	0	3	4
	Hierarchical	Formal	Centralized	0	0	1

Table 10 presents a list of internal and external actors derived from the interview analysis. Internal actors include groups and individuals that work within the company that a given fleet operates. Six categories of internal actors were discussed in the interviews as influential in fleet acquisition decisions: company leadership, divisions/ departments, drivers, finance teams, environmental teams, and maintenance teams. External actors were grouped into four categories based on function: financial institutions, regulators, energy/infrastructure providers, and other. These actors and actor groups are described in Table 10.

Table 10: Internal and external actor definitions

Actor Definitions			
Actor Groups		**Actors**	**Definition**
Internal Actors		**Company Leadership**	Anyone in a leadership position within the company (e.g. president, owner, CEO, etc.) involved in the truck acquisition process.
		Divisions/ Departments	Functional actor groups within the company that are involved in the truck acquisition process.
		Drivers	Anyone driving a truck for the organization; including owner-operators contracting with the organization.
		Finance Team	A group of actors or individual actor within the that manages the organization's financial operations relating to truck acquisitions.
		Environmental Team	A group of actors or individual actor within the company that is tasked with minimizing the environmental damages associated with truck acquisitions.
		Maintenance Team	A group of actors or individual actors employed by the company providing at least some maintenance services to the fleet's trucks.
External Actors	**Financial Institutions**	**Banks**	Institutions providing financing for truck acquisitions.
		Leasing Companies	Companies providing long-term lease agreements for fleets (e.g. Ryder, Penske, Enterprise, etc.).

		Insurance Companies	Companies that work with fleet organizations to insure trucks.
		Dealers	Suppliers of trucks to fleets, including new and used truck dealers.
		Fleet Procurement Companies	Companies providing only acquisition assistance services to companies operating fleets. This includes finding trucks, brokering deals, assisting with paperwork, etc.
		Maintenance Vendors	Any external actor providing maintenance services for the truck; including maintenance teams at dealerships, certified service centers, and other external vendors.
		Truck Manufacturers	Truck manufacturers.
	Regulators	**Local Governments**	Including counties, air quality management districts, etc.
		State Governments	Including state agencies (e.g., CARB, California Energy Commission), state law enforcement (e.g., California Highway Patrol), etc.
		Federal Government	Federal agencies including the US Department of Transportation, National Highway Traffic Safety Administration, etc.
		Port Authorities	Including port management and staff.
		Rail Yards	Management for freight rail yards and hubs.
		Standard Board (FASB)	The FASB organization establishes the "Generally Accepted Accounting Principles" used by companies in the US (Financial Accounting Standards Board, 2020). In 2016, the FASB began requiring fleets to include leases as liabilities on their balance sheets.
	Energy/ Infrastructure Providers	**Utilities**	Electric utility companies.
		Fuel Providers	Providers of liquid fuels for trucks.
	Other	**Consultants**	Actors outside of the fleet who are involved in acquiring or modeling the cost components of truck acquisitions; directly working with the fleet, providing a model for fleets to use, or providing standard cost calculations.
		Fleet Management Companies	Companies that contract with fleets to manage day to day operations including truck maintenance and driver management. May lease vehicles to the fleet or assist in brokering acquisitions.
		Customers	Individuals or companies who hire the fleet to move goods.
		Booking agent	Individuals who help owner-operators find loads.
		Contractor Drivers	Truck drivers not employed by the fleet, including owner-operators who contract with the fleet to move the company's trailers.
		Landowners	Individuals or companies who own land leased to the organizations.
		Fleet Associations	Organizations that facilitate interaction amongst fleets or provide information to them. Examples include the Harbor Truck Association, California Trucking Association, American Trucking Association, etc.
		Other Fleets	Fleets the company interacts with, but which are outside of it.

4.4.1 Case Studies

Case studies describing each fleet type as shown in Table 9 were developed. Results are derived from all 25 fleets interviewed for this study, however, just three example case studies are presented here while the remaining case studies are presented in Appendix 9. The three example case studies were selected to illustrate differences in internal structure and external network heterogeneity between fleets with and without experience operating electric trucks. They are also intended to provide examples of the possible changes in external actor involvement between general and electric truck acquisition decisions. Definitions for factors described in the interviews and presented in the case study diagrams are shown in Appendix 10.

4.4.1.1 Fleet 23: Autocratic, Low Heterogeneity

Overview

- **Ownership model:** Mixed
- **Fleet size:** Large
- **Vehicle class(es):** Class 8
- **Application(s):** Long-haul
- **Acquisition type(s):** Purchase
- **Truck acquisition condition(s):** New
- **Electric truck experience:** None

Fleet 23 operates in the long-haul sector, moving goods between the East and West coasts of the United States. Figure 9 depicts Fleet 23's decision-making structure, including all internal actors, external actors, and factors involved in their general (left) and electric (right) truck acquisition decisions. The organization was characterized as having an autocratic internal decision-making structure. All decisions related to truck acquisitions are made by Interviewee 23, the company's General Manager. Internally, this led Fleet 23's acquisitions to be based solely on Interviewee 23's understandings and opinions of each truck option.

The company's general acquisition decisions had low external network heterogeneity, having been influenced by only three outside actor groups: dealers, manufacturers, and contract truck drivers who are not employees of Fleet 23. Interviewee 23 begins their general purchase process by acquiring price quotes from many dealerships. Quotes are evaluated based on warranty coverage and after-sales maintenance support, which Interviewee 23 negotiates with the dealership. With regards to these factors, Interviewee 23 believes he has, "*dealt with these [dealers] long enough. I know how they're going to be after the sale… some people want to sell you a truck, but after they sell you the truck they don't really care anymore*." Thus, Interviewee 23 factors his personal relationships with the dealerships into his general truck acquisitions. Interviewee 23 favorably recalled when a truck broke down in California and the dealer, who was in Missouri, reached out to their contact in California to conduct warranty work. While Fleet 23's internal maintenance team conducts routine truck maintenance and repairs, Interviewee 23 relies on dealership mechanics to provide non-routine repair services. This relationship resulted in Interviewee 23 continuing to purchase trucks from this dealership.

Contract drivers, who are not employees of Fleet 23 but are contracted to haul Fleet 23's trailers, have influence over Fleet 23's purchases. To support these contract drivers, Interviewee 23 orders more trucks than needed for Fleet 23's employee drivers. When a new contractor signs on with Fleet 23, they are given the option of leasing a truck through Fleet 23 or acquiring their truck elsewhere. The company leases new or used trucks to 90% of their contract drivers. Interviewee 23 attributes this high rate to the lower cost he can provide due to discounts Fleet 23 receives on bulk purchases. Contract drivers choosing to lease trucks from Fleet 23 are only given the option of leasing a truck of Fleet 23's preferred brand, however, Interviewee 23 allows them to "special order" these trucks with custom specifications.

Interviewee 23 felt that all the truck manufacturers he worked with pushed fuel economy as an important consideration. This led Interviewee 23 to utilize aerodynamic technologies including wheel covers, side skirts, shortened wheelbase, etc. on the company's trucks. Interviewee 23 emphasized the importance of having a network to support his decision-making, stating, "*the more people you can get involved, the more relationships open up and it just helps you out across the board. If you don't have that support, it makes it difficult sometimes*." While Interviewee 23 reports relying heavily on this external network for information to support his decisions, the small number of external actors involved in the decision gives

Fleet 23 a low heterogeneity. By involving these three groups in his acquisition decisions, Interviewee 23 can rely on them to provide information and support when choosing which trucks to acquire.

Interviewee 23's existing consideration of electric trucks is simpler than for general truck acquisitions and Interviewee 23 has ceased consideration of electric trucks. Compared to general truck acquisitions, electric trucks consideration involved fewer internal actors, fewer decision factors, and no external actors. The influential factors include one that is different from those in general truck acquisitions: the perceived negative impact on fleet operations due to a lack of charging infrastructure. Maintenance remains an influential factor, but in this case it is based on concern the in-house maintenance team would not be able to service electric trucks. Interviewee 23 reported these barriers currently prevented him from considering electric trucks further and led to his view that Fleet 23's acquisition of electric trucks was, "*down the road quite a way*." Because of this assessment, Interviewee 23 has not engaged with any external actors about electric trucks. The lack of external actors is potentially a result of low electric truck consideration and an indication that the external actors in conventional truck purchases had not mentioned electric trucks to Interviewee 23.

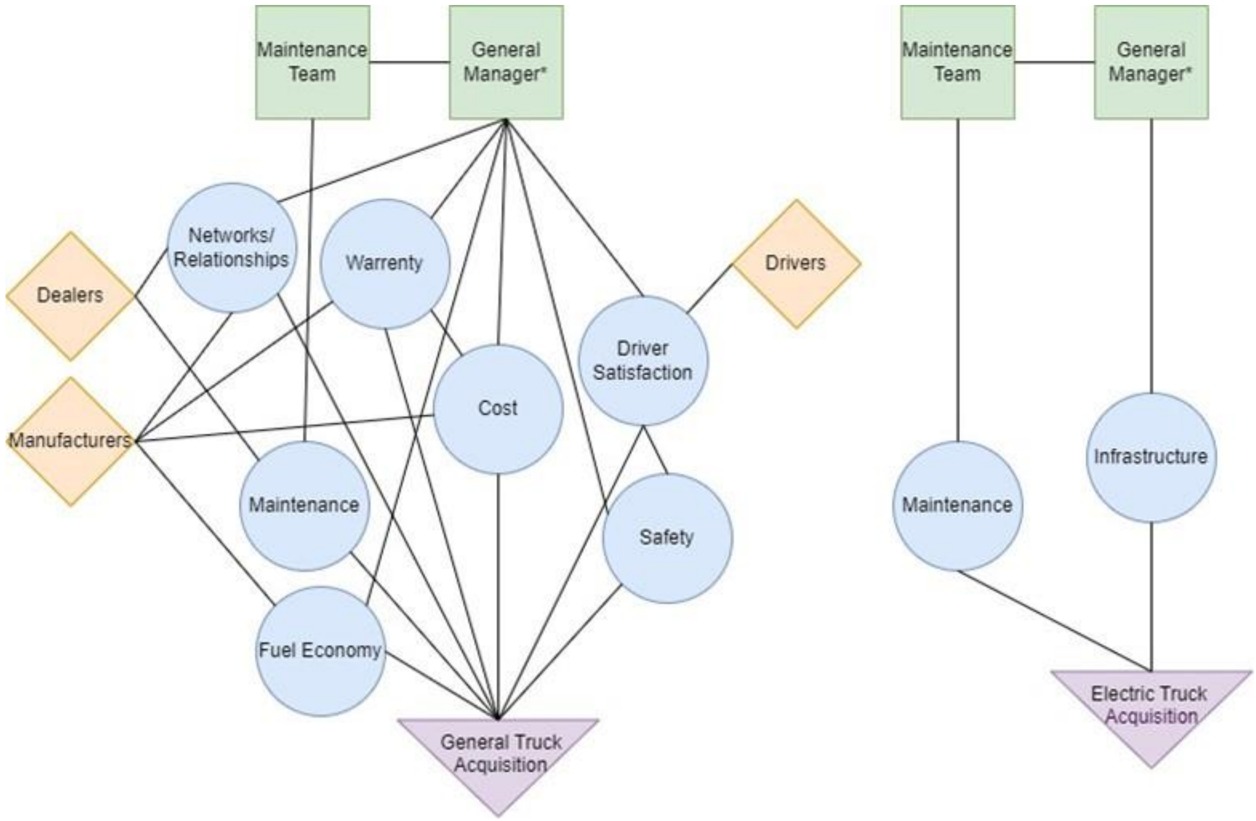

Figure 9: Diagrams representing Fleet 23's general (left) and electric (right) truck acquisition considerations

4.4.1.2 Fleet 24: Democratic, Mid Heterogeneity

Overview

- **Ownership model:** Centrally-owned
- **Fleet size:** Large
- **Vehicle class(es):** Class 2-6
- **Application(s):** Short-haul
- **Acquisition type(s):** Purchase
- **Truck acquisition condition(s):** New
- **Electric truck experience:** None

Fleet 24 is characterized as having a democratic decision-making structure as their decisions are made by several internal actors (i.e., decentralized) who are not guided by formal written rules and policies (i.e., informal). As shown in Figure 10 the company's internal structure consists of Interviewee 24 (Director of Fleet Operations), associates, the finance team, and drivers, all of whom have input into the truck acquisition decisions, which are then sent to corporate leadership for final approval. While the corporate leadership team is responsible for approving the truck acquisition, the choice of which truck to acquire is made by the whole team, giving Fleet 24 a democratic decision-making structure. Fleet 24 considers acquisition cost, operating cost per month, and depreciation. Delivery driver's opinions were seen as being important to the acquisition decision, which Interviewee 24 attributed to the high turnover rate of drivers and direct interactions with customers. To keep drivers happy, the company has tried many different vehicles to see which are preferred. Any changes in the fleet's acquisitions are proposed by the Interviewee and approved by the corporate leadership team.

External actors involved in the truck purchase decision include the Financial Accounting Standards Board (FASB), a fleet management company, manufacturers, and dealers. This number of external actors is observed to be a mid-level of external heterogeneity. Fleet 24 previously worked with a fleet management company to lease vehicles. While Fleet 24 no longer leases trucks, the fleet management company is still used to manage truck service and is responsible for acquiring rental trucks when company-owned trucks are down for extended maintenance periods. A primary motivation for transitioning from both purchasing and leasing trucks to solely purchasing trucks was changes in FASB regulations, "*where you had to start showing your equipment as a capital*." Vehicle purchases are also influenced by manufacturers and dealers. Interviewee 24 reports that his relationship with their primary manufacturer influences their purchase decisions because, "*if I have an issue, I know who to go to, if I got a question about warranty I just go to my main contact and we get it taken care of. So there's been some loyalty on their end and on our end*."

