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

Claire Sugihara[1,2], Scott Hardman[2], Kenneth Kurani[2]

[1] *Corresponding Author; ccsugihara@ucdavis.edu*

[2] *Electric Vehicle Research Center, Institute of Transportation Studies, University of California, Davis*

1605 Tilia Street, Davis CA, 95616, USA

Executive Summary

This study compares decisions to acquire fossil fuel-powered vehicles with decisions about or consideration of electric vehicles for fleets operating medium- and heavy-duty vehicles. Based on interviews with decision-makers in 25 such organizations, we characterize the organizations according to their internal decision-making structure (i.e., who within the organization takes part in decisions) and the heterogeneity of the external networks involved in those decisions. We examine whether internal structure and external heterogeneity impact an organization's decisions. This provides insights into whether some organization types are more willing and able to adapt to electric trucks, and which may require different types of support to consider electric vehicles. Identifying external actors identifies other groups that may may need to be engaged to facilitate truck electrification.

Keywords: BEV (battery electric vehicle), Fleet, Heavy-duty, Medium-duty, Freight transport

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 [1]. Diesel contributes 40% of on-road vehicle carbon emissions despite making up less than 10% of vehicles on the road [2]. Diesel-fueled vehicles emit substantial levels of particulate matter and NO_x, leading to higher rates of cancer, respiratory damages, and asthma [3]. Freight trucks frequently operate in and around dense urban areas and disadvantaged communities leading to adverse health effects in communities living in these areas [4]. 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 trucks have a gross vehicle weight rating between 8,501 and 26,000 lbs. (Class 2b-6) [5]. 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 [6]. 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% [7]. 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) [8].

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 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 [9]. 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 [10].

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 [11]. An organization's internal decision-making structure and external network heterogeneity have been shown to impact an organization's ability to innovate [12], [13].

Based on interviews with 25 fleet decision-makers across a wide variety of fleet size and purpose, we describe the social context of the truck acquisition decision-making within those organizations 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 are associated with differences in their interest and ability to acquire and operate electric trucks. The exploratory analysis describes the variety and complexity of truck acquisition decision-making.

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 truck acquisition decision making associated with the introduction of medium- and heavy-duty electric trucks. Analysis begins by establishing a baseline decision structure for conventionally fuelled trucks, then describes changes in the role or presence of actor types in that structure as those same organizations acquire or consider electric trucks. For example, electric trucks may necessitate the involvement of electric utility companies which were previously not involved in truck acquisitions. Other actor types 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.

While results may not be representative of the entire heavy-duty truck sector, they do help identify issues where interventions may be needed and useful and can inform future research. The results provide insights into which actor types are involved in the transition to electric trucks and what their role is. They reveal levels of control exercised by different actor types over conventional and electric truck acquisition decisions. The research may also help policymakers and truck manufacturers identify types of fleets that need greater levels of support to transition to electric trucks. 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.

2 Literature Review

2.1 Internal Organizational Structure

Organizational structure has been shown to play an important role in a company's decision-making and their ability to innovate and experiment with novel technologies [12], [14]. Two of the most commonly studied structural variables are formalization and centralization [15]. Formalization is the level to which formal rules, procedures, and guidelines dictate decision-making [12]. In a highly formalized organization, the role and responsibilities of individuals are well defined and codified, and the decision-making process is systemized. Formalization may be more common and more important in larger organizations than smaller ones [14]. High levels of formalization has also been found to inhibit organizational innovation [16].

Centralization is a measure of how decision-making authority is distributed within an organization [17]. In centralized organizations, decisions are made by a few people. Organizations with low levels of centralization involve many different individuals in decision-making [12]. Arad, Hanson and Schneider [12] relate an organization's centralization to it's 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, but their centralized decision-making authority makes organizations less likely to innovate [12].

As centralization and formalization increase, an organization's ability to innovate is reported to decrease [12], [15]. High levels of centralization and formalization restrict communication between individuals in the organization, lessening their ability to effectively contribute to decision-making [15], [17]. In contrast, organizations with less formalized and less centralized structures are better able to quickly adapt in dynamic environments [15]. Arad, Hanson, and Schneider [12] 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. We extend the study of organizational structure and propensity to innovate to the question of fleet operators acquiring electric trucks.

2.1.1 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 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 [18]. Decision-makers may be influenced by other internal actors, such as drivers, who care more about user experience [18], [19].

