Transportation Research Part E 163 (2022) 102753

Contents lists available at ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

Influencing factors of trucking companies willingness to shift to alternative fuel vehicles

Víctor Cantillo [a], Johanna Amaya [b,*], Iván Serrano [a], Víctor Cantillo-García [c], Janer Galván [a]

[a] Department of Civil and Environmental Engineering, Universidad del Norte, Colombia
[b] Department of Supply Chain and Information Systems, Pennsylvania State University, United States
[c] Proyectos Técnicos Ltda, Colombia

ARTICLE INFO

Keywords:
Freight transport
Alternative fuels
Willingness to pay
Alternative fuel vehicles

ABSTRACT

Freight transportation is a manifestation of a vibrant economy, but it is also associated with negative externalities such as greenhouse gas emissions. To mitigate these impacts, freight vehicles using alternative fuels have been developed, but they are not widely adopted. Moreover, there is not much information on the factors that could incentivize trucking companies to adopt such vehicles, especially in emerging economies where diesel engines dominate the market. Using Colombia as a case study, this paper aims to evaluate the factors that influence businesses to shift towards acquiring trucks powered by alternative fuels, applying an econometric approach based on discrete choice models. Results suggest that demand for alternative fuel vehicles (AFVs) is highly sensitive to purchase costs, operational range, and environmental awareness. Hybrid fuel alternatives seem to be preferred over electric and compressed natural gas vehicles. The analysis is supplemented with the estimation of marginal substitution rates, elasticities, and the simulation of scenarios considering subsidies and tax exemptions, from which we identify implications and draw policy recommendations to promote the use of AFVs.

1. Introduction

Freight movement is the reflection of a vibrant and dynamic economy. However, this movement also brings such negative externalities as emissions, traffic, and congestion among other impacts. In terms of emissions, freight transportation activity represents 7% of the total global greenhouse gases (GHG) (UNCTAD, 2017). According to the International Transport Forum (ITF) projections, CO2 emissions related to international trade transport will grow 290% by 2050, compared to a baseline scenario in 2010. Road transport will account for 56% of these emissions compared to its share of 53% in 2010, while air transport will produce 9% (7% in 2010), maritime transport share will decrease to 32% (from 37% in 2010), and rail should remain at around 3% (ITF, 2015). In this context, it is important to explore alternatives that will reduce the negative environmental impacts of freight transportation. To meet this need, alternative fuel vehicles (AFVs) have emerged as a solution to reduce emissions, with the promotion of a switch to cleaner fuel technologies for commercial activities. Municipalities and government agencies worldwide are proposing policies, incentives, and new regulations to foster the adoption of AFVs in private and public fleets. These policies have also attracted the interest of investors

* Corresponding author.
E-mail addresses: victor.cantillo@uninorte.edu.co (V. Cantillo), amayaj@psu.edu (J. Amaya), idserrano@uninorte.edu.co (I. Serrano), victor.cantillo@proyectostecnicos.co (V. Cantillo-García), jgalvan@uninorte.edu.co (J. Galván).

https://doi.org/10.1016/j.tre.2022.102753
Received 8 July 2021; Received in revised form 23 February 2022; Accepted 15 May 2022
Available online 22 May 2022

and truck manufacturing companies, who seek to meet the potential demand for these vehicles (Arslan et al., 2015).

In terms of the penetration of AFVs in the commercial vehicles market, researchers have identified that large freight transport companies are more likely to be early adopters given new vehicle requirements and high purchase rates; a better comprehension of lifetime vehicle costs; frequent usage; and a small number of decision-makers within the company (Dijk et al., 2013; Sierzchula, 2014). Notwithstanding, most AFVs are used for passenger transportation (i.e., buses, taxis, and passenger cars), and not much adoption has taken place in truck fleets (Zhang et al., 2019). Other studies identified several barriers to the adoption of AFVs by companies, such as limited refueling/recharging stations, limited driving range, high purchase prices, and high refueling costs (Wang & Lin, 2009; Davis & Figliozzi, 2013). To reduce such barriers, policies promoting AFV usage play a key role in facilitating the greening process of road cargo fleets and freight transportation in general. However, the design of adequate policies requires a good understanding of the market conditions and stakeholders' perceptions and attitudes toward alternative fuels (Roche et al., 2010). In other words, proposing strategies to boost the adoption of cleaner trucks requires a better understanding of consumer behavior and an in-depth analysis of the variables that influence purchasing decisions. Trucking companies consider numerous attributes in selecting a new vehicle, including fuel technology, availability of fueling stations, purchase prices, operational costs, fuel efficiency, driving range and maintenance costs. Nonetheless, there is a lack of knowledge of how these factors are accounted for when purchase decisions are made, and this limitation becomes a major obstacle for practitioners and policy makers.