When deciding to acquire an electric truck, Interviewee 24 continues to be influenced by the fleet management company and manufacturers, although in a different capacity. He additionally is influenced by potential federal regulations, but no longer influenced by the FASB or dealers. Interviewee 24 was first introduced to the idea of electric trucks when a representative from a vehicle manufacturer asked him if he would be interested in learning about their electric truck. This led Interviewee 24 to attend a showing of the vehicle to learn more. Possible forthcoming federal regulations caused Interviewee 24 to begin seriously considering acquiring an electric vehicle. The Interviewee noted that federal regulations do not currently influence their purchase decisions, however, "*if everything goes the way our current* *administration wants it to go, then we're probably going to have to really push for an alternative fuel vehicle*." With this understanding, Interviewee 24 called on the fleet management company to benchmark Fleet 24's carbon footprint against the industry, which will help determine whether the company should procure electric trucks.

Of the four external actors who were involved in Fleet 24's general purchase considerations, two remained the same (fleet management companies and manufacturers), two were no longer involved (dealers and the FASB), and one was added (the federal government). This resulted in a lower overall external network heterogeneity, however, the number of factors considered in the purchase consideration increased from five to six. This indicates that Interviewee 24 had more deeply considered the implications of acquiring an electric truck than the interviewee in the previous case study. Interviewee 24 acknowledged that barriers to electric trucks existed but was open to the technology because he felt the industry was moving towards electrification. The interviewee was also personally supportive of electrification and wanted to reduce Fleet 24's carbon emissions, stating, "*it's really something I want to look at for the future, especially if the future is going to change the way we think it's going to change. But damn it, I think it's the way to go.*" Interviewee 24's view of the industry and desire to reduce the fleet's emissions allowed him to consider electrification beyond initial consideration of barriers.

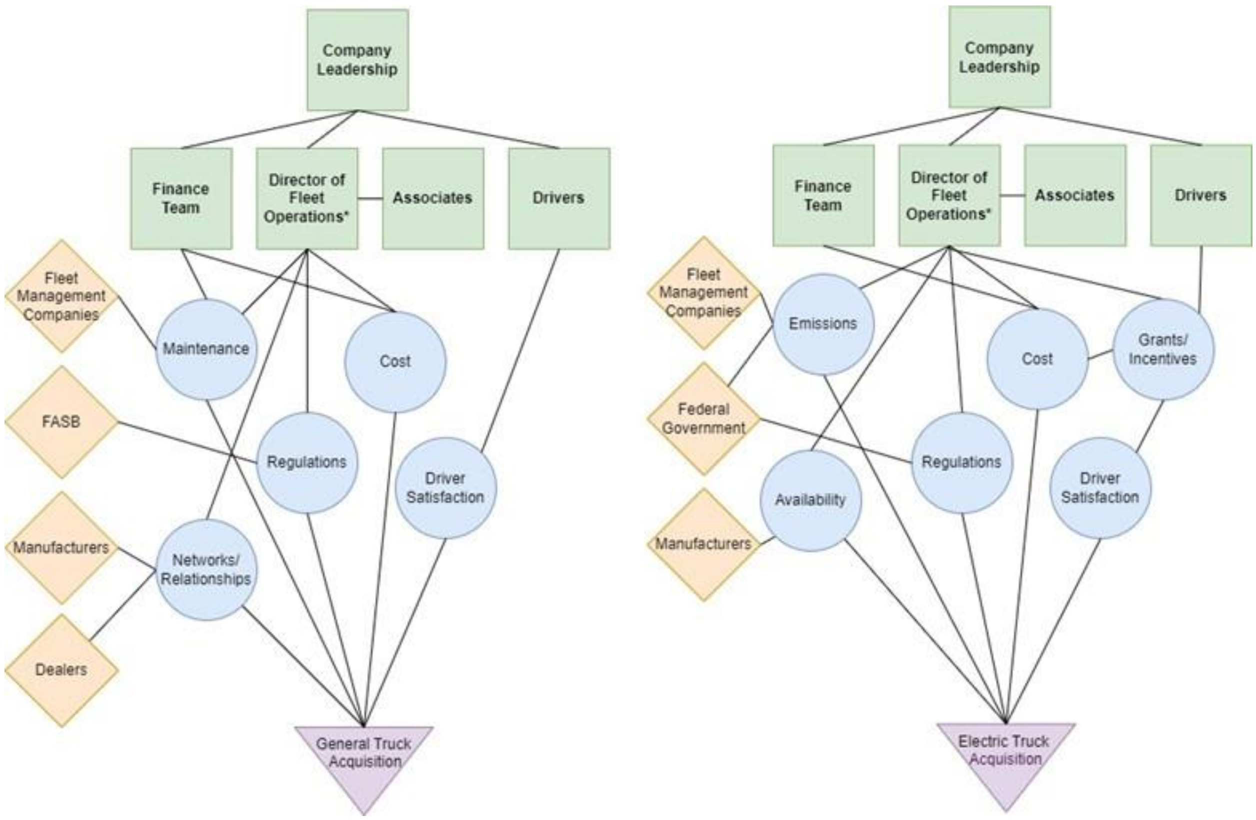

Figure 10: Diagrams representing Fleet 24's general (left) and electric (right) truck acquisition considerations

4.4.1.3 Fleet 25: Bureaucratic, Mid Heterogeneity

Overview

- **Ownership model:** Mixed (Centrally-owned and owner-operator)
- **Fleet size:** Large
- **Vehicle class(es):** Class 4-8
- **Application(s):** Short-haul
- **Acquisition type(s):** Purchase and lease
- **Truck acquisition condition(s):** New
- **Electric truck experience:** Currently

Fleet 25 is an international parcel delivery company operating medium-duty trucks nationwide. Figure 11 shows that, in the US, truck acquisition decisions are made by the Director of Fleet Management (Interviewee 25), corporate leadership, the procurement department, country level management, and regional teams (including safety and security teams responsible for acquisitions in North, Central, and South America). Fleet 25 is a bureaucratic fleet, with first level acquisition proposals made by the procurement department and country level management who determine which vehicles need to be replaced each year. Once these groups decide which trucks they need, the Interviewee and regional teams must give the second level of approval for the acquisition. The third and final level of approval comes from the regional CEO and global corporate leadership. The formal process each acquisition must follow gives the organization a highly formalized decision-making process. Outside the formal process, industry-wide driver shortages have led the organization to consider input from drivers for acquisition decisions. The large number of individuals involved in the decision-making process makes the organization decentralized, leading to a bureaucratic internal structure.

Four external actors are involved in Fleet 25's decision-making process, giving them a mid-level heterogeneity. At the regional level, the organization has relationships with preferred manufacturers, which are the default suppliers of Fleet 25's trucks. The procurement department manages these corporate-level relationships, allowing the organization to receive better pricing and support for bulk acquisitions. Interviewee 25 recalled, *"because of our global volume, we may have a very significant rebate from the manufacturer at the factory level".* For their US fleet, the organization primarily leases their trucks, which are procured using a fleet management company and through leases with two major banks.

Emissions regulations in California and the northeastern US were identified by Interviewee 25 as driving the organization to reduce their fleet's emissions. Interviewee 25 was planning to introduce zero-emission vehicles "*as quickly as possible"*, starting with their West Coast operations. He decided to begin electrifying the West Coast fleet to meet current emissions requirements, in anticipation of future regulations, and because of incentive availability. While zero emission vehicles will first be introduced in the West Coast, the organization has a goal of transitioning to a 100% zero emission fleet by 2050. The organization has introduced some electric, compressed natural gas (CNG), and fuel cell trucks in the US.

For electric truck acquisition decisions, Fleet 25 involves the same four external actors: manufacturers, fleet management companies, banks, and state agencies. Electric and other alternative fuel trucks are considered during their general acquisition considerations, allowing the same actors to be involved in both decisions. Manufactures play a more supportive role in helping Fleet 25 transition to electric trucks by assisting in the development of total cost of ownership (TCO) models comparing electric and diesel trucks. Interviewee 25 recalled difficulties working with the banks to provide financing for electric trucks, *"no one knows what they're gonna be worth, and the banks are having a significant issue determining what the residual value of that vehicle be, which is how we determine what our lease rates going to be"*. While the organization was able to negotiate a lease price, Interviewee 25 recalled this being a significant issue when they first began leasing electric trucks. To assist with electric truck acquisitions, the fleet management company and dealerships provide Fleet 25 with information on electric trucks and work to apply the financial incentives to reduce lease payments.

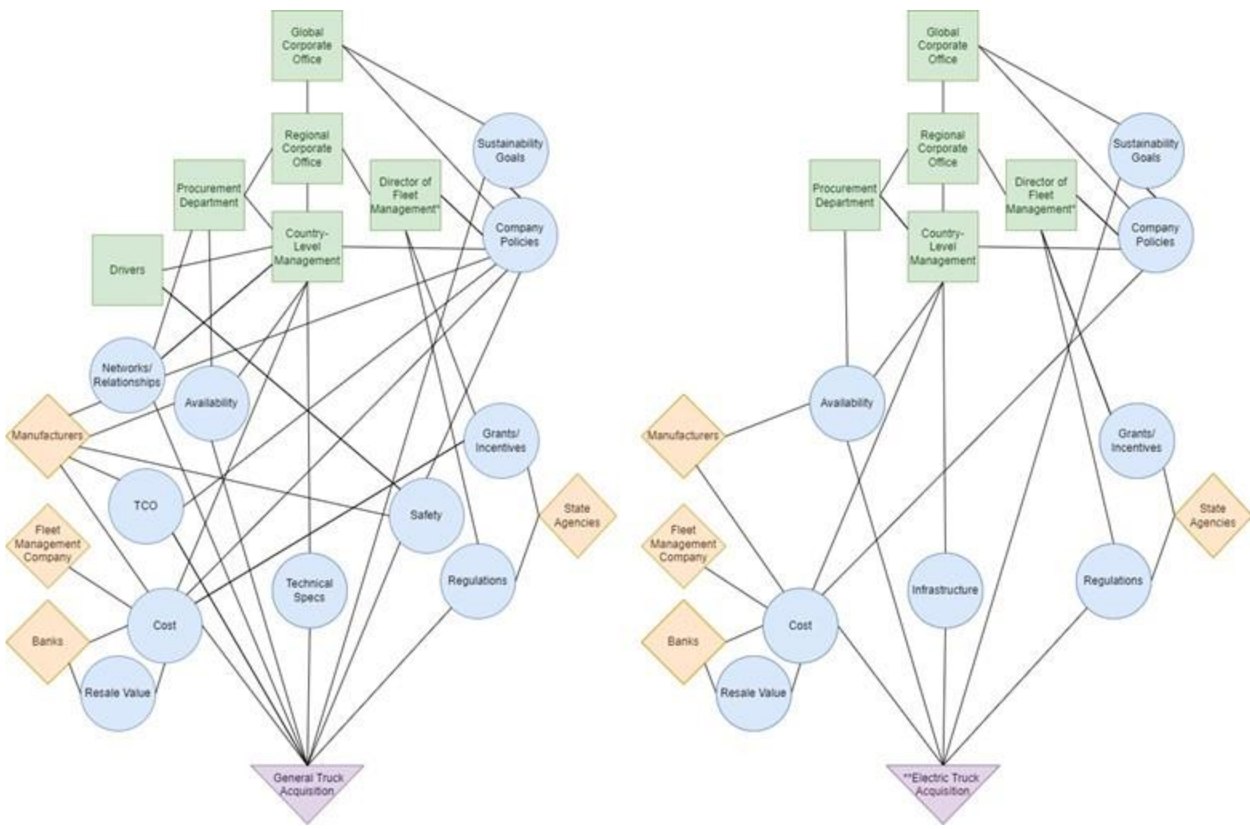

Figure 11: Diagrams representing Fleet 25's general (left) and electric (right) truck acquisition considerations

4.4.2 Changes to decision-making structures for electric truck adoption

A summary of findings for all fleets included in the study is shown in Table 11. This includes an overview of each fleet's internal decision-making structure, overall network heterogeneity, changes in heterogeneity between general and electric acquisition decisions, and changes in the number of factors considered between general and electric acquisition decisions. This allows for a comparison of descriptors between fleets who do and do not have electric truck experience, revealing which descriptors may be correlated with willingness or ability to acquire electric trucks.

For our sample, as levels of centralization and formalization increase, the number of external actors involved also generally increases. We find no autocratic fleets in this study with high external network heterogeneity, whereas the bureaucratic and democratic fleets exhibit mid to high external networks. The sole hierarchical fleet was observed to have high external network heterogeneity.

Table 11: Summary of Results

Fleet Number	Internal decision-making structure	Overall network heterogeneity	Heterogeneity change from general to electric decisions	Factor changes from general to electric decisions	Electric truck experience
18	Democratic	Mid	Higher	More	None
24*		Mid	Lower	More	None
10		High	Higher	Same	None
09*		High	Lower	Fewer	Previous
04		High	Lower	Fewer	None
06		High	Lower	Fewer	Previous
22	Autocratic	Low	Lower	Fewer	None
21		Low	Lower	Fewer	None
17		Low	Lower	Fewer	None
02		Low	Lower	More	None
23*		Low	Lower	Fewer	None
01		Low	Lower	Fewer	None
12		Mid	Same	Fewer	None
20		Mid	Lower	Fewer	None
19		Mid	Lower	Fewer	None
16		Mid	Lower	Fewer	None
14*		Mid	Lower	Fewer	None
15*	Bureaucratic	Mid	Higher	More	None
03		Mid	Higher	More	Current
25*		Mid	Same	Fewer	Current
07		High	Higher	More	Current
08		High	Lower	Fewer	None
05		High	Same	More	Current
13*		High	Same	Fewer	None (LDV experience)
11*	Hierarchic	High	Same	More	Previous (LDV experience)

*indicates fleet is a case study

4.4.2.1 Impacts of internal network structure on electric truck adoption

Our findings suggest a possible relationship between internal organizational structure and electric truck acquisitions. We observe bureaucratic organizations were most likely to have experience with electric trucks: four of seven bureaucratic fleets in our sample have electric trucks while no fleet of any other type presently has any. We observe democratic and hierarchical organizations may have had previous experience operating electric trucks. Thus, some of these democratic and hierarchical fleets may have been willing to try electric trucks but are not yet willing to commit to them. None of the autocratic fleets in our sample had current or previous experience operating electric trucks.