As shown in Table 1, Nesbitt and Sperling [11] used centralization and formalization to classify organizations operating fleets of light-duty vehicles (LDVs) 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 1: Typology used to categorize fleets in Nesbitt and Sperling [11]

		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 past practices. 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 by 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. 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 based on 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.

2.2 External Network Heterogeneity

Organizational decision-making is further influenced by actors external to the organization. Organizations have been found to modify their practices to meet expectations from external actors or market pressures [20].

Social networks allow for information to be exchanged, influencing attitudes around new technologies [21], [22]. 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 [22]. 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, products, 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 [23].

An important metric used in Social Network Analysis is heterogeneity, a measure of the diversity of actor types within 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 [13] 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 [12], innovation in organizations is also advanced when a large and diverse number of information sources are consulted.

2.2.1 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 [19]. 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. [24]. 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 [21], [25]. Higher levels of network connectivity are positively related to levels of innovation, meaning individuals with connections to a larger number of actor types are more likely to acquire alternative fuel vehicles earlier. This influence was found to be especially pronounced for first-time purchasers.

This study defines external network heterogeneity as the number of external actor types involved in the organization's overall decision-making process. This includes and individuals, groups, or organizations who influence the decision but are not employed by the organization.

3 Methods

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 interviewees were recruited via email, offered a $150 incentive, and asked to complete a pre-interview questionnaire to ensure they were involved in the truck acquisition process. Interviewees who 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. A summary of these organizations is presented in Table 2.

Table 2: Overview of organizational characteristics

Fleet #	Fleet Size[1]	Truck Classes[2]	Application[3]	Purchase or Lease	Purchase Condition	Operating Model	Electric Trucks[4]	Other Alt. Fuels	Headquartered in CA?	Operating Region
1	Medium	8	SH, LH	Mixed	New	For-hire	No	None	No	National
2	Small	8	LH	Purchase	Mixed	For-hire	No	None	No	National
3	Large	8	SH, LH	Mixed	New	Dedicated	Yes	None	No	National

4	Medium	8	LH	Mixed	New	For-hire	No	None	Yes	Western U.S.
5	Large	8	SH, LH, D	Mixed	New	For-hire	Yes	Natural gas, Fuel cell	Yes	National
6	Large	7, 8	LH	Mixed	New	For-hire	Previous	Natural gas	No	National; Canada
7	Large	2-8	SH	Purchase	New	Dedicated	Yes	Natural gas, Fuel cell	Yes	Northern CA
8	Large	2-4, 7, 8	SH, LH	Mixed	New	Dedicated	No	Natural gas	No	National
9	Medium	8	D	Purchase	New	For-hire	Previous	Natural gas	Yes	Southern CA
10	Small	8	D	Mixed	Mixed	For-hire	No	None	Yes	Northern CA
11	Large	2-8	SH	Purchase	New	Dedicated	Previous	None	Yes	Southern CA
12	Medium	2-8	SH, D	Mixed	Mixed	For-hire	No	None	Yes	Southern CA
13	Large	2-8	SH	Purchase	New	Dedicated	No	Natural gas, Fuel cell	Yes	Northern CA
14	Medium	8	SH	Mixed	New	For-hire	No	None	No	National; North America
15	Large	2-8	SH	Mixed	New	Dedicated	No	Natural gas	Yes	Southern CA
16	Small	8	D	Mixed	Mixed	For-hire	No	None	Yes	Southern CA
17	Small	8	LH	Purchase	Mixed	For-hire	No	None	No	National
18	Medium	4, 8	SH, D	Purchase	New	For-hire	No	None	No	Western U.S.
19	Small	8	LH	Purchase	New	For-hire	No	None	No	National
20	Small	8	LH	Purchase	Used	For-hire	No	None	No	National
21	Small	8	LH	Lease	New	For-hire	No	None	No	National
22	Small	8	LH	Purchase	New	For-hire	No	None	No	National
23	Large	8	LH	Purchase	New	For-hire	No	None	No	National
24	Large	2-4, 6, 8	SH, LH	Purchase	New	Dedicated	No	None	No	National; Canada
25	Large	4-8	SH	Mixed	New	Parcel	Yes	Natural gas, Fuel cell	No	National; North and Central America

[1]Small fleet are classified as having 1-20 trucks; medium fleet, 21-149 trucks; and, large fleets, 150 trucks or more.
[2]Classifications are 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 of 8,501 to 26,000 lbs. (Class 2b-6).
[3]Long-haul (LH) trucks are used in operations where drivers spend multiple nights per week away from home. Short-haul (SH) trucks are used in operations that do not meet the requirements for long-haul classification. Drayage (D) trucks are a subset of the short-haul application referring to trucks that provide pickup or delivery services to a seaport.
[4]Experience with electric trucks includes any operation of electric trucks by the organization including use via purchase, lease, or demonstration project.