In general terms, most studies focused on the demand for AFVs concentrate on developed countries (Globisch et al., 2018). Thus, not much is known about the preferences that drive purchasing decisions in emerging economies, where social, economic, and political constraints impose unique conditions for policy design. Findings from other contexts might not apply to developing countries, due to significant differences in the behavior and motivations of social groups, fragmented logistics operations, inadequate infrastructure, and a lack of proper policy making (Díaz-Ramirez et al., 2017). On the other hand, a few studies have analyzed the demand for trucks powered with alternative fuel sources in developing economies (Zhang et al., 2019).

In Colombia, gasoline and diesel are the most used energy sources in road transportation, accounting for 97% of the market, followed by compressed natural gas (CNG) (1.6%) (UPME, 2020). In recent years, the Colombian government has implemented policies and regulations to promote greener energy sources to foster an increase in the use of AFVs. The Cargo Vehicle Modernization Program (PMVC, for its acronym in Spanish) by the Ministry of Transportation aims to reduce emissions and improve productivity by offering economic benefits to renovate trucks with a work life of 20 years or more. Similarly, the National Energy Plan project by the Mining Energy Planning Unit (UPME, for its acronym in Spanish) proposes an energy transition for freight transport, setting the goal of AFVs market share reaching 52% by 2050 (UPME, 2020). Despite these efforts, the introduction of AFVs in the Colombian freight transport sector is minimal. In 2019, only 79 trucks in the country were electric, and 50 were hybrid (Ministerio de Transporte, 2020). Some companies have implemented pilots to introduce electric vehicles, mainly small trucks and delivery vans used for parcel deliveries. But these initiatives have not had a significant impact since very few companies have been involved. Also, there is still minimal infrastructure available for charging AFVs, so truck fleets at the national level are still dominated by diesel powered vehicles, and the market conditions have remained practically unchanged in the last decade. AFVs have been introduced mainly in the public transport sector, where some cities, such as Bogotá, have made efforts to update the bus fleet in the BRT system by introducing electric and CNG vehicles. Thus, to reach the goal of broader AFVs adoption, the private sector must be engaged. It is urgent to develop a quantitative analysis of truck companies' perspectives to understand the determinants influencing their demand for AFVs, so adoption can proceed at a faster pace.

This paper aims to fill these gaps by analyzing the factors that motivate trucking companies and owner-operators in their decision to buy trucks powered with alternative fuels, compared to traditional vehicles. Using Colombia as a case study, we propose a methodology based on estimating discrete choice models using stated preference data collected through surveys with truck operators and road freight company administrators. This approach allows us to quantify the factors, preferences and attributes that determine the willingness to use AFVs in the freight transport sector, as well as to simulate potential policy scenarios. The findings from this study serve as a tool for policymakers and planners to design policies focused on enhancing the adoption of alternative fuel vehicles to reduce environmental externalities. The results could also be of interest to AFV manufacturers and dealers as they will be able to identify key factors that need to be addressed to increase market penetration.

The rest of the paper is organized as follows: Section 2 includes a review of the relevant literature and Section 3 provides a description of the case study in Colombia. Section 4 presents the methodological approach adopted, with a description of the survey design, econometric method, and model specification. Section 5 describes the results and analyses, including sample description, modeling results, willingness to pay, elasticities and market shares simulation. Section 6 discusses the implications of our findings, and the paper concludes in Section 7.