4.4.2.2 Impacts of external network heterogeneity on electric truck adoption

Higher external network heterogeneity has been shown to be positively related to innovativeness for private consumers (Axsen, 2010), thus we might expect organizations with high heterogeneity to have a greater likelihood of acquiring alternative fuel vehicles sooner than organizations with lower levels of network heterogeneity. In our sample, organizations such as Fleet 25 who are currently operating electric trucks were found to involve the same number or a higher number of external actors for their electric acquisition decisions than their general acquisition decisions. Fleets with previous electric truck experience all had high-level network heterogeneity for general acquisition decisions, but the same or lower levels of network heterogeneity for electric truck decisions. This indicates that electric truck acquisition decisions may require at least the same level of external input and support as conventional trucks.

4.4.2.3 Impacts of external actors on electric truck adoption

Comparing general and electric truck acquisitions, the role of internal and external actors was observed to take four forms. Actors typically involved in routine, general truck acquisitions might be *omitted* from the acquisition or consideration of electric trucks. Alternatively, actors absent from general truck acquisitions could be *added* to electric truck acquisition or consideration. Further, the role of actors who appear in both decision types might be *static* (i.e., they play the same role in both) or their roles may be *dynamic* (i.e., they play a different role in each decision). A complete list of actors involved in each fleet's general and electric truck acquisitions is shown in Appendix 11.

Omitted actors included vehicle dealers, liquid fuel providers, and other fleets. Despite their removal from electric truck decisions now, these actors may play a role in electrifications decisions in the future. Someday dealers will supply electric trucks and act as information sources, for now though most fleets in the sample did not view them as having a strong influence in their decisions to acquire electric trucks. As shown in Fleet 24's case study, early electric truck acquisitions were often made through partnerships with the truck manufacturers rather than dealers. Other fleets were also seen as less influential given the unique duty cycle and operational requirements of each truck, leading fleets to want to try electric trucks in their own fleet rather than relying on other fleets to determine when the technology is ready.

Added actors included landowners from whom the fleet organization leased their location(s), local governments, and utilities. Fleets who currently refuel trucks at a central depot with organization-owned liquid fuel infrastructure typically saw the involvement of electric utilities as essential for installing on-site charging infrastructure. In these cases, utilities were seen as additions to or replacements for liquid fuel providers as organizations expected to continue refueling or recharging their vehicles on-site. Some organizations whose trucks currently refuel at public fuel stations also discussed the need to install charging infrastructure at their depots if they were to acquire electric trucks. Some of these fleets, however, reported leasing the land on which the infrastructure would need to be installed. They would therefore need to involve the landowners in the decisions to install charging infrastructure, which some fleets did not believe was feasible.

Actors whose role remained static included banks, consultants, customers, and fleet associations are described as playing the same role in electric truck acquisition decisions as they play in general truck acquisition decisions. Consultants and fleet associations serve largely as sources of information for fleets looking to electrify. While banks and customers play the same role in general and electric truck acquisitions, interviewees perceive them as having a stronger influence over the fleet's ability to electrify. Banks continue to serve as funding sources for general and electric truck acquisitions, with the case study for Fleet 25 demonstrating the Interviewee's difficulties working with their bank to finance electric trucks due to the uncertainty of their residual value. Fleet's relationships with their customers have similarly been reported to hinder electric truck adoption as they are reportedly unwilling to adapt to schedule and pricing changes that may result from transitioning to electric trucks. Interviewees report this lack of flexibility as significantly hindering their ability to acquire electric trucks.

Actors who played continuing but dynamic roles included vehicle leasing companies, vehicle manufacturers, port authorities, and state agencies. State agencies and port authorities (for fleets operating drayage) were discussed as influencing general truck acquisition decisions due to regulations requiring the use of certain emissions reduction technologies and prohibiting the use of certain model year engines. While these public-agency actors continue their role as regulators, fleets now additionally view them as sources of funding to support fleet organizations' transitions to electric trucks. This is shown in the case study for Fleet 25, in which the interviewee reported they relied on state agencies to provide financial incentives to acquire electric trucks. Vehicle manufacturers and leasing companies continue to serve as educators and truck suppliers. Fleets who lease trucks report relying on the leasing companies to apply for grants and rebates for electric trucks as the trucks are registered to the leasing company. Leasing companies also determine the price of electric trucks, leading fleets to be reliant on them to pass through the savings from the incentives. For some fleets, the role of manufacturers is also changing as they transition from suppliers and educators to funders. Two fleets reported gaining experience with electric trucks by participating in demonstration programs in which the manufacturer provided the organization with an electric truck to use for a limited time at little or no cost. This allowed individuals in the organization to gain experience with electric trucks without having to invest large amounts of money to acquire one.

4.5 DISCUSSION AND CONCLUSIONS

Medium- and heavy-duty truck acquisition decisions involve actors internal or external to the organization operating the truck(s). These actors are connected through social networks that may differ for acquiring conventionally-fueled vs. electric vehicles and may change over time. Thus, vehicle acquisition decisions are the result of a dynamic social system in which the outcome is rarely determined solely by a single individual. Differences and changes in these social networks are measured here in terms of the number of, roles of, and relationships between internal actors (i.e., internal structure) and the number of different types of external actors (i.e., their external network heterogeneity). Internal structure is assessed along two dimensions. Formalization is the extent to which decision making is proscribed by formal rules and structures. Centralization is the extent to which decision-making authority is diffused throughout an internal actor network or concentrated in one or a few internal actors.

Prior studies report the organizations least likely to innovate were those that have low external network heterogeneity (Nesbitt and Sperling, 2001; Carlsson and Sandström, 2008). Our results tend to confirm the importance of external network heterogeneity to innovation: fleets currently operating electric trucks involved the same or a higher number of external actors in their electric truck acquisition decisions as in their general truck acquisition decisions. This shows that larger social networks facilitate information exchange and supports fleet decision-makers in choosing an electric truck. For example, decision-makers may be more willing to try an electric truck if they are able to draw on knowledge from other fleets who have experience with electric trucks.

However, our findings on the impacts of internal structure on an organization's willingness to adopt electric trucks do not fully align with Nesbitt and Sperling (2001). They observed fleets with a democratic internal structure are the most likely to innovate, followed by hierarchical fleets, with bureaucratic and autocratic fleets being the least likely. In the present case of electric truck adoption, we find bureaucratic fleets—not democratic ones– were the most likely to innovate, followed by democratic and hierarchical fleets, with autocratic fleets being the least likely. These findings may suggest the presence of additional factors impacting organizational innovativeness such as organizational size and financial resources, the presence of public facing sustainability goals, etc.

Decision-makers in the autocratic fleets in our data typically have lower external network heterogeneity (only low and mid) and the fewest people involved in internal decisions. Such fleets may require the most external support to acquire electric trucks, though the support will likely have to come from actors not currently in their external network which could require proactive engagement from actors outside of these fleets. These fleets also often have lower workforce and financial resources than fleets with other internal structures, lessening autocratic fleets' willingness to experiment, and potentially creating more barriers to electric truck acquisition. These fleets may require the most external support to acquire electric trucks, though the support will likely have to come from actors not currently in their social network. This could require proactive engagement from policymakers and other stakeholders by facilitating these connections and driving educational campaigns. These fleets also often have lower financial and workforce resources than fleets with other internal structures, lessening their willingness to experiment, and potentially creating more barriers to electric truck purchase.

Decision-makers in the democratic, bureaucratic, and hierarchical fleets in our data typically have mid to high external network heterogeneity. Such fleets may still require external support to acquire electric trucks, though their workforce and financial resources are typically higher than fleets with autocratic internal structures, increasing their willingness to experiment, and potentially reducing barriers to electric truck purchase.

The role of external actors in truck acquisition is different between conventional and electric truck consideration. Some differences may be a result of fleets not yet considering or being in an early stage of considering electric trucks. For example, fewer external actors associated with an electric truck decision than a conventional truck decision may simply mean the fleet hasn't yet thought much about electric trucks. Other differences are due to variations in how fleets consider electric trucks, including the factors they consider and actors involved. External actors, such as vehicle dealers, liquid fuel providers, and other fleets who are involved in the acquisition of conventionally-fueled trucks may have played less prominent roles in decisions to acquire an electric truck. These actors may become important again in future deliberations about electric trucks. It seems plausible vehicle dealers may be expected to play a larger role in future considerations once electric truck availability increases. Conversely, the reduced role of liquid fuel provides is expected to become more permanent as fleets transition away from liquid fueled trucks. Meanwhile, landowners, local governments, and utilities who previously played little to no role in any truck acquisition decisions may need to be recruited to fleet organizations' external actor networks to support transitions to electric trucks. While local governments were discussed as becoming involved in truck acquisitions via regulations and incentive programs, the importance of these programs would likely decrease once electric trucks become routine acquisition decisions. Importantly, the role of vehicle leasing companies, manufacturers, port authorities, and state agencies is changing as they come to be perceived as not just suppliers and regulators, but also as educators and funders. As the roles of these external actors multiply, they may exert increasing level of influence over fleets' acquisition decisions.

We note the absence of discussions around some actors who may play a role in the transition to electric trucks. This includes charging station providers who install publicly available charging stations as a business. These groups may play a large role in helping alleviate some barriers to electrification but are not yet reported as partners in the decision-making process. Efforts to bring these actors into the heavy-duty freight sector may help alleviate concerns about electric trucks.

As fleet decision-makers turn to external actors for information on general and electric trucks, it will become important to ensure these groups have correct and adequate information to support this decision-making. Manufacturers, fleet associations, utilities, and government agencies are often reported as trusted sources of information by interviewees across the sample. Some interviewees report working with dedicated and informed electric truck personnel within these organizations to get support for learning about and deploying electric trucks. As public policy continues to push fleet operators towards zero-emission trucks, insights such as those provided in this study can help policymakers understand which fleet types are more likely to adapt to these regulations, which will require additional support, and which new actors may need to be involved.

Chapter 5: Conclusion

This dissertation examines electric vehicle acquisition decision-making in public and private fleets in the United States, with an emphasis on fleets operating in California. To understand fleets' willingness and ability to adopt electric vehicles, this dissertation utilized data collected from two sets of interviews with fleet decision-makers. These interviews sought to understand decision-maker's perceptions of electric vehicles, what is preventing them from adopting electric vehicles, how these issues can be overcome, and how these perceptions are influenced by the social environment in which acquisition decisions are made. These interviews provide insights into the unique perspectives of individuals involved in the decision-making process.

While many factors affecting the adoption of personally-owned vehicles are also seen as issues for fleets, the way in which these barriers manifest is often different. For example, though high purchase prices are a perceived barrier for consumers, some consumers are willing to pay a premium for PEVs (Hidrue *et al.*, 2011) whereas some fleet managers cannot purchase vehicles with a price premium even if they wish to do so. Additional fleet specific barriers, including issues with employee buy-in, having to procure vehicles under the competitive bid process, the need for standardizing vehicle makes in a fleet, lack of certain vehicle options, and difficulties with installing charging infrastructure and ensuring drivers charge the vehicles. Fleet managers were still concerned with the usage of these vehicles after they were integrated into the fleet as some drivers were concerned about using new technologies, although this was not found to be as prohibitive as other barriers. Fleet managers were found to be driven by their desire to try new technologies, lessen environmental impact, improve their public image, and use grants.

Chapter 2 explored the motivations for acquiring conventional and electric light-duty vehicles. The impact of these processes on PEV acquisitions was explored through the lens of Self-Determination Theory. The results show PEVs are not necessarily aligned with existing purchasing considerations of light-duty fleet managers in California. Examining fleet purchase motivations under the framework of Self-Determination Theory, we find that it is most common for fleet purchase decisions to come from more internalized extrinsic motivations including integrated and identified regulations. This is perhaps because light-duty fleet managers are accustomed to purchasing conventional vehicles and have internalized these purchase considerations due to them aligning with their own motivations. This contrasts with the electrification decisions, which primarily come from less internalized motivations that fall under external regulations. This disparity may be at least partially attributable to the relative novelty of electric vehicles, which require some level of external motivation to spur initial adoption. As fleet managers become more experienced with using and purchasing light-duty electric vehicles, fleets may begin to internalize these motivations, thus moving them further along the spectrum towards integrated regulation. Until that occurs though, external regulations may be required to motivate fleet managers to continue fleet electrification.

Chapter 3 investigated perceived barriers to the adoption of electric heavy-duty trucks by decision makers within fleets operating heavy-duty trucks in California. This qualitative research allows for a deeper understanding of the impacts of barriers on fleets including which barriers are most prevalent across electric truck experience levels. Barriers were classified into six categories: technological, economic, social, socio-economic, socio-technological, and techno-economic. As advancements in technology and policy move the heavy-duty trucking sector towards electrification, a greater understanding of the barriers to adoption is needed to inform solutions that are sensitive to differences between fleets. While multiple interviewees may discuss the same barriers, those barriers manifest in different fleets in different ways, suggesting multiple approaches may be required even to address conceptually similar barriers.

Chapter 4 examined the social environment in which decision-making for medium- and heavy-duty truck acquisitions are made. Organization’s social networks are found to be complex, involving internal and external actors connected to acquisition decisions through dynamic and intertwined networks. Acquisitions are made by fleet decision-makers acting as part of a dynamic social system in which the outcome is often not based solely on an individual’s decisions. Decision-making also differs between fleets based on internal structure and external network heterogeneity. We also find the role of external actors in truck acquisitions is different between conventional and electric truck considerations. Some differences may be a result of fleets not yet considering or being in an early stage of considering electric trucks. Other differences are due to variations in how fleets consider electric trucks, including the attributes and actors they consider.

