ARE WE READY FOR ZERO- AND LOWER-EMISSION TRUCKS? EXPLORING THE VIEWS OF MANITOBA TRUCKING COMPANIES

JYOTI MANDHANI
Postdoctoral Research Fellow at University of Manitoba, Winnipeg. Obtained Ph.D. in Transportation Systems from Indian Institute of Technology Roorkee, India.

PHANI KUMAR PATNALA
Research Fellow at University of Manitoba, Winnipeg. Obtained Ph.D. in Transportation Systems from Indian Institute of Technology Roorkee, India.

AHMED LASISI
Postdoctoral Research Fellow, University of Manitoba, Winnipeg. PhD in Civil Infrastructure Systems, University of Delaware, United States

DAVID LINTON
MCP, RPP MCIP
Policy Analyst, Manitoba Trucking Association.

BABAK MEHRAN
PhD, P.Eng.
Associate Professor of Civil Engineering (Transportation) University of Manitoba

CARL HO
PhD
Professor, Department of Electrical and Computer Engineering University of Manitoba

JONATHAN D. REGEHR
PhD, P.Eng.
Professor of Civil Engineering (Transportation) University of Manitoba

Abstract
With ever-growing concerns about climate change, the road freight transport sector is under increasing pressure to reduce emissions. The transition in road freight transport to zero- and lower-emission truck (ZLET) technologies will be a step toward achieving sustainability goals. However, there is limited understanding of the readiness of trucking companies in Canada to adopt ZLETs when they become available. This research aims to examine the awareness of ZLETs among trucking companies based in Manitoba, Canada through a web-based

questionnaire survey. The survey questionnaire was disseminated to 122 trucking companies, yielding 29 completed responses. Findings highlight that trucking companies look for 'durability/reliability', 'total operating cost', and 'maintenance cost' factors the most when buying a new power unit. Concerning ZLET awareness and readiness, the trucking industry in Manitoba is in the pre-adoption phase. Overall, the findings from this research provide valuable insight for policymakers seeking to accelerate the transition from diesel-powered to ZLETs in Canada.

1. Introduction

Road freight transportation is a major contributor of global green-house gas (GHG) emissions. In Canada, the transportation sector accounts for 35% of total GHG emissions (Environment and Climate Change Canada, 2022), with medium and heavy-duty trucks (MHDTs) comprising half of these emissions (Pembina Institute, 2023). The number of MHDT registrations in Canada has doubled in the past two decades (Statistics Canada, 2022). In response to the environmental impacts posed by MHDTs, the Canadian government has established an Emission Reduction Plan aiming to reduce GHG emissions by 40% less than 2005 levels by 2030 (Environment and Climate Change Canada, 2022). To support this transition, the government is investing $547.5 million in purchase incentives and $33.8 million in ZLET demonstration projects (Government of Canada, 2023). Despite these efforts to introduce ZLETs into the market, their penetration is limited. To accelerate this transition, federal, provincial, and local governments must realize the needs of trucking companies.

Research exploring the factors influencing ZLET adoption has revealed significant challenges faced by the trucking industry from the perspectives of fleet managers, truck manufacturers, government regulators, and infrastructure experts (Khan et al., 2021; Konstantinou and Gkritza, 2023a). These studies identified key barriers to ZLET adoption such as limited charging infrastructure, range anxiety, higher upfront costs, insufficient incentives, and financial limitations (Anderhofstadt and Spinler, 2019; Talebian et al., 2018). While some studies emphasized the need for clean energy production, many highlighted infrastructure constraints as a key obstacle to the transition (Konstantinou and Gkritza, 2023b; Zhou et al., 2019). For long distances, battery size and weight can significantly reduce payload capacity, while battery efficiency and recharging times pose challenges in cold regions (Khan et al., 2021; Melander et al., 2022; Hovi et al., 2020). Notably, most of these findings are derived from questionnaire surveys, interviews, and pilot tests intended for light-duty vehicles.

Existing research has not adequately explored the awareness or readiness of using ZLETs for long-haul operations from the viewpoint of trucking companies. It is important to identify the factors considered by trucking companies when purchasing new power units and how these factors influence ZLET adoption for long-haul operations in cold regions. To address this gap, the present study examines the views on ZLETs from trucking companies in the province of Manitoba, Canada. This province stands as an ideal case for the study due to its three strong assets: (i) it is a logistics and transportation hub for the country, moving freight across Canada and into United States, (ii) Manitoba companies are experts in managing long-haul MHDT operations under severe cold weather conditions, and (iii) Manitoba is a producer of clean low-cost hydroelectricity. This study seeks insight into the feasibility of a ZLET transition within the province, by conducting a questionnaire-based survey. The findings contribute to a better understanding of the current state of industry readiness, and insight for supporting the successful integration of cleaner technologies in Manitoba's trucking sector.