2. Literature review

In recent years, awareness of climate change and renewable energy has risen, increasing the interest in AFVs (Kardooni et al., 2018). Consequently, engine and vehicle manufacturers have developed alternative energy technologies that aim to reduce transport emissions. The leading AFV technologies available in the market include electric, hybrid, and CNG. Hybrid vehicles combine an electric motor with an internal combustion engine (diesel or gasoline), which usually charges from regular electric power outlets, improving the efficiency in long-distance trips. Electric engines reduce operational costs and GHG emissions when compared to pure internal combustion engines using fossil fuels. On the other hand, CNG vehicles are an alternative that generates less CO_2 emissions than gasoline and diesel engines (Hekkert et al., 2005; Goyal & Sidhartha, 2003; Kado et al., 2005). Due to these features, electric and hybrid vehicles are promising alternatives to accomplish sustainability goals in activities related to transport and logistics. The

trucking industry is one of the largest contributors to transport operations that could help reduce emissions by adopting cleaner technologies. The market is dynamic and always looking for ways to increase efficiency, but it is usually overlooked by decision makers, especially in Latin America. Evaluating the factors that could determine AFV use contributes to the development of policies and market analyses. Despite its relevance, this topic has not received much attention in the literature, especially in developing economies.

Specific research on truck fleets and what influences the decision to purchase AFVs in the freight sector is scarce (Globisch et al., 2018), especially in developing economies and overall in the global south. Most studies addressing these preferences focus on the demand for AFVs in passenger transportation and individual mobility. Table 1 summarizes recent studies evaluating the factors influencing the adoption of AFVs in the freight transport sector, together with the countries where the studies were conducted.

The work by Osieczko et al., 2021 include aggregated analysis evaluating market trends at the country level in the European Union (EU), while in the UK Meelen et al. (2021) proposes a qualitative approach based on stakeholders' interviews, concluding that behavioral changes will shape the adoption of AFVs. In contrast, Bynum et al. (2016) and Jaller et al. (2020), evaluate the impact of behavioral and environmental policies in the US. Both studies conclude that policies could foster behavior changes that would lead to a faster adoption of AFVs in the freight sector.

The studies by Anderhofstadt and Spinler (2019, 2020), Meelen et al. (2021) and Zhang et al. (2019) make their analyses at the consumer level. Anderhofstadt and Spinler (2019) applied the Delphi technique to study the factors that affect the adoption of alternative fuel-powered heavy-duty trucks (HDT), finding that trucks' reliability, fueling infrastructure, the ability to enter low-emission zones, and fuel costs are the key factors considered when purchasing and operating alternative fuel-powered HDTs in Germany. In this line, Zhang et al. (2019) estimated ordinal regression models to evaluate the willingness to purchase AFVs in China's freight sector. Results suggest that improving performance, reducing costs, increasing the number of manufacturers, communicating AFVs benefits and identifying which sector could benefit the most by adopting AFVs are policies recommended to facilitate AFV adoption in truck fleets.

The research conducted by Tanco et al. (2019) is particularly relevant, as it analyzed the penetration of electric trucks in Argentina, Brazil, Chile, Colombia, and Uruguay. The paper concludes that tax benefits and subsidies might be an alternative to overcoming cost-related barriers for introducing AFVs in the Latin American freight transport market. In Latin America, the initial investment or purchase price is the main barrier to their adoption, since it is the leading cause of the cost of ownership gap in relation to traditional diesel trucks.

Purchase costs, refueling infrastructure, operational costs and emission regulations are some of the most important attributes that influence the decision to adopt AFVs. These variables determine costs, routing and emission levels, which define in what contexts AFVs can be viably used (Erdoğan and Miller-Hooks, 2012; Sathaye & Kelley, 2013; Felipe et al., 2014; Murakami, 2017). There is some evidence that electric vehicles might work better where there are dense clusters of customers close to the depots (Juan et al. 2014), while Arslan et al. (2015) note that the use of hybrid vehicles could entail lower costs and environmental benefits, especially when electricity prices are lower than gasoline costs. Electric vehicles could reduce operational costs and pollution, but the limited driving range, long recharging times, and higher purchase costs are barriers to overcome. Even though electric and hybrid alternatives could be financially viable in the long term, purchase cost competitiveness is the main advantage of diesel and gasoline vehicles (Jaffe et al., 2005; Sierzchula, 2014). Furthermore, Feng & Figliozzi (2012) show that electric trucks are only competitive if their utilization is high and vehicle prices are reduced by 15% to 30%, while Davis & Figliozzi (2013) determined that diesel vehicles' are less elastic to purchase cost than electrics.