These studies have also demonstrated ways in which fleets are internally and externally motivated to adopt electric vehicles. Chapter 2 shows how decision-makers face pressures from external company regulations or government mandates to adopt electric trucks. Meanwhile, other decision-makers express a personal motivation to electrify and make the fleet more sustainable. Chapter 4 reinforces these findings, showing the ability of organizations to adopt electric trucks is influenced by the attitudes of internal decision-makers as well as the inputs they receive from external actors. Understanding the impact of these internal and external pressures on fleets' willingness to consider and adopt electric vehicles can allow their utilization in motivating fleets to electrify.

The importance of grant and incentive programs in helping fleets overcome the higher upfront costs of acquiring an electric vehicle was reported across the dissertation. Interviewees reported that by utilizing grants and incentives to lower the upfront cost of PEVs, they may be able to compete with the upfront cost of conventionally fueled vehicles. Many fleets included in this dissertation mentioned they had not applied for inventive programs because they were unaware such programs existed or were confused about the whether programs could be used in conjunction with one another. Interviewees also commonly reported lacking the time needed to understand the requirements of and apply for incentives. These interviewees reported the need for a more standardized application process to reduce the time burden of applying to them. Chapter 3 reported additional concerns interviewees had with incentive programs, such as HVIP, which has previously run out of funding within 24 hours of applications opening. This limits the ability of fleets to apply for this program, leading to calls for more reliable funding sources.

Chapters 2 and 3 revealed concerns over technological and techno-economic issues such as limited driving range, long charging times, and lack of vehicle availability. For light-duty vehicles, the Advanced

Clean Cars Program played a role in the technological development of light-duty ZEVs (Axsen, Hardman and Jenn, 2022). It is possible the ACT and ACF regulations, once passed, will have similar effects on California's freight sector by influencing the development of zero-emission trucks. Another technoeconomic issue discussed in Chapter 3 was high truck weight. In the European Union, weight constraints are being addressed by allowing zero-emission trucks to carry an additional 2 metric tons (4,400 pounds), allowing fleets to adopt zero-emission trucks without sacrificing their ability to transport (EUR-Lex, 2019). Such measures have yet to be implemented in the United States.

Chapter 3 discusses education, outreach, and technical assistance from policymakers as a necessary component to reducing social based barriers. These could include programs that introduce drivers and decision-makers to the technology (Wikström, Hansson and Alvfors, 2016; Globisch, Dütschke and Wietschel, 2018). For example, programs could discuss ways in which the limited range of electric trucks compared to their diesel counterparts might be mitigated through increased charging frequency or altering existing routes. Other educational components could include strategies for adjusting financial models to account for total cost of ownership rather than purely focusing on upfront costs. Smaller fleets may especially benefit from this assistance due to a lack of in-house resources. For light-duty vehicles, public funding has been used for outreach (Veloz, 2022), policymakers have formed public private partnerships (Hyundai Motor Company, 2017), and policymakers have directed private companies to conduct outreach activities (California Air Resources Board, 2018). Similar efforts may be needed for ZEV trucks and fleet operators.

A lack of model availability in certain vehicle platforms was seen as detrimental to many fleets who wished to acquire an electric truck. At the time Chapter 2 was written, there was no commercial electric pickup trucks commercially available, which many fleets specifically mentioned as an obstacle to electrifying. While electric pickup trucks have since become commercially available, they have high upfront costs and are limited in availability. Similar concerns were found with medium- and heavy-duty trucks with interviewees reporting a lack of vehicles available in certain classes or meeting certain specifications. California's Advanced Clean Cars and Advanced Clean Trucks regulations create manufacturing targets for ZEVs, which may help spur the electrification of these vehicles and make them available for fleets (California Air Resources Board, 2019, 2022a).

These studies find it may be important to more directly show the cost savings associated with PEVs before they are purchased, such as at the dealership or online purchasing sites. These should display not only the purchase costs, but also the running costs (both fuel and maintenance costs) of the vehicle or TCO estimates. The cost savings can also be clearly communicated through traditional advertisements which can include cost savings estimates.

Chapter 4 found utilities and infrastructure providers to be new actors to the transportation sector which were added with the transition to electric trucks. Fleets who typically fuel away from a base location were reliant on publicly available charging stations to charge their vehicles. The buildout of public charging infrastructure typically implicates government agencies or private infrastructure provider companies. Conversely, fleets who typically refuel vehicles at a central depot with organization-owned liquid fuel infrastructure typically saw the involvement of electric utilities as essential for installing charging infrastructure for electric vehicles. Interviewees look to electric utilities for support beyond electric grid upgrades as financial incentives to offset the cost of charging station hardware and installation is offered by many California utilities (PG&E, 2022; Southern California Edison, 2022). Some fleets reported leasing the land on which the infrastructure would need to be installed. They would therefore need to involve the landowners in the decisions to install charging infrastructure, which some fleets did not believe was feasible.

The findings of this dissertation also have implications for organizations looking to electrify their fleets. The results show that electric vehicles are not necessarily aligned with the existing acquisition considerations of decision-makers, who typically seek to acquire vehicles that are compatible with their current financial and operational schedules. The decision-makers interviewed in these studies do not typically use TCO calculations as a primary factor in their acquisition decisions. The focus on reaching upfront cost parity between electric and conventionally fueled vehicles currently negates the potential benefits of operational or overall cost savings. Allowing exceptions to these rules, utilizing grants, or changing them to consider TCO instead of purchase price may help encourage fleets to purchase electric vehicles.

Despite this misalignment with their typical acquisition decisions, many light-duty fleets in Chapter 2 have begun acquiring PEVs. They commonly report choosing to electrify vehicles due to sustainability goals and other environmental motivations. Despite this, many of the fleets studied do have not have regulations that require purchasing PEVs. Regulations currently exist for state owned fleets, but these do not apply to city, county, or privately owned fleets. To encourage the transition away from fossil fuels, California state policymakers could seek to regulate the purchasing of light-duty vehicles in fleets beyond their state organizations.

Barriers of range and driver resistance were reported throughout the studies presented in this dissertation. Range limitations are overcome through education, increasing charging frequency, and altering operations to assign electric vehicles to tasks that fit their driving range. Furthermore, fleet managers are overcoming the barriers to PEV adoption by educating fleet vehicle users about PEVs and assigning the vehicles to more receptive drivers and departments.

The role of banks and other financial institutions was reported in Chapters 3 and 4. Banks serve as funding sources for general and electric truck acquisitions, with one fleet reporting difficulties working with their bank to finance electric trucks due to the uncertainty of their residual value. Ensuring individuals within these financial institutions understand electric truck costs, such as their residual value, is important in allowing fleets to gain the financing necessary to acquire these trucks.

Fleet’s relationships with their customers have similarly been reported to hinder electric truck adoption as they are reportedly unwilling to adapt to schedule and pricing changes that may result from transitioning to electric trucks. Interviewees report this lack of flexibility as significantly hindering their ability to acquire electric trucks.

As decision-makers turn to external actors for information on general and electric trucks, it will become important to ensure these groups have correct and adequate information to support this decision-making. Manufacturers, fleet associations, utilities, and government agencies are often reported as trusted sources of information by interviewees across the sample. Some interviewees report working with dedicated and informed electric truck personnel within these organizations to get support for learning about and deploying electric trucks.

The findings presented in Chapter 2 are limited to public and semi-public light-duty fleets. As discussed in this paper, public fleets face pressures to be fiscally responsible and are often required to purchase through competitive bids or cooperative purchasing contracts. Private fleets may not face the same constraints to acquire the lowest priced vehicle and may more easily use TCO calculations in their acquisition decisions. Both public and private fleets, however, may be subject to similar constraints such as range, charging infrastructure, and employee buy-in. Future studies should examine the extent to which these findings differ between fleet types.

While this dissertation presented decision-maker's views on electric vehicles under current conditions, these findings may change over time. Future studies may seek to capture changes in attitudes and barriers as technologies, policies, and industry-wide understandings progress. These studies can be extended to examine organizational decision-making around other alternative fuels and technologies, such as hydrogen fuel cell vehicles. The findings presented in this dissertation can also be used to inform a survey examining the prevalence of barriers throughout the fleet industry and test for differences between fleets of different types, sizes, organizational structures, etc.

The chapters presented in this dissertation present key findings which underlie fleet decision-making around electric vehicle adoption. We find that barriers to electric vehicle adoption are discussed as such because of their differences from incumbent fossil fuel vehicles. While fleets often expect electric vehicle technologies to advance to a point where they reach operational parity with fossil fuels, many perceived barriers can be partially or fully addressed through education or operational changes.

This research sought to expand the literature on electric vehicle adoption behavior by providing insights into the ways organizations with fleets make decisions about which vehicles to acquire. It presents both opportunities for electrifying the fleet sector and challenges that must be addressed before this can be achieved.

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Appendix 1: Interview protocol

Note: Not all questions asked in the interviews were discussed in this chapter.

General Information on Fleet and Procurement of Vehicles

- Vehicle fleet information
  - Number of light-duty vehicles in fleet, number of purchases per year
  - Number of cars
  - Range of light-duty vehicle costs
  - Number of drivers
  - Vehicle uses
  - Average, minimum, and maximum VMT of vehicles in the fleet?
    - How predictable are the vehicle use patterns?
  - Does the fleet have any special requirements for vehicles?
- Fleet vehicle purchase decision process
  - Total costs
  - Purchase Price
  - Maintenance costs
  - Reduced reliability
  - Improved image
  - Climate protection
  - Reduced comfort
  - Reduced safety
  - Improved employee motivation
  - Operational capabilities
  - Meeting Regulation
- Does the fleet purchase vehicles from any particular place?
  - Any requirements to buy from specific organization?

Sustainability Questions

- Fleet environmental or sustainability goals
- Organization environmental or sustainability goals

Alternative Fuel Vehicle Questions

- Does the fleet have any alternative fuel vehicles?
  - If no EV
    - Thoughts on how plug-in electric vehicles could fit in the fleet?
      - Special vehicle needs
      - Pros and cons of the vehicles
      - Barriers to adoption
    - If you were to purchase an EV, what price would you want to pay in comparison to the average vehicle in the fleet?
  - If yes EV
    - How was the decision to purchase electric vehicles made? Why did the fleet buy them?
    - What experiences have you had using the EVs in the fleet?
      - Special vehicle needs
      - Pros and cons of the vehicles
      - Barriers to use
    - How are the vehicles charged?
    - Compared to the typical vehicle in your fleet, how much did the EV cost?
    - Have you used any subsidies/ grants/ purchase programs?
      - If no, why not?

- Are you aware of the public/ private fleet requirements
    - If yes, what are they?
- Have you ever procured a second hand or used vehicle?
    - Thoughts on used electric vehicles?
    - Compared to a new gasoline vehicle what would you want to pay for a used electric vehicle?

Fleet Management Information and Software

- What information do you use to track vehicles in the fleet?
    - Such as maintenance, costs, mileage
- Do you use any management tools/software for the fleets?
- What information would you like to see for electric vehicles?
- How do you see the profile of the fleet changing over the next couple of years?

Interaction Questions

- Interaction with others in the organization? (Facilities, energy, management, etc.)
- How often do they speak to fleet managers in other organizations?
    - Have you spoken about electric vehicles?

Appendix 2: Reported alternative fuel types by fleet

Fleet Number	BEV (n=21)	PHEV (n=19)	HEV (n=18)	Hydrogen (n=7)	CNG (n=12)	Renewable Diesel (n=10)	Other (n=4)
1	✓	✓	✓	✓	✓	✓	
2	✓		✓	✓	✓	✓	
3		✓	✓				
4	✓	✓	✓	✓			
5	✓	✓	✓	✓		✓	
6			✓			✓	
7	✓	✓	✓				
8	✓	✓	✓		✓		✓
9	✓	✓			✓		
10	✓	✓				✓	✓
11	✓	✓	✓		✓		
12	✓	✓	✓	✓	✓	✓	✓
13	✓	✓	✓				
14	✓	✓	✓				
15	✓	✓			✓		
16	✓	✓	✓				
17	✓		✓		✓		
18	✓	✓			✓		
19	✓	✓	✓	✓	✓	✓	
20	✓	✓	✓				✓
21	✓		✓			✓	
22	✓	✓	✓	✓	✓	✓	
23	✓	✓			✓	✓	

Appendix 3: Reported use of incentives by fleet and incentive type

Fleet Number	Federal		State		Air District	Utility	Other	
	Vehicle (n=2)	Charging Stations (n=1)	Vehicle (n=14)	Charging Stations (n=4)	Vehicle (n=6)	Charging Stations (n=7)	Vehicle (n=5)	Charging Stations (n=3)
1			✓					✓
2			✓			✓		
3			✓		✓	✓	✓	✓
4			✓	✓				
5				✓				
6								
7	✓		✓					
8			✓	✓	✓	✓		
9								
10			✓			✓	✓	
11							✓	
12			✓	✓				✓
13			✓					
14								
15								
16							✓	
17								
18					✓			
19			✓		✓	✓	✓	
20			✓		✓			
21	✓	✓	✓		✓	✓		
22			✓					
23			✓			✓		

Appendix 4: Interview Protocol

Intro/ Rapport Building

- Gain consent for interview and recording
- What is your current role?
  - At what level of the organization are you?
  - What level of control do you have versus what is decided at another level?
- When did you begin working at/for (name of company)?
  - What was your prior role/ how did you come to be the fleet buyer?