3.2 Analysis

All interviews were conducted and recorded via Zoom by two interviewers. Transcripts were created and reviewed for accuracy by a member of the research team. Transcripts were uploaded to the qualitative analysis software program Dedoose, to code the transcripts. Transcripts were coded for thematic analysis following Gibbs [26] in a process to identify patterns, themes, and the "ideas that help explain why those patterns are there." In a first reading, codes for factors 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 actor types 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, 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 actor types 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. 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.

3.3 Typology of internal structure and external heterogeneity

Each organization is classified according to their internal structure and external network heterogeneity using 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 [11], 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).

Here, external network heterogeneity is determined based on the number of unique external actor types involved in the organization's overall decision-making process, including both their conventional and electric truck decisions. As shown in Table 5, external actors include individuals, groups, or organizations, who are not employed by the organization. These actors are grouped into "actor types" based on their function.

To determine a fleet's network heterogeneity, connections were drawn between the organization and any external actor type reported to have influence on the acquisition decision. The number of actor types involved in the decision was then used to divide fleets into three categories based on the observed sample variation. Decisions within an organization involving one to three external actor types were categorized as having low heterogeneity, those with four to five actor types were categorized as having a mid-level heterogeneity, and those with more than six external actor types were categorized as having high heterogeneity.

3.4 Organizational structure and external social networks

For each organization, acquisition considerations for conventional vehicles are examined, followed by an examination 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. Conventional vehicle acquisitions include any routine truck acquisitions made by the fleet such as diesel, gasoline, or natural gas trucks. While natural gas trucks would be novel acquisitions for some fleets, fleets in our sample reported natural gas truck acquisitions as being a routine decision.

Each organization was evaluated to answer the following questions:

- What is the organization's internal decision-making structure for conventional truck acquisitions? How does this structure shape the organization's truck acquisition decisions?
- What is the organization's external network heterogeneity for conventional 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?

4 Results

Table 3 shows the distribution of interviewed organizations according to our typology based on organizational structure and external network heterogeneity. Of the 12 possible fleet types, we observe seven in the sample. For our sample, as levels of centralization and formalization increase, the number of external actor types 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 3: 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

4.1 Changes to decision-making structures for electric truck adoption

Table 4 presents an overview of each fleet's internal decision-making structure, overall network heterogeneity, changes in heterogeneity between conventional and electric acquisition decisions, and changes in the number of factors considered between conventional 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.

Table 4: Summary of results

Fleet #	**Internal decision-making structure**	**Overall network heterogeneity**	**Heterogeneity change from conventional to electric decisions**	**Factor changes from conventional 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)

Our findings suggest a possible relationship between internal organizational structure and electric truck acquisitions. We observe bureaucratic organizations were most likely to have present experience with electric trucks: four of seven bureaucratic fleets in our sample have electric trucks. No fleet of any other type presently has any. We observe two of the six democratic and the one hierarchical organizations 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. No autocratic fleet in our sample had current or previous experience operating electric trucks.

Higher external network heterogeneity has been shown to be positively related to innovativeness for private consumers [27], thus we might expect organizations with high external 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 actor types for their electric acquisition decisions than their conventional acquisition decisions. Fleets with previous electric truck experience all had high-level network heterogeneity for conventional 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.

Table 5 presents a list of internal and external actor types derived from the interview analysis. 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 actor typess were grouped into five categories based on market segment: financial institutions, truck suppliers, regulators, energy/infrastructure providers, and other.

Table 5: Internal and external actor type definitions

Actor Definitions			
Actor Groups		**Actor Types**	**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.
	Truck Suppliers	**Dealers**	Suppliers of trucks to fleets, including new and used truck dealers.
		Fleet Procurement Companies	Companies providing acquisition assistance services to companies operating fleets including finding trucks, brokering deals, assisting with paperwork, etc.
		Maintenance Vendors	External actors providing maintenance services for trucks; including maintenance teams at dealerships, service centers, and other external vendors.
		Truck Manufacturers	Medium- and heavy-duty truck manufacturers.
	Regulators	**Local Governments**	Including counties, air quality management districts, etc.
		State Governments	Including state agencies (e.g., California Air Resources Board, California Energy Commission) and law enforcement (e.g., California Highway Patrol).
		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.
		Financial Accounting Standard Board (FASB)	The FASB organization establishes the “Generally Accepted Accounting Principles” used by companies in the US [28]. In 2016, the FASB began requiring fleets to include leases as liabilities on their balance sheets.
		Utilities	Electric utility companies.