The article comprises five sections, including this introduction. The next section provides a review of relevant literature concerning ZLET adoption from an industry perspective. The third section describes the study methodology, including the survey design, data collection and analysis. The fourth section presents and discusses the results, and the paper concludes by considering the study's limitations and recommendations for future work.

2. Literature Review

From the past two decades, decarbonization of medium and heavy-duty trucking (MHDT) has been pursued by policy makers, equipment manufacturers, and technologists. Several studies have investigated the feasibility of replacing diesel-powered trucks with zero or low-emission trucks (ZLETs) using powertrain technologies such as battery electric (Zhou et al., 2017), hydrogen fuel cells (Kast et al., 2017), hybrid electric (Liu and Song, 2018), liquified natural gas (Anderhofstadt and Spinler, 2019), and biofuels (Sathre and Gustavsson, 2023) for various applications. These studies show that ZLETs can lower greenhouse gas (GHG) emissions, and life cycle costs, when they replace conventional diesel trucks. For instance, a battery electric truck can reduce GHG emissions by 40-60% (Lal et al., 2023), and fuel costs by 29-44% (Gao et al., 2017) over its life cycle as compared to a diesel one. Some studies describe increased investments in charging or refueling infrastructure, energy grid systems, and innovative management strategies to enable ZLETs to perform long-haul operations (Li et al., 2023; Liu and Song, 2018). Other studies highlight the need for a careful understanding of the factors influencing ZLET adoption from different contexts (Golob et al., 1997; Konstantinou and Gkritza, 2023b).

Table 1 presents a summary of studies focused on views, intentions, and purchase decisions of trucking industry stakeholders involving fleet managers, manufacturers, government regulators, and employees of trucking companies. Researchers have employed survey, interview, workshop, demonstration, or Delphi methods for gathering perception data (Hovi et al., 2020; Khan et al., 2021). Delphi method refers to "a survey technique to facilitate an efficient group dynamic process. This is done in the form of an anonymous, written, multi-stage survey process, where feedback of group opinion is provided after each round" (Von der Gracht, 2012). Among these methods, questionnaire surveys have been the most common method to gather perception data. For instance, Parker et al., (1997) conducted a mail-based questionnaire survey to gather perceptions of 139 US fleet managers on alternative fuels. They found that fleet managers do not perceive fuels as a cost-effective option for commercial operations due to insufficient government reforms towards alternative fuels. Kaplan et al., (2016) instrumented a web-based questionnaire survey to understand the motivations and barriers of electric truck adoption in Austria, Denmark and Germany. Applying behavioral theory, that study suggested further investigation into the interactions between policy, cognitive, and emotional motivators to better understand the adoption behavior of fleet managers. Zhou et al., (2019) used a face-to-face questionnaire survey to capture the intentions of 366 drivers towards electric truck adoption for delivery applications in China. They identified range anxiety as a key factor influencing adoption.

Other research methods have also been employed. For example, Anderhofstadt and Spinler (2019) applied a Delphi technique to identify factors influencing ZLET purchase decisions in Germany. They recommended increased charging or refueling stations combined with supportive subsidies to help improve ZLET penetration rates. Hovi et al., (2020) conducted semi-structured interviews with electric truck users of pilot projects in Norway. They suggested that government incentive schemes are important to ZLET adoption. Konstantinou & Gkritza (2023a) analyzed perception data from 200 US fleet managers using ordered probit regression models. They found that the availability of charging infrastructure, charging price, and media support influences ZLET adoption. Khan et al., (2021) used a latent class model to analyze perceptions of 1,008 fleet managers in Canada and found that a lack of charging infrastructure,