Truck Turnover

- Most Recent Truck Acquisition
  - Can you walk us through your fleets most recent acquisition process?
    - How does the organization decide when to purchase vs lease a vehicle?
  - What factors are considered in deciding which vehicles to acquire? How important are these?
  - How does this truck fit in with the overall fleet operations?
  - Do you acquire vehicles from any specific manufacturers or suppliers?
  - What uncertainties are there and to what extent are they an issue?
  - Are there any policies that impact fleet acquisitions?
  - How does the fleet decide when to replace, buy, repurpose, repower a truck?
  - Are vehicles ever retired ahead of schedule? What causes this?
  - What does the fleet do with the vehicles when they are retired? Where do they go?
- Can you give me an example of how the procedure for either buying, selling, or scrapping trucks has changed? What caused this?

Purchasing AFVs

<u>For fleets with AFVs</u>

- You indicated you have ---, how many trucks of this fuel type do you have?
- What role does --- play in the overall fleet story?
- How did you make the decision to purchase ----- vehicles?
  - Were there any differences between the purchase process for these and conventional vehicles?
  - How did you decide which type of AFV you were going to use?
  - Do driver experiences influence decisions to purchase AFVs?
- How were you originally introduced to the idea of using -----?
  - Did you work with any other organizations or other resources to get information?
  - Do you wish there were additional sources of information?
- What has prevented these vehicles from playing a larger role in the overall fleet?
  - What uncertainties are there and to what extent are they an issue?
    - Are there any absolute barriers? (Barriers that they absolutely can't purchase them)
    - What could motivate you to purchase an AFV even with these uncertainties?
  - How have you handled charging and other new infrastructure needs?
    - How has access to charging been at both your facilities and on longer routes?
- Are you planning on purchasing additional AFVs for your fleet?

For fleets without AFVs

- Has the fleet considered purchasing any alternative fuel vehicles? Which ones?
- How were you originally introduced to the idea of using alternative fuels?
    - Do you work with any other organizations or other resources to get information on AFVs?
    - Do you wish there were additional sources of information?
- How supportive are the company's (drivers/ management/ leadership) with alternative fuels, and fuel saving technologies in general?
- What stage of considering a commercial electric vehicle are you in?
- What would motivate (you/your fleet) to purchase an alternative fuel vehicle?
- What would prevent you from adopting them?
- What uncertainties are there and to what extent are they an issue?
    - Are there any absolute barriers? (Barriers that they absolutely can't purchase them)
    - What could motivate you to purchase an AFV even with these uncertainties?
    - Would you be willing to make changes to your operational schedules to help utilize AFVs?
- Could these vehicles play a role in your company in the future?

Fleet Evolution

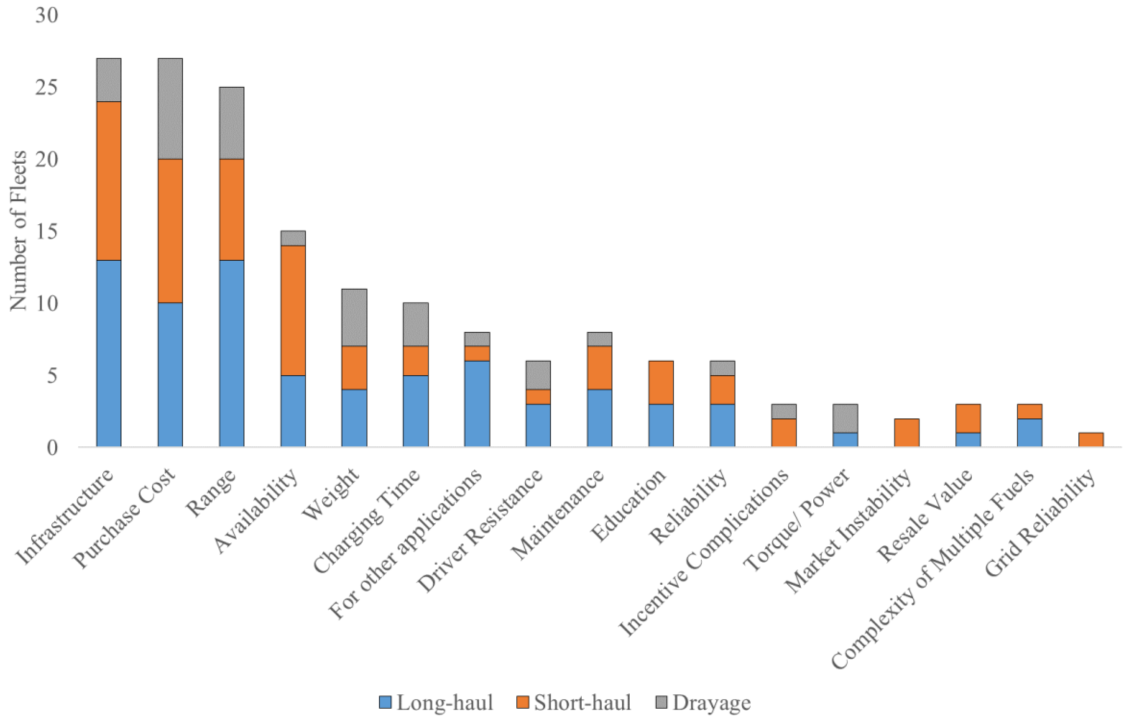
- Do you think there will be any significant changes in the way you/the owners purchase vehicles in the future?
    - Will upcoming mandates and regulations affect your purchasing process? (ZEV mandate)
        - Have you started preparing for this/ thinking about how you will handle it?
    - Will this have any significant effects on the fleet composition?
    - Are there other changes coming from within the fleet or from outside regulations?

Appendix 5: Barrier categories discussed by interviewees

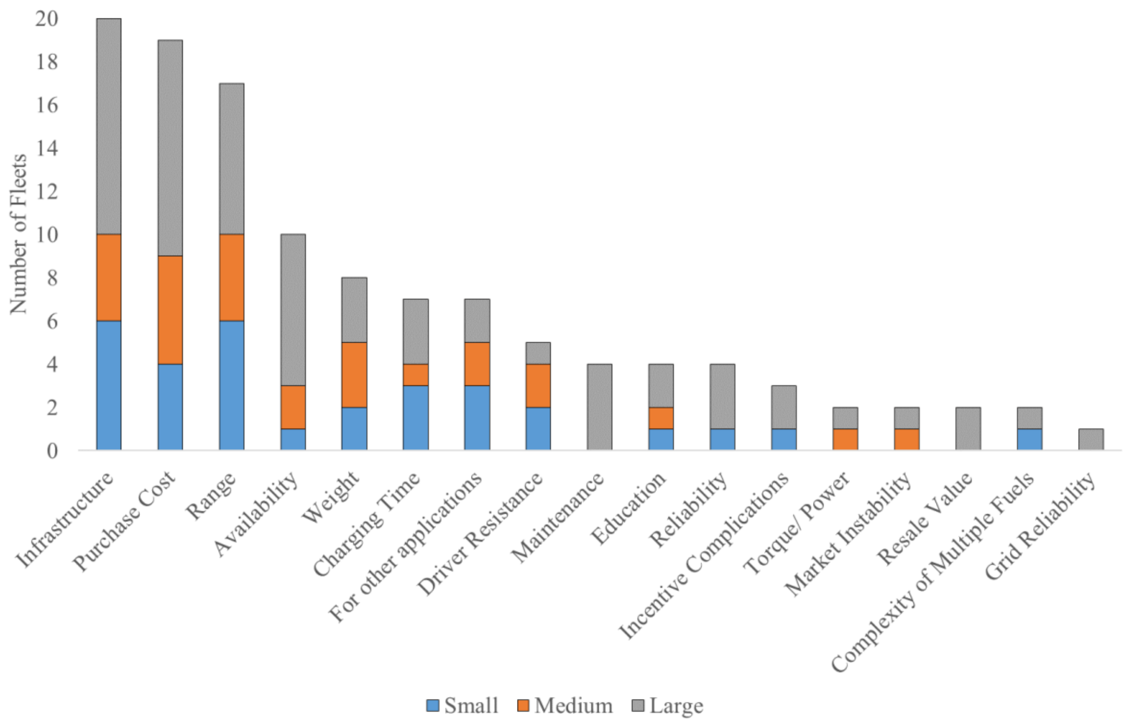
	Fleet Interview Number																												Category Totals						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	T	TE	E	ST	SE	S	Total
Infrastructure	T	T		TE	TE	T	T			TE			T	T	TE		TE		T	TE	T		T	T	T	TE	T	T	13	7	0	0	0	0	20
Purchase Cost		E	E	SE	TE	E	E		E	E	E	E	E	E		SE				SE		E	E			E	E	E	0	1	15	0	3	0	19
Range	T	TE	T	TE	TE		TE		T	T		T		T							T	T	T	T	T	T		T	13	4	0	0	0	0	17
Availability						T	T					T		T	T		T						T			TE	TE	TE	7	3	0	0	0	0	10
Weight				TE	TE			T	T	T	T									TE	TE								4	4	0	0	0	0	8
Charging Time					TE									T				TE	ST	TE			TE		T				4	2	0	1	0	0	7
For other applications		ST	ST	ST											ST				ST					S	ST				0	0	0	6	0	1	7
Driver Resistance		S														SE				SE				S		S			0	0	0	0	2	3	5
Maintenance					TE	TE		ST																	ST				0	2	0	2	0	0	4
Education	S																S							ST		S			0	0	0	1	0	3	4
Reliability		ST	TE			T																					T		2	1	0	1	0	0	4
Incentive Complications										SE			SE				E												0	0	1	0	2	0	3
Torque/ Power			TE						T																				1	1	0	0	0	0	2
Market Instability											SE				SE														0	0	0	0	2	0	2
Resale Value														E													E		0	0	2	0	0	0	2
Complexity of Multiple Fuels		ST																								S			0	0	0	1	0	1	2
Grid Reliability							T																						1	0	0	0	0	0	1
																													45	25	18	12	9	8	

Legend	
T	Interviewee discussion was classified as a technological barrier only
E	Interviewee discussion was classified as an economic barrier only
S	Interviewee discussion was classified as a social barrier only
TE	Interviewee discussion was classified as a technological and economic (techno-economic) barrier
ST	Interviewee discussion was classified as a social and technological (socio-technological) barrier
SE	Interviewee discussion was classified as a social and economic (socio-economic) barrier

Appendix 6: Reported barriers to fleet adoption of electric trucks by fleet application. (n drayage= 8, n short-haul= 14, n long-haul= 16)



Appendix 7: Reported barriers to fleet adoption of electric trucks by fleet size. (n total=28, n small=8, n medium=7, n large=13)



Appendix 8: Overview of fleet demographics and summary of results

Fleet #	Internal Structure	External Heterogeneity	Fleet Size*	Application			Truck Acquisition Type	Purchase Condition	Operating Model	Alt. Fuel Truck Experience			Ownership Model	Headquarter Location	Operating Region
				Short- haul	Long- haul	Drayage				Natural Gas	Fuel Cell	Electric			
18	Democratic	Mid	M	Yes	No	Yes	Purchase	New	For-hire	No	No	No	Centrally -owned	HI	Western US
24*	Democratic	Mid	L	Yes	Yes	No	Purchase	New	Dedicated	No	No	No	Centrally -owned	GA	National; Canada
10	Democratic	High	S	No	No	Yes	Mixed	Mixed	For-hire	No	No	No	Mixed	CA	Northern CA
09*	Democratic	High	M	No	No	Yes	Purchase	New	For-hire	Yes	No	Previous	Centrally -owned	CA	Southern CA
04	Democratic	High	M	No	Yes	No	Mixed	New	For-hire	No	No	No	Mixed	CA	Western US
06	Democratic	High	L	No	Yes	No	Mixed	New	For-hire	Yes	No	Previous	Centrally -owned	TX	National; Canada
22	Autocratic	Low	S	No	Yes	No	Purchase	New	For-hire	No	No	No	Driver-owner	TX	National
21	Autocratic	Low	S	No	Yes	No	Lease	New	For-hire	No	No	No	Driver-owner	Unknown	National
17	Autocratic	Low	S	No	Yes	No	Purchase	Mixed	For-hire	No	No	No	Driver-owner	CO	National
02	Autocratic	Low	S	No	Yes	No	Purchase	Mixed	For-hire	No	No	No	Driver-owner	SD	National
23*	Autocratic	Low	L	No	Yes	No	Purchase	New	For-hire	No	No	No	Mixed	MO	National
01	Autocratic	Low	M	Yes	Yes	No	Mixed	New	For-hire	No	No	No	Centrally -owned	OH	National
12	Autocratic	Mid	M	Yes	No	Yes	Mixed	Mixed	For-hire	No	No	No	Mixed	CA	Southern CA

Fleet #	Internal Structure	External Heterogeneity	Fleet Size*	Application			Truck Acquisition Type	Purchase Condition	Operating Model	Alt. Fuel Truck Experience			Ownership Model	Headquarter Location	Operating Region
				Short- haul	Long- haul	Drayage				Natural Gas	Fuel Cell	Electric			
20	Autocratic	Mid	S	No	Yes	No	Purchase	Used	For-hire	No	No	No	Driver-owner	?	National
19	Autocratic	Mid	S	No	Yes	No	Purchase	New	For-hire	No	No	No	Driver-owner	IL	National
16	Autocratic	Mid	S	No	No	Yes	Mixed	Mixed	For-hire	No	No	No	Centrally-owned	CA	Southern CA
14*	Autocratic	Mid	M	Yes	No	No	Mixed	New	For-hire	No	No	No	Centrally-owned	Canada	National; North America
15	Bureaucratic	Mid	L	Yes	No	No	Mixed	New	Dedicated	Yes	No	No	Centrally-owned	CA	Southern CA
03	Bureaucratic	Mid	L	Yes	Yes	No	Mixed	New	Dedicated	No	No	Yes	Centrally-owned	AR	National
25*	Bureaucratic	Mid	L	Yes	No	No	Mixed	New	Parcel	Yes	Yes	Yes	Mixed	FL	National; North and Central America
08	Bureaucratic	High	L	Yes	Yes	No	Mixed	New	Dedicated	Yes	No	No	Centrally-owned	PA	National
07	Bureaucratic	High	L	Yes	No	No	Purchase	New	Dedicated	Yes	Yes	Yes	Centrally-owned	CA	Northern CA
05	Bureaucratic	High	L	Yes	Yes	Yes	Mixed	New	For-hire	Yes	Yes	Yes	Centrally-owned	CA	National
13*	Bureaucratic	High	L	Yes	No	No	Purchase	New	Dedicated	Yes	Yes	No	Centrally-owned	CA	Northern CA
11*	Hierarchic	High	L	Yes	No	No	Purchase	New	Dedicated	No	No	Previous	Centrally-owned	CA	Southern CA

*S (Small); M (Medium), L (Large)

Appendix 9: Supplemental Case Studies

Case studies describing each fleet type which was not presented in the Results section of the paper are presented below. Each case study describes the decision-making network and process for a single fleet. Case studies are presented beginning with democratic organizations, then autocratic, bureaucratic, and hierarchical organizations. Within these sections, case studies are presented from low to high levels of heterogeneity, as outlined below.