	Energy/ Infrastructure Providers	**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.

Comparing conventional and electric truck acquisitions, four types of changes in the role of internal and external actor types were observed. Actor types typically involved in conventional truck acquisitions might be *omitted* from the acquisition or consideration of electric trucks. Alternatively, actor types absent from conventional truck acquisitions could be *added* to electric truck acquisition or consideration. Further, the role of actor types who appear in both decision types might be *static* (i.e., they play the same role) or their roles may be *dynamic* (i.e., they play a different role).

Omitted actor types included vehicle dealers, liquid fuel providers, and other fleets. Despite their omission from electric truck decisions at present, these actor types may play a role in electrifications decisions in the future. Someday dealers will supply electric trucks and act as information sources, for now though few fleets in the sample described them as having a strong influence in decisions to acquire electric trucks. Early electric truck acquisitions were often made through partnerships with the truck manufacturers rather than dealers. Fewer fleets included other fleets in their external networks associated with electric truck decisions than did so for general truck decisions. Given the unique duty cycle and operational requirements of each truck, interviewees mentioned wanting to try electric trucks in their own fleet rather than relying on other fleets to determine when the technology is ready.

Actor types added to external networks associated with electric truck decisions included landowners from whom the organization leased their location(s), local governments, and utilities. Fleets who currently refuel conventional 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, and in some case replacements for, liquid fuel providers as organizations expected to continue refueling or recharging their vehicles on-site. Some organizations whose conventional trucks currently refuel at public fuel stations 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 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.

Actor types whose role remained static included banks, consultants, customers, and fleet associations; these are described as playing the same role in electric truck acquisition decisions as in conventional truck acquisition decisions. Consultants and fleet associations serve largely as information sources for fleets looking to electrify. While banks and customers play the same role in conventional and electric truck acquisitions, interviewees perceive them as having a stronger influence on the fleet's ability to electrify. Some interviewees report difficulties working with banks to finance electric trucks due to uncertainties on residual value. Fleet's relationships with customers have similarly been reported to hinder electric truck adoption as they are reportedly unwilling to adapt to schedule or pricing changes that may result from electrification. Interviewees report this lack of flexibility significantly hinders their ability to acquire electric trucks.

Dynamic actor types who played a different role in conventional and electric truck decisions included vehicle leasing companies, vehicle manufacturers, port authorities, and state agencies. State agencies and port authorities (for fleets operating drayage) were discussed as influencing conventional truck acquisition decisions due to regulations requiring the use of emissions reduction technologies and prohibiting the use of certain model year engines. While public-agency actors continue their role as regulators, fleets additionally view them as sources of funding to support fleet organizations' transitions to electric trucks. Vehicle manufacturers and leasing companies serve as information sources and suppliers for conventional truck decisons. For some fleets, the role of manufacturers in electric truck decisions shifts from information to educator and from a vendor-customer relationship to more of a partnership. 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 investing large amounts of money to acquire one. Fleets who lease trucks report relying on the leasing companies to apply for rebates for electric trucks as 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 incentives.

5 Discussion and conclusions

Medium- and heavy-duty truck acquisition decisions involve actors internal or external to the organization operating the truck(s). These actor types differ when organizations acquire conventionally-fueled vs. electric vehicles. 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., 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. External network heterogeneity is a measure of the number of external actor types with which the organization interacts in the course of making truck acquisisiton decisions.

Prior studies in contexts other than consideration of electric trucks report the organizations least likely to innovate were those with low external network heterogeneity [11], [13]. Our results tend to confirm the importance of external network heterogeneity to innovation. For decisions on whether to acquire electric trucks, we find that, on average, fleets who currently operate electric trucks have higher external network heterogeneity than fleets who do not currently operate electric trucks. When comparing the external network heterogeneity of conventional vehicle acquisitions with the external network heterogeneity of electric vehicle acquisition decisions, we find that, on average, fleets currenty operating electric trucks increased in heterogeneity while fleets not operating electric trucks decreased in heterogeneity. 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 earlier results in organizations operating light-duty fleets. Nesbitt and Sperling [11] 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 autocratic fleets in our data typically have lower external network heterogeneity and the fewest people involved in internal decision-making. Such fleets may require the most external support to acquire electric trucks. This may require proactive engagement from actors outside these fleets. Autocratic fleets also often have lower workforce and financial resources than fleets with other internal structures, lessening their willingness and ability to experiment and potentially creating more barriers to electric truck acquisition. Decision-makers in democratic, bureaucratic, and hierarchical fleets in our data have mid to high external network heterogeneity. Such fleets may still benefit from external support to acquire electric trucks.