Table 1. Summary of existing studies on investigating industry perspectives

Reference	Context	Survey method	Analysis approach	Responses	Research aim	Key findings
Parker et al. (1997)	US	Mail-based questionnaire survey	Descriptive analysis	139	Views/intention to adopt electric vehicles	Fleet managers do not perceive alternative fuels as a cost-effective option. Government reforms towards alternative fuels are half-hearted and superficial.
Kaplan et al. (2016)	Austria, Denmark, Germany	Web-based questionnaire survey	Structural equation modelling	1493	Intention (Motivation and barriers to adopt electric vehicles)	Readiness to adopt electric vehicles varies across the industries with high-technology sector being early adopters, and agriculture and public administration being laggards.
Anderhofstadt and Spinler (2019)	Germany	Semi-structured workshop	Descriptive analysis	23	Factors affecting purchase decision of ZLET alternatives	Truck reliability, charging infrastructure, fuel costs are key influential factors affecting purchase decision of ZLET
Zhou et al. (2019)	Changsha, China	Face-to-face questionnaire survey	Structural equation modelling	366	Intentions to adopt electric trucks	Technology anxiety is found to be a significant factor influencing delivery drivers' intention to adopt electric trucks.
Imre et al. (2021)	Turkey	Workshop	Descriptive analysis	64	Barriers and enablers of electric vehicles in urban freight	Enablers have low operating costs, reduced noise and environmental impact. Barriers are high initial cost of vehicle
Brito et al. (2022)	US & Canada	Online questionnaire survey & interviews	Descriptive & thematic analysis	49	Barriers & opportunities for zero-emission trucks	The well-functioning ZLET market, availability public charging infrastructure and information sharing would be vital for small fleets to have smooth technology transition.
Melander et al. (2022)	Stockholm, Sweden	Semi-structured interviews	Thematic analysis	10	Drivers and barriers to electric truck adoption	Uncertainties like political, technological, willingness to pay and operational uncertainties deter firms from investing into electric freight vehicles.
Sugihara and Hardman (2022)	California, US	Semi-structured interviews	Thematic analysis	23	Motivations and barriers	Motivators behind purchasing ZLETs are environment and sustainability goals, grants, external influences, and desire to reduce operating costs
Konstantinou and Gkritza (2023a)	US	Online questionnaire survey	Descriptives & Ordered probit model	200	Intentions to adopt electric trucks	Fleet size, trucking segment and awareness on innovative charging solutions are factors affecting fleet managers' intention to electrify their fleets.

awareness, and incentives are key barriers to a ZLET purchase. Innovative Vehicle Institute (2024) utilized a Delphi method to capture feedback on electric truck technology from fleet managers and drivers based on their experience with electric truck tests and trials in Quebec. It was inferred that educating and training drivers about new technologies plays a significant role in the smooth transitioning to truck electrification. Few studies used a descriptive approach to identify best practices, challenges faced, and lessons learned from real-world deployments (Karlsson & Grauers, 2023; Malender et al., 2022).

While considering the literature that focused on perceptions of trucking industry stakeholders towards ZLET adoption, two major research gaps emerge. Firstly, vehicle characteristics such as sticker price, cost per mile, operating range, maintenance cost, power, resale value, and warranty are key considerations of trucking companies when purchasing a new power unit. Only a few studies such as Melander et al., (2022), Golob et al., (1997), and Skippon and Chappell (2019) have partly analyzed the operational suitability of ZLETs for long-haul operations based on perception data. A better understanding of the operational factors influencing purchase decisions is desirable. Secondly, trucking companies that operate long-haul trucks can have a different view on ZLET adoption compared to those operating short-haul trucks. It is important to understand the readiness or ZLET awareness of long-haul trucking firms and their willingness to accept these newer technologies. Only two studies, Seitz et al., (2015) and Zhang et al., (2019) have investigated the willingness of trucking firms for short-haul applications. More understanding of the long-haul operations is required. The present study intends to address these two gaps, and other issues related to ZLETs for long-haul operations in cold regions.

3. Study Context

Manitoba is a gateway for freight transportation, linking shipments between Eastern and Western Canada, as well as facilitating cross-border trade with the United States. Despite having just 3% of Canada's population, Manitoba accounts for a 5.1% of the country's trucking industry. According to the Manitoba Trucking Association (MTA), this province is home to 475 for-hire trucking companies, including some of the largest in Canada. The Manitoba trucking industry collectively operates over 15,000 power units and 20,000 trailers, transporting dry goods, temperature-sensitive freight, bulk commodities (fuel, fertilizer, grain, and liquids), flat deck loads, livestock, and hazardous materials (described as "dangerous goods" in Canadian regulations). This industry is vital in moving freight across vast distances and through harsh weather conditions, generating approximately $4.0 billion in revenue annually (Statistics Canada, 2021).