Fleet 09: Democratic, High Heterogeneity

Fleet 14: Autocratic, Mid Heterogeneity

Fleet 15: Bureaucratic, Low Heterogeneity

Fleet 13: Bureaucratic, High Heterogeneity

Fleet 11: Hierarchic, High Heterogeneity

Fleet 09: Democratic, High Heterogeneity

Overview

- **Ownership model:** Centrally-owned
- **Fleet size:** Medium
- **Vehicle class(es):** Class 8
- **Application(s):** Drayage
- **Acquisition type(s):** Purchase and Lease
- **Truck acquisition condition(s):** New
- **Electric truck experience:** Previously

Fleet 09 operates drayage services in and out of the Ports of Los Angeles and Long Beach hauling dry goods and liquid chemicals. As shown in Figure A, decisions in Fleet 09 are made by several internal actors who are not guided by formal written rules are policies, giving the company a democratic decision-making structure. While the company's CEO (Interviewee 09) is the ultimate decision-maker, he is strongly influenced by input from the company's drivers and in-house mechanic. The mechanic informs Interviewee 09 about which trucks incur the highest maintenance costs, so those trucks can be retired from the fleet and avoided in future acquisitions. Given driver preferences for new vehicles with the latest technology, Interviewee 09 turns vehicles over every 10 years. Interviewee 09 believes this helps with driver recruitment and retention, which puts the drivers in a better mood when interacting with clients, thus strengthening customer relationships. He notes that purchasing trucks based on driver preferences is a "*high determining factor.*"

Interviewee 09 is additionally influenced by external actors, including state agencies, port authorities, the federal government, manufacturers, fleet associations, other fleets, and maintenance vendors. The large number of external actors involved gives Fleet 09 high network heterogeneity. A primary acquisition consideration is regulations set by the State of California and the Ports of Los Angeles and Long Beach. Interviewee 09 states that upcoming requirements for purchasing trucks with zero- and near-zero-emission engines have prevented the fleet from acquiring vehicles the last three years. This time has been spent applying for grants. On the federal side, Interviewee 09 reports retiring trucks when they reach around 250,000 miles to avoid damaging their compliance, safety, accountability (CSA) score, regulated by the US Department of Transportation.

Interviewee 09's acquisition decisions were heavily influenced by advancements in technologies offered by manufacturers. The interviewee recalled a time when Fleet 09 was acquiring primarily Volvo trucks until Freightliner came out with a new line of safety technologies, which caused him to switch to Freightliner trucks. Later, when International came out with a new emissions reduction technology, the Interviewee switched to International. Interviewee 09 reported learning about these technological developments from the other fleets, fleet associations, and dealership salespeople and managers. Interviewee 09 is involved in the Harbor Truck Association and the California Trucking Association, which helps him learn from larger fleets about *"what was done right and what was done wrong because even though they're your competitors, you're still friends."*

Of the seven external actors involved in Fleet 09's general acquisition decisions, just three are involved in the electric truck acquisition decisions: port authorities, state agencies, and manufacturers. While Fleet 09 previously participated in a demonstration program with a truck manufacturer, they no longer operate these trucks because the drivers felt unsafe with the high amount of torque the truck had, which caused the weight of the cargo to shift while accelerating and decelerating. Despite the interviewee's experience with electric trucks, Interviewee 09's electric truck acquisition considerations were simpler than the general truck acquisition considerations. Additional barriers such as high acquisition cost and limited infrastructure prevented Fleet 09 from acquiring any electric trucks, leading Interviewee 09 to report regulations are, *"the only thing that's going to move the needle… until we're regulated to do so, we're not going to."*

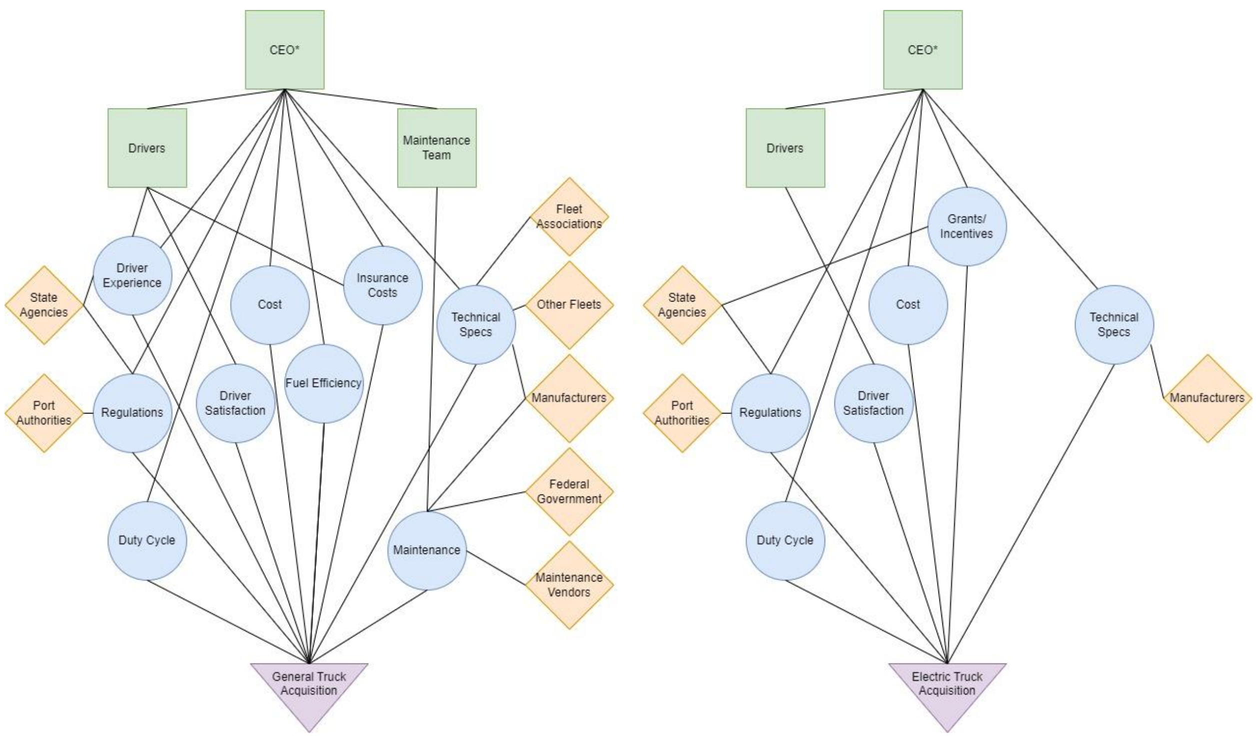


Figure A: Diagrams representing Fleet 09's general (left) and electric (right) truck acquisition considerations

Fleet 14: Autocratic, Mid Heterogeneity

Overview

- **Ownership model:** Centrally-owned
- **Fleet size:** Medium
- **Vehicle class(es):** Class 8
- **Application(s):** Short-haul
- **Acquisition type(s):** Purchase and lease
- **Truck acquisition condition(s):** New
- **Electric truck experience:** None

Fleet 14 is an intermodal freight carrier, moving goods over long distances via rail and using hub-based trucks for regional deliveries. The company has hubs in Chicago, Los Angeles, and multiple Canadian provinces. Figure B shows Fleet 14 has an autocratic decision-making style with all acquisition decisions made by Interviewee 14, the company president. Interviewee 14's decisions are strongly influenced by employee-drivers because, "*in today's day and age, you have to get quality equipment if you want to get quality drivers*." Drivers were reported as preferring comfortable and reliable equipment: "*nothing gets the driver upset as his equipment always breaking down. They hate that*." Driver recruitment and retention led Interviewee 14 to exclusively acquire new trucks.

Under typical conditions, Interviewee 14s purchase decisions are influenced by state governments, rail yards, manufacturers, and dealers, characterizing Fleet 14 as mid-level heterogenous. Regulations set by the state of California and the rail yards have a strong influence on the type of trucks the fleet could operate. Interviewee 14 felt he was, "*really not in a position to dictate, it's really dictated to us what we're required to continue to operate*." Acquiring new trucks and retiring them within 5 to 6 years lessens the strain of regulations; keeping the fleet younger makes compliance easier. Interviewee 14 relies on manufacturers and dealerships to stay up to date on regulations, new technologies, and incentives. Each year, Interviewee 14 and the dealership discuss these points and create an acquisition plan. This takes the pressure off Interviewee 14 to keep up with regulatory changes, "*because the manufacturers are going to be on top of it. That's their role, and if they're not on top of it, they're going to be out of business*."

Interviewee 14's decision making network for electric trucks is simpler than their general acquisition considerations, with all actors and factors considered in general truck acquisitions replaced by other actors and factors. When considering whether to acquire an electric truck, Interviewee 14 focuses on maintaining their relationship with customers and no longer considers their relationships with dealerships, manufacturers, rail yards, or state governments. This lower level of consideration is due to lack of infrastructure, lack of electric truck availability, and other technological constraints, which the interviewee felt prevented them from further considering electric truck acquisitions. While acknowledging that electric trucks could work in some applications, Interviewee 14 felt electrification would still not work for their company's application because their customers currently only allow Fleet 14's trucks to deliver loads between 8am and 4pm. The limited availability of public charging infrastructure led Interviewee 14 to report trucks would need to detour 50-70 miles out of the way to find charging, perpetuating concerns about meeting delivery windows. Interviewee 14 did not report that he would be able to plan out charging schedules ahead of time because their routes vary significantly based on customer demands. Without advanced planning, charging would need to occur during driving shifts. This led Interviewee 14 to report they would only consider acquiring an electric truck *"if necessary."*

"*When you're a regional carrier, you don't have time to go shopping for fuel, you got to pump and go because a lot of the warehousing and distribution centers are not open 24 hours a day… if [the driver] can't deliver or pick up because the manufacturer is shut down… what's the point?*"

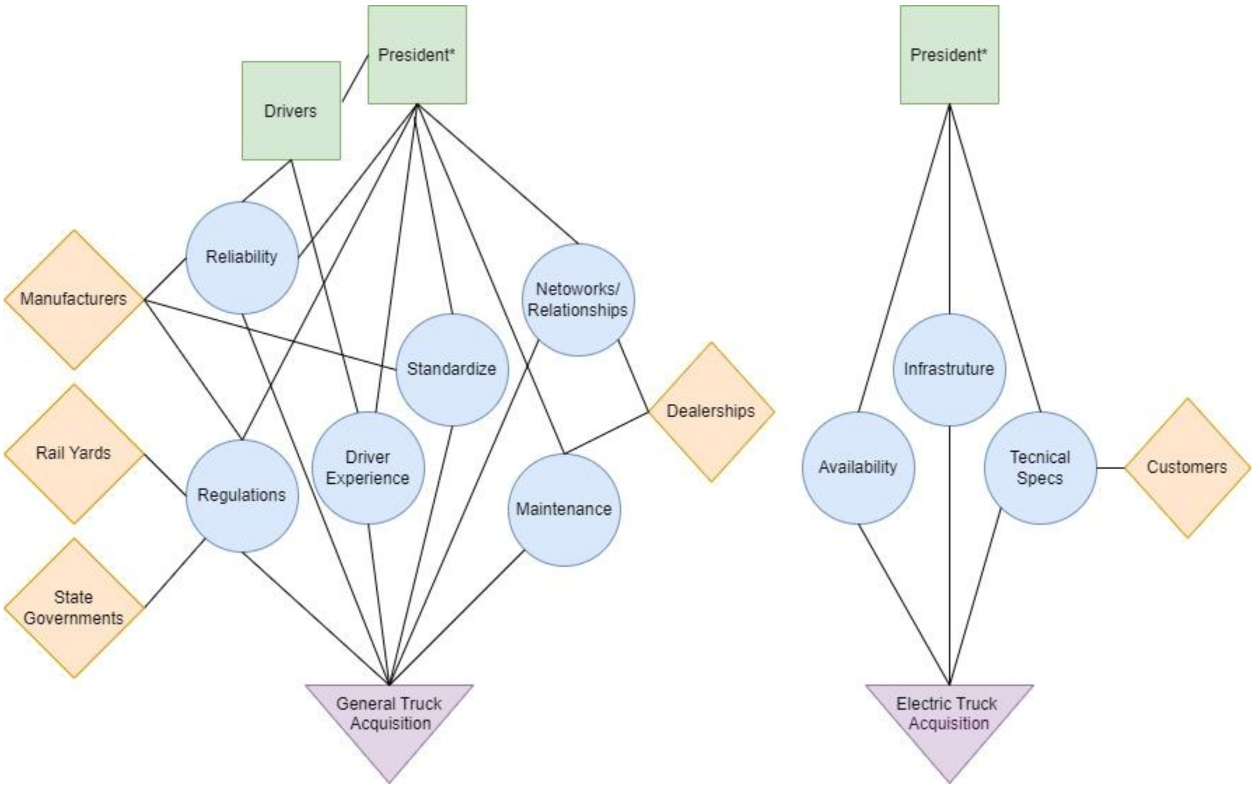


Figure B: Diagrams representing Fleet 14's general (left) and electric (right) truck acquisition considerations

Fleet 15: Bureaucratic, Mid Heterogeneity

Overview

- **Ownership model:** Centrally-owned
- **Fleet size:** Large
- **Vehicle class(es):** Class 2b-8
- **Application(s):** Short-haul
- **Acquisition type(s):** Purchase and lease
- **Truck acquisition condition(s):** New
- **Electric truck experience:** None

Fleet 15 is a dedicated fleet moving goods owned by Organization 15 between locations owned by Organization 15. The organization is bureaucratic, involving many individuals (i.e., decentralized) in their formalized decision-making process. Interviewee 15 is a manager in the company, coordinating vehicle acquisitions and maintenance. As shown in Figure C, Interviewee 15 manages the acquisition and specification process, acting as a mediator between the needs of the end users (departments), the finance team, and the environmental team. Once the truck specifications are developed, the interviewee sends them to the finance team for review and subsequently sends them to the company's leadership team for final approval. Company policies require Interviewee 15 to involve these internal actors in the acquisition process and restrict the acquisition of diesel trucks.