Economic constraints and sectoral differences in freight transportation operations also affect the adoption of AFVs. For instance, as much as 71% of Swiss road transportation ton-kilometers could be electrified using battery-electric trucks (Liimatainen et al. 2019), while Finland only has a 35% potential due to operational constraints (Sathaye & Kelley, 2013). The adoption of AFVs requires solutions to operational issues that differ from conventional technologies. Among others, it requires that consumers modify their habits by adapting to new routines, especially regarding refueling methods and travel constraints due to fueling station availability. In addition, the limited consumer experience of AFVs in the truck sector generates some uncertainty towards its adoption. Some of these limitations could be overcome by implementing policies such as price subsidies and tax benefits that incentive the adoption of AFVs

Table 1
Recent studies evaluating the factors influencing the adoption of trucks powered with alternative fuels.

Study	Countries	Factors
Anderhofstadt & Spinler, 2019	Germany	Purchase cost, operational costs, taxes and insurance, emissions, reliability, fueling infrastructure, fueling time, safety, capacity, design, driver comfort, performance, driving range
Anderhofstadt & Spinler, 2020	Germany	Purchase cost, fueling infrastructure, operational costs, driving range, emissions, driving automation
Bynum et al., 2016	United States	Emissions policy model
Jaller et al., 2020	United States	Purchase cost, operational costs, emissions
Meelen et al., 2021	United Kingdom	Purchase cost, fueling infrastructure, operational costs, emissions policies
Osieczko et al., 2021	European Union	Fueling infrastructure, operational costs, subsidies
Tanco et al., 2019	Argentina, Brazil, Chile, Colombia, Uruguay	Purchase cost, fueling infrastructure, operational costs, insurance
Zhang et al., 2019	China	Purchase cost, fueling infrastructure, operational costs, driving range, cargo capacity, vehicle appearance, vehicle safety, policies, subsidies, environmental impact, insurance

(Sierzchula, 2014), as well as by developing programs to communicate the benefits of their adoption in the long term. Another alternative is to set policies or standards to reduce emissions. However, this could negatively affect the operation of companies with fleets that do not meet the standards proposed. Subsidizing the costs associated with adopting greener technologies might be a better alternative to promote AFV adoption (Bae et al., 2011).

Regarding methods to evaluate the factors that define the adoption of AFVs in both the freight and passenger sectors, the modeling of attitudinal and stated preferences surveys are common approaches. These procedures have been implemented in China (Zhang et al., 2011; Zhang et al., 2019), Germany (Petschnig et al., 2014; Hackbarth & Madlener, 2016), the Netherlands (Koetse & Hoen, 2014), and Colombia for vehicle owners and public transportation entrepreneurs (Soto et al., 2018; Galván et al., 2016). Other relevant methodologies evidenced in the literature are the use of questionnaire surveys (Golob et al., 1997; Stephen Parker et al., 1997), ordinal regressions, discrete choice modeling (Musti & Kockelman, 2011; Soto et al., 2018; Galván et al., 2016), game theory applications (Bae et al., 2011), and multiple-criteria decision analysis methods (Deason & Jefferson, 2010). Other less common approaches combine qualitative and quantitative information as questionnaires, interviews or GPS data to evaluate barriers in the adoption of AFV fleets (Wikström et al., 2016).

In summary, most studies evaluating preferences towards AFVs focus on developed countries and passenger cars (Globisch et al., 2018). Not much is known about the preferences influencing the willingness to adopt alternative fuel trucks by trucking companies in emerging economies, where social, economic, geographical, and political constraints impose specific conditions for the penetration of AFVs and policy design. To fill this gap, this paper proposes a comprehensive analysis of the preferences, factors, and attributes that motivate trucking companies and owner-operators in Colombia to shift to trucks powered with alternative fuels. Following the review,