Figure 1 illustrates freight truck activity and the GHG emissions from MHDT in Manitoba. Over the past 20 years, there has been a substantial increase in truck activity, leading to 3.1 million tons of CO_2-equivalent GHG emissions for the year 2021, where MHDTs alone account for 22% of the total GHG emissions in the transportation sector (Natural Resources Canada, 2023). This positions Manitoba among the four Canadian provinces where emissions have been rising since 2020 (Environment and Climate Change Canada, 2022). Nearly all MHDT movement energy in Manitoba—close to 100%—is derived from diesel fuel. The trucking industry recognizes the importance of transitioning from diesel-powered trucks to zero- or low-emission powertrain technologies to reduce its carbon footprint. However, challenges persist in adopting ZLETs, particularly for long-haul operations in rural and cold regions. Barriers such as infrastructure, energy requirements, and performance reliability in extreme conditions

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remain a concern. Addressing these barriers is essential for the sector to achieve sustainability goals while continuing to fulfill its critical economic role.
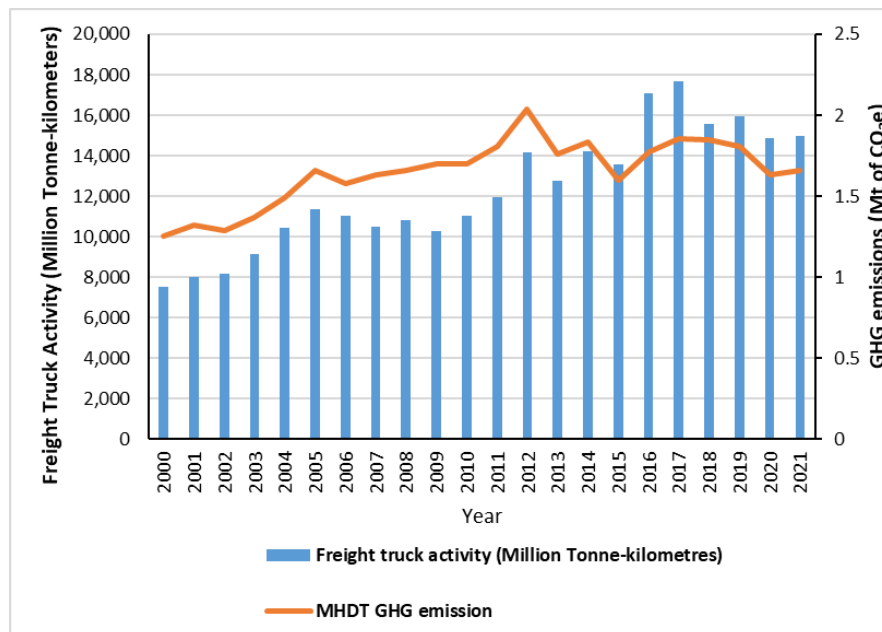

Figure 1. Freight Truck Activity and its associated GHG emissions in Manitoba (Source: Natural Resources Canada, 2023)

4. Survey Design and Data Collection

The present study conducted a web-based survey on the readiness of trucking companies towards ZLET adoption and on factors that influence purchasing decisions for new power units. The questionnaire design was based on existing literature, expert consultation, and internal review. The questionnaire had three sections: (i) characteristics of the company, including questions related to years in business, fleet size, origin and destination of most trips, trip distance, and equipment configuration categories; (ii) factors influencing purchase decisions, using a 5-point Likert scale ranging from '1' being 'not at all important' to '5' being 'extremely important'; and (iii) awareness and interest in adopting ZLETs for their truck fleets. The Research and Ethics Board of the University of Manitoba reviewed the questionnaire and confirmed that no ethics approval was necessary, as the study focused solely on companies, not individuals.

The survey questionnaire was deployed using the SurveyMonkey[TM] online platform. In March and April 2024, the MTA distributed the survey link to its 122 member trucking companies by e-mail and survey responses were obtained. The trucking companies included companies that operate trucks as their primary business (for-hire trucking companies), or as part of their primary business (processors and manufacturers). Prior to launching the survey, an invitation email was sent to each carrier, outlining the study's purpose, objectives, and requesting their participation. To ensure confidentiality, respondent companies remained anonymous, with no identifying information linked to their submissions. This process resulted in 29 completed responses from trucking companies, with an average survey questionnaire completion time of approximately 15 minutes.

5. Survey Results

5.1 Trucking firm and fleet characteristics

Table 2 provides an overview of firm and fleet characteristics for the respondent companies. Notably, 82% of the companies have been in the trucking industry for more than 20 years, with 51% having over 40 years of experience. In contrast, only 11% of the companies are relatively new, with less than 10 years in operation. Nearly 54% of the respondents operate fleets of fewer than 30 trucks, while 72% categorize 90-100% of their power units as Class-8 tractors. Additionally, half of the companies have 30 or fewer trailers in their fleet, while 21% manage fleets with over 200 trailers. Regarding operations in northern Manitoba, 54% of companies reported never operating there, with 18% occasionally, and 21% on a regular basis. Only 7% of the companies have 90% or more of their trucks driven by owner-operators. Overall, the survey dataset reflected trucking companies that have been in business for over 10 years, consisting of mostly Class-8 tractors, not driven by owner-operators, and that conduct their business primarily in southern Manitoba.