Fleet 15's vehicle acquisition process shows mid external network heterogeneity, involving three external actors: dealers, state agencies, and local governments. Interviewee 15 manages the fleet's relationships with dealers, selecting preferred dealers based on criteria such as communication, order completion, price competitiveness, etc. Interviewee 15 reported being limited in their ability to acquire diesel trucks due to regulations set by the California Air Resources Board and the city government, leading them to acquire four CNG trucks. Fleet 15's Environmental Team is tasked with ensuring compliance with these regulations, with Interviewee 15 needing their approval for any diesel truck acquisitions.

With electric truck acquisitions, Fleet 15 adds more actors to its external network. They continue to involve dealers, state agencies, and local governments while adding utilities and manufacturers. Fleet 15's goal is to convert their fleet entirely to electric vehicles. This goal was developed in part due to the California Air Resources Board's announcement that medium- and heavy-duty fleets must begin acquiring electric trucks. Interviewee 15 is now looking to state programs, such as HVIP, as a source of funding to offset the higher costs of electric trucks. Interviewee 15 looks to the dealers and manufacturers to provide information on electric trucks. He recalled asking the dealership if electric or CNG options were available for one of their forklifts, with the salesperson replying that Fleet 15 should not consider converting it to electric because there was no infrastructure available to charge it. This caused Fleet 15 to delay consideration of electric trucks until the California Air Resources Board regulations requiring electric truck acquisitions were announced. Interviewee 15 has begun talking with their local utility company about installing charging infrastructure.

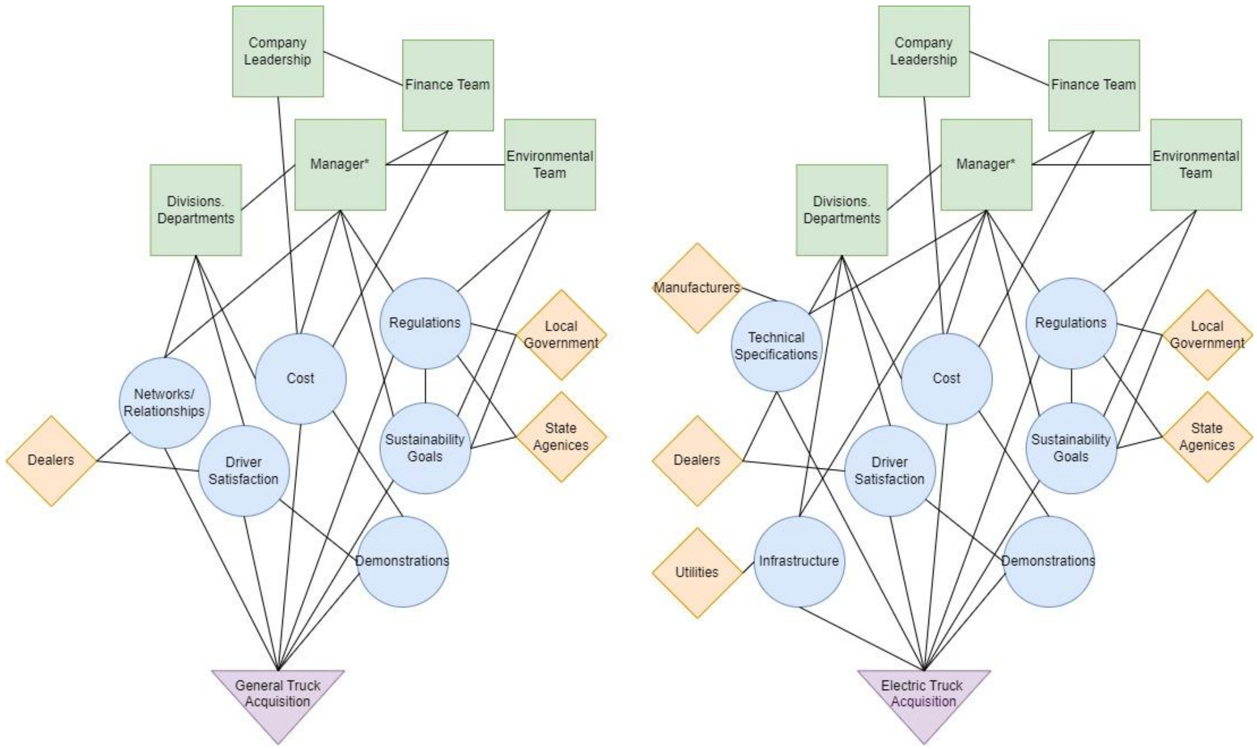


Figure C: Diagrams representing Fleet 15's general (left) and electric (right) truck acquisition considerations

Fleet 13: Bureaucratic, High Heterogeneity
Overview

- **Ownership model:** Centrally-owned
- **Fleet size:** Large
- **Vehicle class(es):** Class 2b-8
- **Application(s):** Vocational
- **Acquisition type(s):** Purchase
- **Truck acquisition condition(s):** New
- **Electric truck experience:** None (current experience with electric LDVs)

Fleet 13 is a municipal organization operating vehicles such as pickup trucks, tow trucks, buses, box trucks, cargo vans, and dump trucks out of multiple fleet yards. The acquisition decision team for Fleet 13, shown in Figure D, is made up of Interviewee 13, Interviewee 13's supervisor, the light-duty fleet manager, the heavy-duty fleet manager, and department leads. This group writes specifications for each truck before sending orders to the purchasing department to initiate the transaction. The purchasing department seeks bids on each truck order and sends them back to decision-making team to evaluate and choose which vehicle to acquire. Generally, all members of the decision-making team must reach an agreement about which vehicles to acquire, although Interviewee 13 and his supervisor are able to override other internal actor's decisions if they deem necessary. Fleet 13 has a high level of formalization due to requirements to reduce emissions and for decision-makers to participate in a formal bid process. The organization is also decentralized due to the high number of individuals participating in the decision-making process. Low centralization and high formalization give Fleet 13 a bureaucratic structure.

Fleet 13 is characterized as high-level heterogeneous, involving six external actors in their purchase process: dealers, manufacturers, state agencies, liquid fuel providers, fleet associations, and other fleets. While Fleet 13 is required purchase vehicles that have gone through a competitive bid process, they are allowed to piggyback off competitive bids that have been acquired by other municipal fleets. This gives other fleets the opportunity to influence Fleet 13's purchase decisions. Interviewee 13 reported sharing information about bid contracts available for piggybacking through fleet associations such as the Municipal Equipment Maintenance Association (MEMA) and the National Association of Fleet Administers (NAFA).

To stay up to date on new vehicle technologies and regulations, Interviewee 13 relies on fleet associations, trade shows, industry publications, dealers, and manufacturers he has close relationships with. Interviewee 13 states *"regulations drive a lot of what we do and cause us to go out and seek solutions where maybe we may not be aware of one."*

Fleet 13 has strong sustainability goals which are incorporated into their general purchasing process. They have begun switching many of their heavy-duty vehicles to CNG and liquefied natural gas (LNG). When LNG was first incorporated, trucks from all of Fleet 13's yards would need to come to a central location to refuel every day. Interviewee 13 recalled being unable to acquire any additional CNG or LNG trucks until the organization was able to procure contracts to install additional fueling stations at other sites.

For electric purchase decisions, Fleet 13 involves four of the same external actors (dealers, manufacturers, state agencies, and fleet associations) involved in general purchase decisions, but now deals with utilities and landowners rather than liquid fuel providers and other fleets. As a part of the MEMA group, Interviewee 13 regularly meets with representatives from the California Air Resources Board to provide feedback on regulations, including those for truck and equipment electrification. While Interviewee 13 has utilized grants on some previous purchases, he reports issues with manufacturers not being able to deliver vehicles within timelines set by these programs. Whether the company can utilize these incentive programs is often, "*the deciding factor whether we go that direction or not.*"

While Fleet 13 has not yet acquired electric medium- or heavy-duty vehicles, they have experience with electric LDVs. Interviewee 13's supervisor worked extensively with their electric utility company to install charging infrastructure at their facilities, with Interviewee 13 noting a similar process would need to occur to support their electrification of their medium- and heavy-duty vehicles. Infrastructure installations were also reported to be difficult at some locations because the land was leased to the organization. Interviewee 13 reported that installing charging infrastructure on leased land was more difficult than on land they owned, but thought it was possible.

Fleet 13's general and electric truck acquisition decisions involve the same number of external actors, although significantly fewer internal actors and factors are involved.

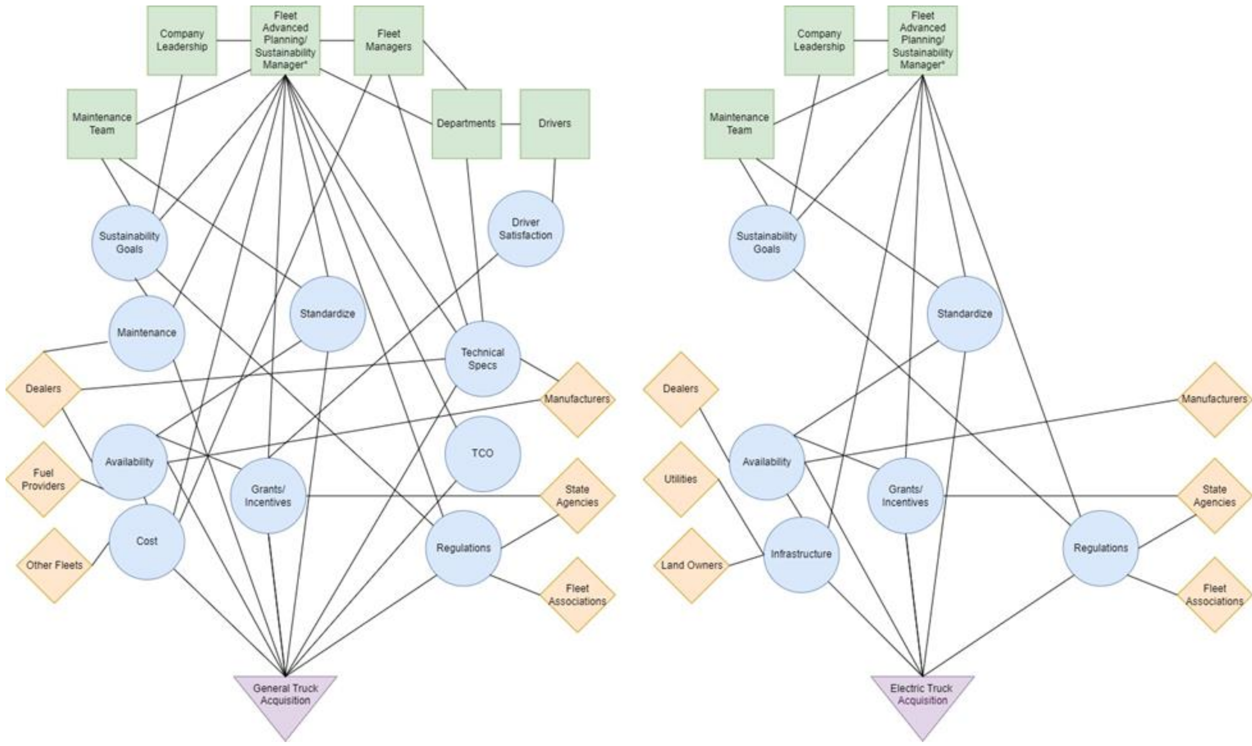


Figure D: Diagrams representing Fleet 13's typical (left) and electric (right) truck acquisition considerations

Fleet 11: Hierarchic, High Heterogeneity

Overview

- **Ownership model:** Centrally-owned
- **Fleet size:** Large
- **Vehicle class(es):** Class 2b-8
- **Application(s):** Vocational
- **Acquisition type(s):** Purchase
- **Truck acquisition condition(s):** New
- **Electric truck experience:** Previously (current experience with electric LDVs)

Fleet 11 is a municipal organization which operates police cruisers, street sweepers, refuse vehicles, pickup trucks, and administrative sedans, among others. The organization's acquisition decisions are shown in Figure E. The primary decision-maker in Fleet 11's hierarchic decision-making structure is the Fleet Manager (Interviewee 11). His decisions are influenced by the city government's vehicle acquisition and sustainability policies. The vehicle acquisition policy requires Interviewee 11 to acquire vehicles with the lowest TCO while the sustainability policies require the acquisition of alternative fuel vehicles where possible. The balance between achieving the lowest TCO and acquiring alternative fuel vehicles is informed by an external consultant. The consultant helps Fleet 11 calculate the TCO for conventional and alternative fuel vehicles and compares them based on how frequently the vehicles are used and whether grants are available. These comparisons inform Interviewee 11's decisions.