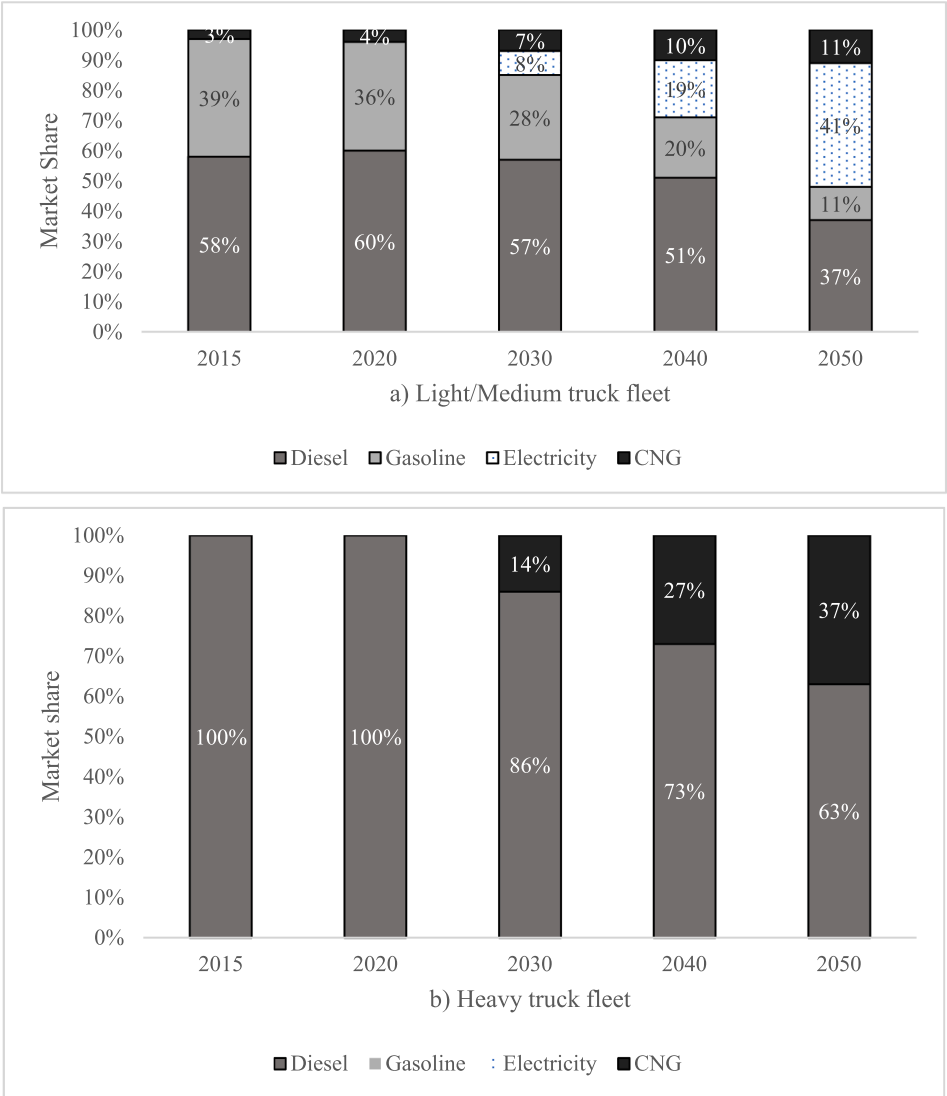

Fig. 1. Projected truck fleet market shares by fuel alternative.

we propose an econometric approach based on the estimation of discrete choice models using stated preferences data. This formulation allows us to evaluate market conditions that are not currently available, as well as to simulate policy scenarios from which we can draw recommendations to encourage AFV market penetration in similar contexts.

3. Case Study: Colombia

In Colombia, the transportation sector represents 43% of total energy consumption. Road transportation represents the greatest contribution to this consumption (88%), followed by air transportation (10%). Particularly, the cargo vehicle fleet is composed of about 378,600 vehicles, which represents 2% of the total number of registered vehicles in the country. The most used type of fuel is diesel with 80% market share, followed by gasoline with 17%, CNG with 1.6%, and electric with 0.4% (UPME, 2020a). The distribution by vehicle category shows that 85% are light/medium trucks, i.e., category C1 (two axles small: 4 to 7 ton) or C2 (two axles big: 7 to 13 ton). This is associated with a high percentage of urban freight trucks, which generally have two axles. The remaining 15% corresponds to heavy truck fleets, i.e., category C3 (three axles or more) or tractor-trailers mainly used for interurban or long-distance services. In general, the average age of the country's vehicle fleet is 12.5 years (UPME, 2020a).