Table 2. Firm and Fleet characteristics of respondent companies

Question description and corresponding response frequency (in %)					
How long has your company been in business?	<5 (4%)	5-10 (7%)	11-20 (7%)	21-40 (31%)	>40 years (51%)
What is the current number of power units in your fleet?	≤10 (25%)	11-30 (39%)	31-50 (7%)	51-100 (7%)	101-200 (15%)	>200 (7%)
What percentage of your fleet's power units are Class 8 tractors?	90-100% (72%)	75-89% (18%)	51-74% (7%)	25-50% (0%)	<25% (3%)
What is the current number of trailers in your fleet?	≤10 (18%)	11-30 (32%)	31-50 (7%)	50-100 (18%)	100-200 (3%)	>200 (21%)
What percentage of your fleet's power units are driven by Owner-Operators?	90-100% (7%)	75-89% (4%)	51-74% (11%)	25-50% (22%)	<25% (56%)
How frequently does your company operate in Northern Manitoba?	Never (54%)	Occasionally (17%)	Routinely (8%)	Regularly (21%)

Respondents were asked to provide details on the distance ranges, primary trip origins, main destinations, and equipment type of their fleets. A "trip" is defined as the movement from the origin to the destination or the first stop in a multi-stop journey. The data revealed a wide variation in trip lengths, with an average of 24% of trips covering less than 50 miles and 36% extending beyond 500 miles. Between these extremes, 10% of trips fell within 50 to 100 miles, 18% between 100 and 250 miles, and 12% between 250 and 500 miles. Descriptive results showed that companies specialize in different types of hauling, with 26% of respondents operating dry vans, (26%), 24% operating tankers, and 13% operating flat deck trailer. Most respondent companies operate 5-axle or 6-axle configurations of tractors and semi-trailers.

A cross-tabulation analysis was carried out to examine the association between fleet size and other variables. The following inferences have been drawn from the crosstabulation analysis.

Irrespective of fleet size, at least half of companies' power units were class 8 tractors. Companies with fewer tucks have fewer trailers in their fleet and vice-versa. Notably, most companies with smaller fleet size tend to have less than 10% of their fleet driven by owner operators, whereas larger fleet companies have 11-40% of their fleet driven by owner-operators.
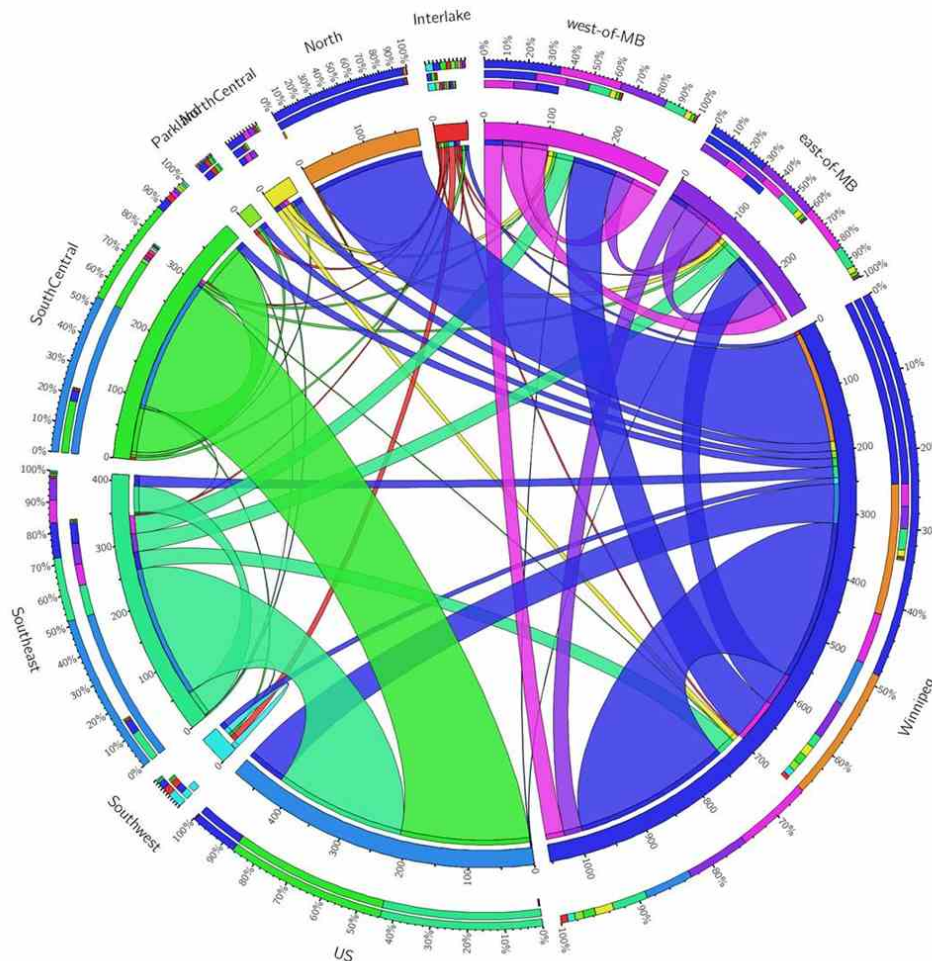