These fleets tend to have larger workforces and greater financial resources than autocratic fleets, thus democratic, bureaucratic, and hierarchical fleets may be more willing and able to experiment, and may face lower barriers to electric truck acquisition.

The role of external actor types in truck acquisition is different between conventional and electric truck consideration. Some differences may be a result of fleets not yet considering electric trucks or being in an early stage of consideration. For example, if a fleet's external network for electric truck consideration has fewer external actor types than their external network for conventional truck decisions does, this may simply mean the fleet has not yet thought much about electric trucks. In such cases, we might expect the external network to become more heterogeneous as consideration deepens.

Other differences in the external networks for conventional and electric trucks are due to differences in which factors they consider and which actor types are involved. External actor types, 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. Some of these actor types, such as vehicle dealers, may be expected to regain their importance in future deliberations about electric trucks as truck availability increases and fleets move from participating in demonstration programs to acquiring their own trucks. Conversely, the role of liquid fuel providers is expected to decline 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 into fleet organizations' external actor type networks to support transitions to electric trucks. While local governments were reported as involved in truck acquisitions via regulations and incentive programs, the importance of these programs would likely decrease once electric trucks become routine acquisitions. 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 actor types multiply, they may exert increasing levels of influence over acquisition decisions.

We note the absence of discussions around some actor types 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 actor types into the heavy-duty freight sector may help alleviate concerns about electric trucks.

As fleet decision-makers turn to external actors for information on conventional and electric trucks, it will become important to ensure these groups have correct and adequate information to support fleet decision-making. Manufacturers, fleet associations, utilities, and government agencies are reported as trusted sources of information by interviewees. 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 actor types may need to be involved.

References

[1] S. C. Davis and R. G. Boundy, "Transportation Energy Data Book: Edition 40," 2022.

[2] M. Muratori *et al.*, "The rise of electric vehicles—2020 status and future expectations," *Progress in Energy*, vol. 3, no. 2, p. 022002, Mar. 2021, doi: 10.1088/2516-1083/ABE0AD.

[3] Caltrans, "Regulations," 2022. https://dot.ca.gov/programs/transportation-planning/freight-planning/freight-performance-management/regulations.

[4] American Lung Association, "American Lung Association," 2022. https://www.lung.org (accessed Feb. 07, 2023).

[5] US DOE, "Alternative Fuels Data Center- Vehicle Weight Classes & Categories," 2012. https://afdc.energy.gov/data/10380.

[6] California Air Resources Board, "Advanced Clean Trucks Regulation," 2019.

[7] California Air Resources Board, "Advanced Clean Fleets," 2021. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets.

[8] California HVIP, "HVIP," *Incentives for Clean Trucks and Buses*, 2022. https://californiahvip.org.

[9] California Air Resources Board, "Truck and Bus Regulation, Final Regulation Order," Jul. 14, 2020. https://ww2.arb.ca.gov/news/15-states-and-district-columbia-join-forces-accelerate-bus-and-truck-electrification.