In addition to the consultant, Interviewee 11 involves local governments, fleet associations, state agencies, maintenance vendors, and other fleets in their acquisition decisions. Fleet 11 has their own internal sustainability goals which are, "*derived from partly CARB's [the California Air Resources Board's] regulations"* and led them to begin purchasing natural gas trucks 15 years ago. As a part of these regulations, Fleet 11 has CNG and LNG trucks, which Interviewee 11 reported sending to maintenance vendors at the dealership. These vehicles were reported to have significantly higher maintenance issues than diesel trucks, which was a strong factor in deciding whether to continue purchasing CNG trucks and which trucks to purchase.

Interviewee 11 is connected with other fleets through the MEMA group, which helps him stay informed about upcoming regulations affecting the fleet's purchases. In particular, the South Coast Air Quality Management District restricts Fleet 11's ability to use diesel trucks, furthering Interviewee 11's emphasis on purchasing alternative fuel vehicles. The interviewee notes that while the TCO informs their general acquisition decisions, in cases where regulations require them to use alternative fuel vehicles, it *"doesn't matter what it costs… it's a fairly easy decisions, ROI [return on investment] be damned.*"

Fleet 11 previously had electric trucks and their general and electric truck social networks have the same level of external network heterogeneity. Interviewee 11 continues to engage with local governments, fleet associations, state agencies, and other fleets. Electric utilities and manufacturers are now involved while consultants and maintenance vendors are no longer consulted. Alternative fuel vehicle regulations set by state agencies (particularly the ACT rule), the air quality management district, and internal to Fleet 11 are essential in Interviewee 11's decisions to consider electric trucks. Fleet 11 previously participated in demonstration projects for medium- and heavy-duty trucks. Interviewee 11 recalled relying heavily on the MEMA group for information and support for these demonstration projects. Through this association, fleets can connect with one another to share expertise and research with one another, which Interviewee

11 recalls as being highly important, especially for smaller fleets who lack time and resources to conduct their own research.

In addition to these traditionally involved actors, Fleet 11 now works with their electric utility, Southern California Edison, to install charging infrastructure in anticipation of future needs. Interviewee 11 notes the importance of involving the utilities in infrastructure development because, *"we're fleet people, we're not engineers, we don't install charging stations, that's not our lane so to speak… it really takes some close coordination*." Finally, Interviewee 11 noted there are very few electric trucks currently available. When they were purchasing electric LDVs, the fleet had to purchase Chevrolet Bolts and Nissan Leafs because no electric vehicles were offered by Ford, their preferred manufacturer. Interviewee 11 noted similar restrictions on the availability of electric medium- and heavy-duty vehicles.

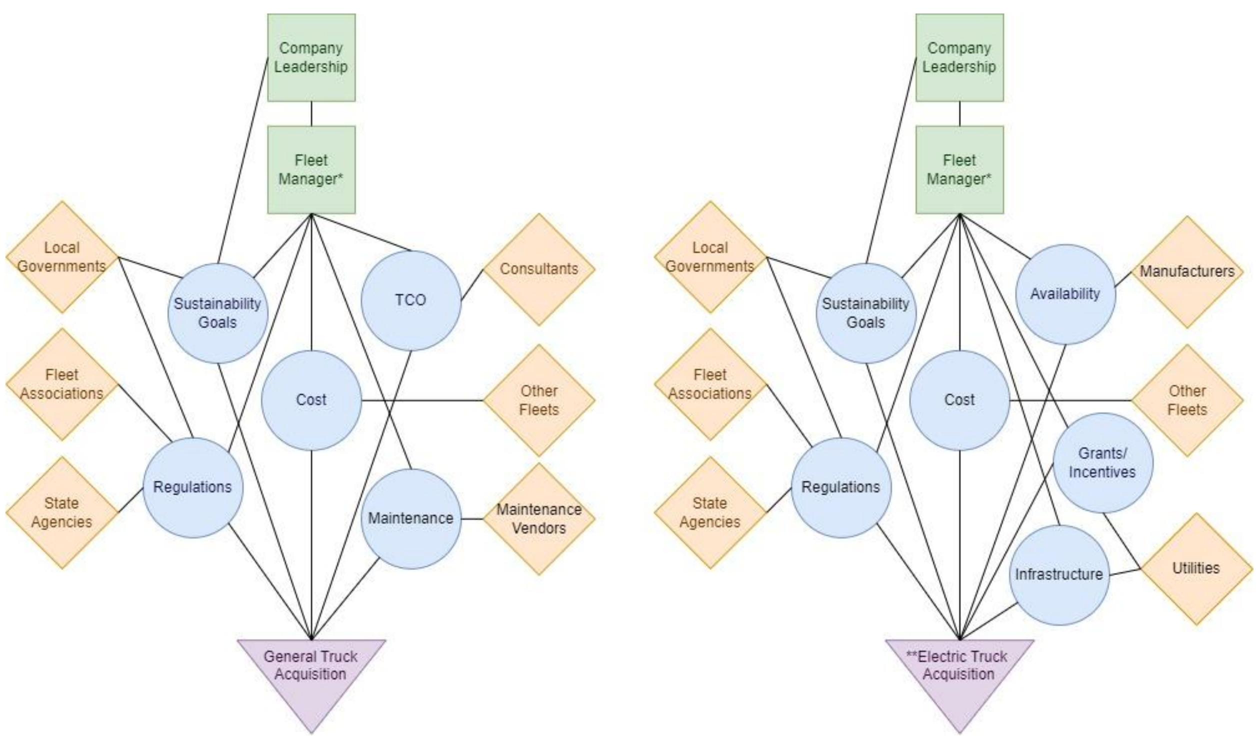


Figure E: Diagrams representing Fleet 11's general (left) and electric (right) truck acquisition considerations

Appendix 10: Factor definitions

Factor	Definition
Availability	Truck purchase is limited by what is offered by a manufacturer in certain areas or over a certain timeframe
Battery Viability	Ability of batteries to last the expected lifetime of the truck
Collisions	Truck collisions resulting in damage to the vehicle
Company Policies	Any policy set by the company in which the fleet resides that impacts the purchase decision or decision-making process
Cost	Upfront or operational costs associated with the truck
Demand	Relative interest in truck acquisitions by the industry at a given time
Demonstrations	Temporary use of a truck for testing purposes; funded by an organization or agency outside the fleet
Driver Availability	Ability of the fleet to recruit and retain drivers
Driver Experience	Knowledge and opinions drivers have gained through operating a truck
Driver Satisfaction	Any consideration involving the company driver’s opinions or preferences; including safety, comfort, privacy, etc.
Duty Cycle	The operational needs of the truck including range, daily downtime, and power requirements
Emissions	Preferences for purchasing trucks with fewer tailpipe emissions
Financing	Ability of the fleet to obtain financing for selected vehicles or through selected companies
Fuel Availability	Availability of a certain fuel type in areas the fleet operates
Fuel Efficiency	Fuel consumed by the truck per distance driven
Grants/ Incentives	Any financial assistance available for acquiring or using vehicles or infrastructure
History	Vehicle purchasing based on the decision-maker's history with a certain vehicle type or manufacturer
Infrastructure	Any factor related to the availability or unavailability of charging or fueling infrastructure
Insurance Costs	Cost of insuring a truck
Lease Terms	Any condition included in the lease contract; including lease length, costs, etc.
Maintenance	Including maintenance time and costs; regularly scheduled and breakdowns
Market Conditions	Price of acquiring and selling trucks at a given time
Networks/ Relationships	The decision-maker's past experience with a specific company (e.g. manufacturer, dealer, maintenance provider, etc.)
Personal Experience	Vehicle purchases are made based on the decision-maker's experience with a vehicle rather than a specific metric
Regulations	Current or future regulations; includes regulations on truck purchase, weight limits, idle limits, etc.

Reliability	Avoiding regular and unexpected maintenance for the truck
Risk	Minimizing financial or legal risk to the company
Resale Value	The price of the vehicle once it leaves the fleet
Safety	Safety features included on the truck
Standardize	Keeping features similar amongst trucks (e.g. same brand, same features, etc.)
Sustainability Goals	Sustainability goals set by the fleet or organization
TCO	Explicit mention of total cost of ownership use
Technical Specs	Technological components of the truck including its weight, range, transmission system, etc.
Technology Advancement	Advancements in technology in trucks over time
Warranty	Standard or extended warranties offered by the truck provider

Appendix 11: Overview of actor involvement in general and electric truck acquisitions

Fleet Number	Internal Decision-making Structure*	External Network Heterogeneity	General Truck Acquisition	Electric Truck Acquisition	Comparison	Electric Truck Experience
22	Autocratic	Low	Manufacturers		Omitted	None
			Other fleets		Omitted	
21	Autocratic	Low	Leasing companies		Omitted	None
			Manufacturers		Omitted	
17	Autocratic	Low	Manufacturers		Omitted	None
			Other fleets		Omitted	
02	Autocratic	Low	Dealerships		Omitted	None
			Manufacturers	Manufacturers	Static	
23*	Autocratic	Low	Dealers		Omitted	None
			Drivers		Omitted	
			Manufacturers		Omitted	
01	Autocratic	Low	Federal governments		Omitted	None
			Manufacturers		Omitted	
				Utilities	Added	
12	Autocratic	Low	Consultants		Omitted	None
				Customers	Added	
			Leasing companies	Leasing companies	Static	
				Manufacturers	Added	
			State agencies		Omitted	
20	Autocratic	Mid	Dealers		Omitted	None
			Manufacturers		Omitted	
			Other fleets		Omitted	
			State agencies		Omitted	
19	Autocratic	Mid	Banks		Omitted	None
			Dealers		Omitted	
			Maintenance vendors		Omitted	
			Manufacturers		Omitted	
			State agencies		Omitted	
16	Autocratic	Mid	Dealers		Omitted	None
			Manufacturers		Omitted	
			Other fleets	Other fleets	Dynamic	
			Port authorities		Omitted	
			State agencies		Omitted	
14*	Autocratic	Mid		Customers	Added	None
			Dealers		Omitted	
			Manufacturers		Omitted	

			Rail yards		Omitted	
			State agencies		Omitted	
18	Democratic	Mid	Manufacturers	Manufacturers	Static	None
			Port authorities	Port authorities	Dynamic	
			State agencies	State agencies	Dynamic	
				Utilities	Added	
24*	Democratic	Mid	Dealers		Omitted	None
			FASB		Omitted	
				Federal governments	Added	
			Fleet management companies	Fleet management companies	Dynamic	
			Manufacturers	Manufacturers	Dynamic	
10	Democratic	Mid		Federal governments	Added	None
			Leasing companies		Omitted	
				Local governments	Added	
				Manufacturers	Added	
			Other fleets		Omitted	
			Port authorities	Port authorities	Static	
			State agencies	State agencies	Dynamic	
				Utilities	Added	
09*	Democratic	Mid	Federal government		Omitted	Previous
			Fleet associations		Omitted	
			Maintenance vendors		Omitted	
			Manufacturers	Manufacturers	Static	
			Other fleets		Omitted	
			Port authorities	Port authorities	Static	
			State agencies	State agencies	Static	
04	Democratic	Mid	Consultants		Omitted	None
			Customers	Customers	Static	
			Dealers		Omitted	
			Fleet associations	Fleet associations	Static	
			Manufacturers	Manufacturers	Static	
			Other fleets	Other fleets	Static	
			State agencies	State agencies	Static	
06	Democratic	Mid		Consultants	Added	Previous
			Dealers		Omitted	
			FASB		Omitted	
			Federal government		Omitted	
			Leasing companies	Leasing companies	Dynamic	
			Maintenance vendors		Omitted	

			Manufacturers	Manufacturers	Dynamic	
			State agencies	State agencies	Static	
15	Bureaucratic	Low	Dealers	Dealers	Static	None
			Local governments	Local governments	Static	
				Manufacturers	Added	
			State agencies	State agencies	Dynamic	
				Utilities	Added	
07	Bureaucratic	Low		Banks	Added	Current
			Consultants	Consultants	Static	
				Local governments	Added	
				Manufacturers	Added	
				Other fleets	Added	
				State agencies	Added	
				Utilities	Added	
03	Bureaucratic	Mid		Fleet associations	Added	Current
				Manufacturers	Added	
				Other fleets	Added	
				State agencies	Added	
				Utilities	Added	
25*	Bureaucratic	Mid	Banks	Banks	Static	Current
			Fleet management companies	Fleet management companies	Dynamic	
			Manufacturers	Manufacturers	Dynamic	
			State agencies	State agencies	Static	
08	Bureaucratic	Mid	Consultants	Consultants	Static	None
			Customers		Omitted	
			Federal government	Federal government	Static	
			Fleet associations		Omitted	
			Manufacturers	Manufacturers	Static	
				State agencies	Added	
05	Bureaucratic	High	Dealers		Omitted	Current
				Local governments	Added	
			Maintenance vendors		Omitted	
			Manufacturers	Manufacturers	Dynamic	
			Port authorities	Port authorities	Dynamic	
				State agencies	Added	
13*	Bureaucratic	High	Dealers	Dealers	Static	Previous (LDV experience)
			Fleet associations	Fleet associations	Static	
			Fuel providers		Omitted	
				Land owners	Added	
			Manufacturers	Manufacturers	Static	

			Other fleets		Omitted	
			State agencies	State agencies	Dynamic	
				Utilities	Added	
11*	Hierarchic	High	Consultants		Omitted	Previous (LDV experience)
			Fleet associations	Fleet associations	Static	
			Local governments	Local governments	Static	
			Maintenance vendors		Omitted	
				Manufacturers	Added	
			Other fleets	Other fleets	Static	
			State agencies	State agencies	Static	
				Utilities	Added	