Figure 2. Origin-Destination pattern of the power units owned by respondent companies

Figure 2 illustrates the origin and destination patterns derived from the sample data. Respondents identified the primary origins and destinations of their trips using a map divided into eight economic regions of Manitoba, and regions east, west, and south of Manitoba. This visualization incorporates the number of power units in each company's fleet to highlight the relative movement between regions. Accordingly, the width of the color bands represents the percentage of shipments between origin and destination points— the wider the band, the greater the volume of business between those regions. Winnipeg is the central logistics hub for most companies, with most shipments originating from the city. These shipments are primarily destined for Winnipeg (intrazonal), the northern region (interzonal), and the US (international). Shipments to the US generally originated from Winnipeg, the South Central, and Southeast regions of Manitoba, while shipments to northern Manitoba originate exclusively from Winnipeg. The Parkland and North Central regions showed the least business activity compared to other areas. The survey data also showed that business activity between both the east and west regions of Manitoba and Winnipeg was lower than the trade between Winnipeg and the

US. The data also highlighted the strong international shipping component among the respondent companies.

5.2 Factors affecting purchase decisions

Figure 3 highlights the factors that influence trucking companies' decisions when purchasing or leasing new power units. The most important considerations include durability/reliability, total operating cost per mile, and maintenance/repair costs. Some 65% of surveyed companies rated total operating cost per mile and durability/reliability as extremely important. Survey respondents ranked eventual resale value as the lowest and emissions/pollution second-lowest among the purchase decision factors, much lower than other operational and performance factors. This suggests that developers of ZLET technologies need to focus on the practical requirements of trucking companies if ZLETs are to compete successfully with diesel-powered vehicles.
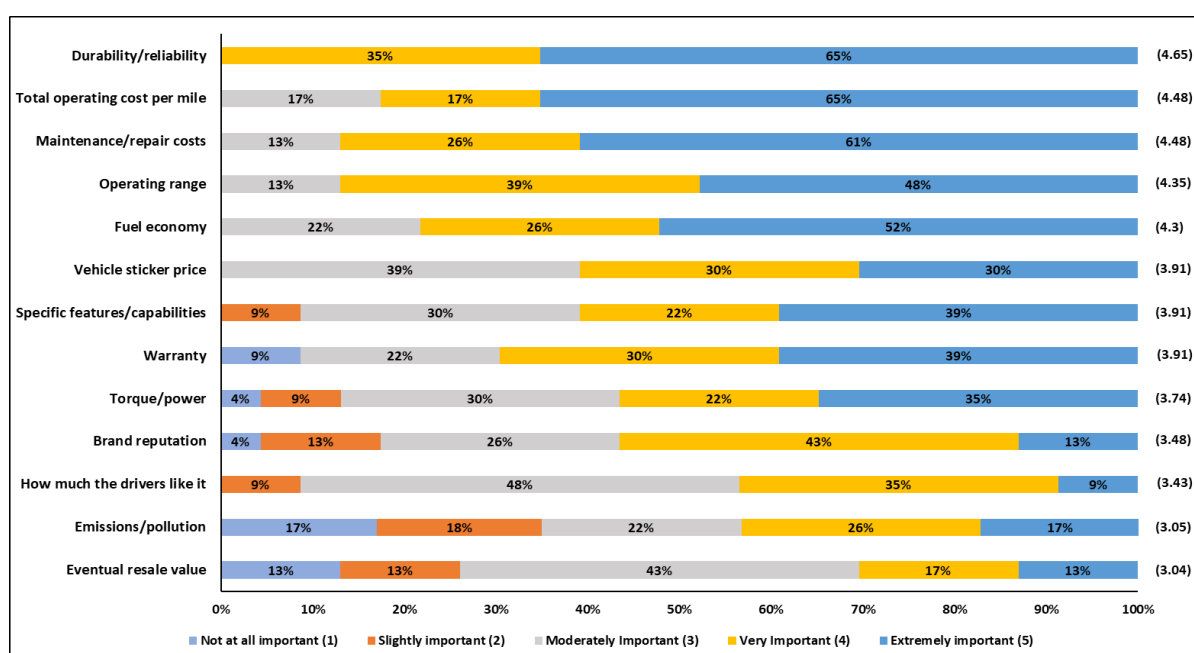
Note: Value in the parenthesis indicates mean importance level of each factor