[10] Government of the Netherlands, “New agreements on urban deliveries without CO2 emission,” Feb. 11, 2021. https://www.government.nl/latest/news/2021/02/11/new-agreements-on-urban-deliveries-without-co2-emission.
[11] K. Nesbitt and D. Sperling, “Fleet purchase behavior: Decision processes and implications for new vehicle technologies and fuels,” *Transportation Research Part C: Emerging Technologies*, vol. 9, no. 5, Oct. 2001, doi: 10.1016/S0968-090X(00)00035-8.
[12] S. Arad, M. A. Hanson, and R. J. Schneider, “A Framework for the Study of Relationships Between Organizational Characteristics and Organizational Innovation,” *The Journal of Creative Behavior*, vol. 31, no. 1, pp. 42–58, 1997, doi: 10.1002/j.2162-6057.1997.tb00780.x.
[13] L. Carlsson and A. Sandström, “Network governance of the commons,” *International Journal of the Commons*, vol. 2, no. 1, pp. 33–54, 2008.
[14] A. Belyh, “A Complete Guide to Organizational Structures,” *Cleverism*, Feb. 20, 2015. https://www.cleverism.com/complete-guide-to-organizational-structures/.
[15] M. I. Rapert and B. M. Wren, “Reconsidering Organizational Structure: A Dual Perspective of Frameworks and Processes,” *Journal of Managerial Issues*, vol. 10, no. 3, pp. 287–302, 1998.
[16] P. R. Schulman, “Organizational structure and safety culture: Conceptual and practical challenges,” *Safety Science*, vol. 126, p. 104669, Jun. 2020, doi: 10.1016/j.ssci.2020.104669.
[17] J. Johari and K. K. Yahya, “Linking organizational structure, job characteristics, and job performance construct: A proposed framework,” *International Journal of Business and Management*, vol. 4, no. 3, Art. no. 3, 2009.
[18] X. Demeulenaere, “The use of automotive fleets to support the diffusion of Alternative Fuel Vehicles: A Rapid Evidence Assessment of barriers and decision mechanisms,” *Research in Transportation Economics*, vol. 76, p. 100738, Sep. 2019, doi: 10.1016/j.retrec.2019.100738.
[19] L. Mohammed, E. Niesten, and D. Gagliardi, “Adoption of alternative fuel vehicle fleets – A theoretical framework of barriers and enablers,” *Transportation Research Part D: Transport and Environment*, vol. 88, p. 102558, Nov. 2020, doi: 10.1016/J.TRD.2020.102558.
[20] S. Soderstrom and K. Weber, “Organizational Structure from Interaction: Evidence from Corporate Sustainability Efforts,” 2020. https://journals.sagepub.com/doi/full/10.1177/0001839219836670 (accessed Oct. 05, 2022).
[21] L. He, M. Wang, W. Chen, and G. Conzelmann, “Incorporating social impact on new product adoption in choice modeling: A case study in green vehicles,” *Transportation Research Part D: Transport and Environment*, vol. 32, Oct. 2014, doi: 10.1016/j.trd.2014.08.007.
[22] J. Kim, S. Rasouli, and H. J. P. Timmermans, “Social networks, social influence and activity-travel behaviour: a review of models and empirical evidence,” *Transport Reviews*, vol. 38, no. 4, pp. 499–523, Jul. 2018, doi: 10.1080/01441647.2017.1351500.
[23] Ö. Bodin, M. Mancilla García, and G. Robins, “Reconciling Conflict and Cooperation in Environmental Governance: A Social Network Perspective,” *Annual Review of Environment and Resources*, vol. 45, no. 1, pp. 471–495, 2020, doi: 10.1146/annurev-environ-011020-064352.
[24] D. Fenton and A. Kailas, “Redefining Goods Movement: Building an Ecosystem for the Introduction of Heavy-Duty Battery-Electric Vehicles,” *World Electric Vehicle Journal*, vol. 12, no. 3, Art. no. 3, Sep. 2021, doi: 10.3390/wevj12030147.
[25] J. Axsen and K. S. Kurani, “Interpersonal Influence within Car Buyers’ Social Networks: Applying Five Perspectives to Plug-in Hybrid Vehicle Drivers,” *Environ Plan A*, vol. 44, no. 5, pp. 1047–1065, May 2012, doi: 10.1068/a43221x.
[26] G. R. Gibbs, “Thematic Coding and Categorizing,” in *Qualitative Research kit: Analyzing qualitative data*, SAGE Publications, Ltd, 2007, pp. 38–55. doi: 10.4135/9781849208574.
[27] J. Axsen, “Interpersonal influence within car buyers’ social networks: Observing consumer assessment of plug-in hybrid electric vehicles (PHEVs) and the spread of pro-societal values - ProQuest,” 2010. https://www.proquest.com/openview/0ae532ae19a4e84be6fc313f9b68ac40/1?pq-origsite=gscholar&cbl=18750.
[28] Financial Accounting Standards Board, “About the FASB,” 2020. https://www.fasb.org/info/facts.

Presenter Biography

Claire is a Ph.D. Candidate in Energy Systems at the University of California, Davis. She works at the Electric Vehicle Research Center at the Institute of Transportation Studies where she focuses on transportation and energy policy. Her research primarily focuses on fleet adoption of electric vehicles and how policy can be used to encourage sustainable transportation electrification.