Given the low adoption of green fuels in the country, the national government developed the National Energy Plan 2020–2050 (PEN, for its acronym in Spanish) (UPME, 2020). This plan aims to generate fuel technology market shares that meet the objective of *Scenario 266*. The number 266 is related to the maximum number of CO_2 tons that should be emitted to comply with a 20% reduction, as defined by the Paris agreement in 2015. The scenario establishes an energy transition program for light and medium truck vehicle fleets. The projected fuel market shares are 41% for electricity and 11% for CNG by 2050 (see Fig. 1a) for light and medium-size trucks. The assumptions used in the PEN also consider a 37% participation of heavy trucks using CNG by 2050 (see Fig. 1b). Note that in the last decades, more than half a million vehicles have converted to CNG, incentivized by a program promoted by the Ministry of Mining and Energy and lower fuel costs, which has also motivated the penetration of the technology in the public transport sector during the last three decades (UPME, 2020).

Consequently, these efforts could anticipate a significant transformation in the energy matrix of freight transportation. The use of gasoline and diesel is expected to be reduced by more than 20%. On the other hand, the use of CNG is projected to increase by a factor of around 3.5. Electricity, which currently registers a minimal market share, is expected to account for between 8% and 15% of the total, depending on the scenarios proposed in the PEN. However, it is possible to infer that the truck market has not significantly changed in the last decade in Colombia, and that preferences and adoption rates have remained practically the same as in 2015 (See Fig. 1). The penetration of trucks powered with alternative fuels has been practically nil, with some isolated pilots by companies introducing small electric trucks and delivery vans with almost no major impact. In addition, there is a widespread lack of charging stations and operational infrastructure. According to the Ministry of Transportation, by 2019, there were only 79 electric trucks and 50 hybrid trucks registered in Colombia. These figures are minimal considering that in 2019 there was a total of 386,727 trucks registered, so electric and hybrid trucks only represent 0.033% of the registered fleet (Ministerio de Transporte, 2020).

The study's target population, trucking companies, can be categorized by economic activity into commerce (65.7%), manufacturing (20.2%), transport and storage (4%), and construction (7.1%). When analyzed by the size of the company, those businesses classified as micro and small represent 98% of the total. In this regard, it should be noted that 22.4% of the companies have their own fleet for transportation services. In the case of companies engaged in transport and storage activities, the proportion of companies with their own fleet increases to 48.0%. On average, 70.5% have urban routes, and 29.5% have national routes (interurban) (ENL, 2020).

4. Methodology

This section presents the methodological approach used in this research, describing the survey design, econometric method, and model specification utilized.

4.1. Survey description

As seen in Section 3, trucks using alternative fuels have not yet significantly penetrated the commercial vehicle market in Colombia. To estimate discrete choice models on vehicle alternatives not available in the market, it is necessary to apply stated preference (SP) techniques. Therefore, we designed and conducted an SP survey administered to owner-operators and decision makers in trucking companies of medium to high-capacity vehicles providing commercial urban and intercity freight transportation services. Surveys were collected face-to-face in six Colombian cities during the last trimester of 2013. Although the data was not collected recently, with electric and hybrid trucks still representing only 0.033% of the market, Colombia's AFV market share has not changed and industry conditions and factors related to fleet expansion and vehicle purchasing decisions remain very similar to 2013, as described in Section 3. In this regard, the validity of the results prevails.

The survey consisted of three sections. The first section gathered general information regarding the trucking company, including characteristics of the service(s) provided (urban or interurban), the vehicle fleet by size, fuel technology used, vehicle ages, and control emissions technology.

The second section presented a series of affirmations to measure the relevance and level of agreement associated with different characteristics considered when buying a truck, using a five-point Likert scale ranging from *not at all important* to *highly important*. The characteristics measured were manufacturer, cost (purchase price), emissions, equipment, high-technology, technical support, and