Figure 3. Level of Importance of Factors Influencing Purchase Decisions

5.3 Awareness and readiness to adopt ZLETs

Figure 4 presents an overview of company responses to survey questions regarding awareness, opinions, and interest in ZLET technologies. Among the 23 companies surveyed, only 4% reported that ZLETs are a topic of regular discussion within their firms, while 42% stated they have never discussed these technologies (see Figure 4(a)). For companies who had no prior conversations about ZLETs, 82% (8 respondents) indicated they would like to learn more about the technologies. Among the companies that do discuss ZLETs occasionally or regularly, battery-electric technology emerged as the most frequently mentioned (see Figure 4(b)). A crosstabulation between frequency of discussion about ZLET and the most heard/discussed alternative suggests that companies are the most familiar with battery-electric ZLET technology. Companies expressed their interest to get more information about what they are already talking about, i.e., battery-electric followed by natural gas.
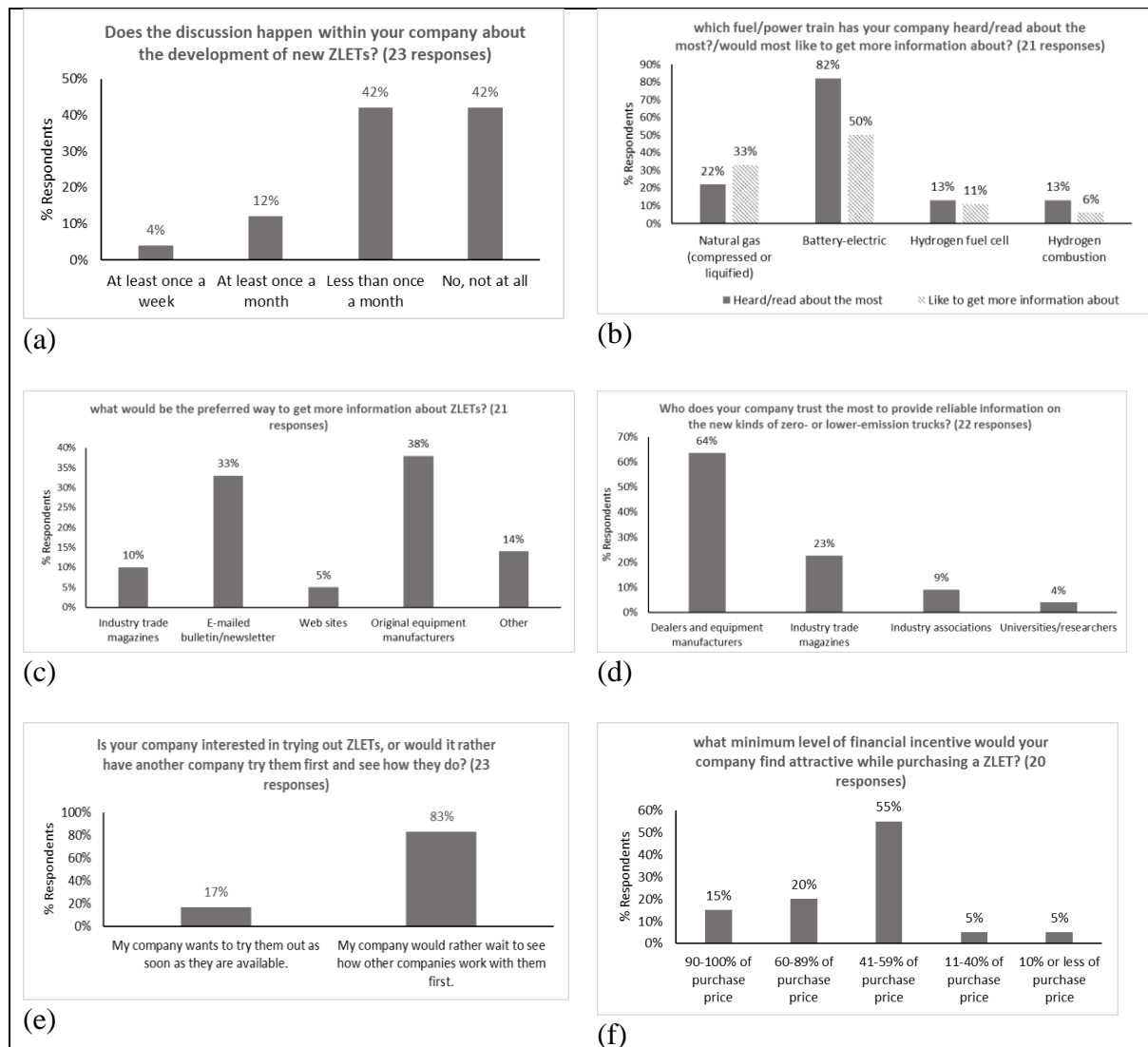
Figure 4. Responses on awareness and readiness to adopt ZLETs

These firms expressed their interest in receiving more detailed and reliable information, primarily from trusted sources such as dealers and original equipment manufacturers (OEMs) (see Figure 4(c) & (d)). However, when it comes to technology adoption, only 14% of the companies (4 companies) expressed immediate interest in procuring ZLETs as soon as they become available (see Figure 4(e)). The majority preferred a more cautious approach, preferring to wait and observe how other companies implement ZLETs before committing to adopt ZLETs themselves. Financial incentives from government were seen as a key factor in encouraging adoption. More than half of the respondents (11 companies) believed that government subsidies covering 41-59% of the ZLET purchase price would significantly influence their decision to invest in technology (see Figure 4(f)). Companies with an interest in natural gas and battery-electric alternatives preferred at least a 40% financial incentive for purchasing ZLETs. By targeting trucking companies with larger fleets, those that operate dry vans or flat decks, and businesses with long routes, the government can effectively promote ZLET adoption among the segments most likely to benefit. Tailoring policies to the operational scope, size, and geographical coverage of these companies will maximize the effectiveness of government incentives, ultimately accelerating the transition to ZLETs.

6. Discussion and Conclusions

The present study implemented an online survey of carrier members of the Manitoba Trucking Association (MTA) to identify their fleet characteristics, factors influencing their truck purchase decisions, and their readiness to adopt ZLETs. The survey obtained a sample of 29 responses from trucking companies, 82% of which have been in business for at least 20 years, 64% operating fleets with less than 30 power units, and 90% operating at least 75% of their fleet with Class 8 tractors.   An effort to understand the needs of trucking companies is rare in the ZLET literature, and the descriptive statistics of survey responses reveal several key insights for ZLET adoption in of ZLETs among trucking companies in Manitoba:

- <u>Diverse range and equipment</u>: Trucking companies operate over a wide range of distances, using a wide variety of trailers, which implies the need for Class 8 tractors that have a high level of operational flexibility.
- <u>No dominant trip patterns</u>: Using the survey data, the analysis of trip distributions between origins and destinations suggests there is no dominant pattern across the industry. It reinforces the need for a wide charging or refueling network that caters to diversified trip patterns if ZLETs are to be widely adopted.
- <u>Emissions not a primary factor</u>: Respondent companies prioritize durability or reliability, total operating cost per mile, operating range, and fuel economy in their truck purchase decisions. emissions when purchasing or leasing new power units. This is attributed to the limited information available on ZLETs, including their life cycle costs, cold weather performance, and operational capabilities. Trucking companies expressed a desire for more detailed information on ZLETs as an alternative to traditional diesel trucks. In addition, the lack of information makes it challenging for policymakers to devise effective subsidy strategies for ZLET adoption.
- <u>Low awareness of ZLETs</u>: Survey responses indicate that the trucking industry in Manitoba is still in the pre-adoption phase for ZLETs. Out of 29 companies, only four showed interests in adopting ZLETs. The MTA estimates there are up to five medium- to heavy-duty ZLETs currently in operation, none of which run on natural gas or hydrogen. The trucking industry in Manitoba has potential to transition from diesel-powered trucks to ZLETs. The province's experience in operating long-haul MHDTs in cold weather conditions could be leveraged to develop a green transportation model, especially given Manitoba's ability to produce clean, low-cost hydroelectricity.

Overall, these findings provide valuable insights for policymakers aiming to accelerate the shift from diesel-powered trucks to ZLETs in Manitoba and Canada. The industry's diversity and generally low interest in ZLETs underscores the need for targeted policies, demonstration projects, and energy infrastructure, to prepare for a technology transition.

In Manitoba and in Canada generally, trucking is a highly competitive industry with low profit margins and many small and medium-sized companies. In this context, the low awareness of ZLETs evident in the survey results is partly a reflection of the companies' focus on day-to-day operations and business risk. Demonstration projects and financial incentives may be helpful to raise awareness and interest in ZLETs, but for adoption to take place, there must also be a

business case that meets companies' operating requirements while supporting their competitive position in the for-hire trucking market.

7. Acknowledgement

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